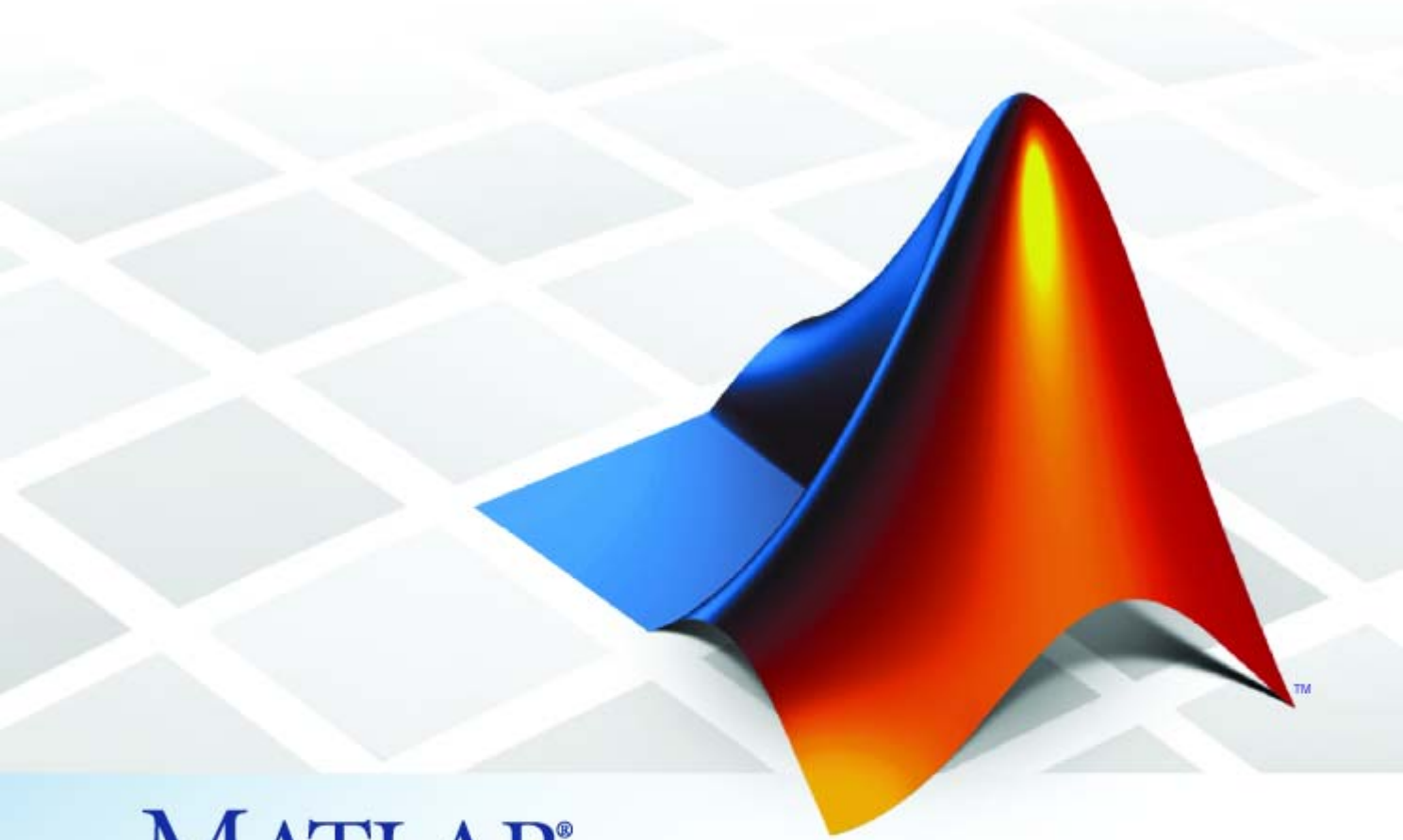
Financial Toolbox™ 3
User's Guide



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Financial Toolbox™ User's Guide

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Glossary

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Getting Started

- "Product Overview" on page 1-2
- "Expected Background" on page 1-4
- "Using Matrix Functions for Finance" on page 1-5
- "Matrix Algebra Refresher" on page 1-8
- "Function Input and Output Arguments" on page 1-19

Product Overview

The MATLAB® and Financial Toolbox™ products provide a complete integrated computing environment for financial analysis and engineering. The toolbox has everything you need to perform mathematical and statistical analysis of financial data and display the results with presentation-quality graphics. You can quickly ask, visualize, and answer complicated questions.

In traditional or spreadsheet programming, you must deal with all sorts of housekeeping details: declaring, data typing, sizing, and so on. MATLAB software does all that for you. You just write expressions the way you think of problems. There is no need to switch tools, convert files, or rewrite applications.

With the MATLAB and Financial Toolbox products, you can do the following:

- Compute and analyze prices, yields, and sensitivities for derivatives and other securities, and for portfolios of securities.
- Perform Securities Industry Association (SIA) compatible fixed-income pricing, yield, and sensitivity analysis.
- Analyze or manage portfolios.
- Design and evaluate hedging strategies.
- Identify, measure, and control risk.
- Analyze and compute cash flows, including rates of return and depreciation streams.
- Analyze and predict economic activity.
- Visualize and analyze financial time series data.
- Create structured financial instruments, including foreign-exchange instruments.
- Teach or conduct academic research.

This chapter uses MATLAB to review the fundamentals of matrix algebra you need for financial analysis and engineering applications. It contains these sections:

- "Using Matrix Functions for Finance" on page 1-5

  Reviews "Key Definitions" on page 1-5 and some matrix algebra fundamentals, such as "Referencing Matrix Elements" on page 1-6 and "Transposing Matrices" on page 1-7.

- "Matrix Algebra Refresher" on page 1-8

  Provides a brief refresher on using matrix functions in financial analysis and engineering

- "Function Input and Output Arguments" on page 1-19

  Describes acceptable formats for providing data to MATLAB and the resulting output from computations on the supplied data.

This material explains some MATLAB concepts and operations using financial examples to help get you started.

Expected Background

In general, this guide assumes experience working with financial derivatives and some familiarity with the underlying models.

In designing Financial Toolbox documentation, we assume that your title is like one of these:

- Analyst, quantitative analyst
- Risk manager
- Portfolio manager
- Asset allocator
- Financial engineer
- Trader
- Student, professor, or other academic

We also assume your background, education, training, and responsibilities match some aspects of this profile:

- Finance, economics, perhaps accounting
- Engineering, mathematics, physics, other quantitative sciences
- Focus on quantitative approaches to financial problems

Using Matrix Functions for Finance

In this section...

"Introduction" on page 1-5

"Key Definitions" on page 1-5

"Referencing Matrix Elements" on page 1-6

"Transposing Matrices" on page 1-7

Introduction

Many financial analysis procedures involve *sets* of numbers; for example, a portfolio of securities at various prices and yields. Matrices, matrix functions, and matrix algebra are the most efficient ways to analyze sets of numbers and their relationships. Spreadsheets focus on individual cells and the relationships between cells. While you can think of a set of spreadsheet cells (a range of rows and columns) as a matrix, a matrix-oriented tool like MATLAB software manipulates sets of numbers more quickly, easily, and naturally.

Key Definitions

Matrix. A rectangular array of numeric or algebraic quantities subject to mathematical operations; the regular formation of elements into rows and columns. Described as a "*m*-by-*n*" matrix, with *m* the number of rows and *n* the number of columns. The description is always "row-by-column." For example, here is a 2-by-3 matrix of two bonds (the rows) with different par values, coupon rates, and coupon payment frequencies per year (the columns) entered using MATLAB notation:

```
Bonds = [1000   0.06   2
          500   0.055  4]
```

Vector. A matrix with only one row or column. Described as a "1-by-*n*" or "*m*-by-1" matrix. The description is always "row-by-column." For example, here is a 1-by-4 vector of cash flows in MATLAB notation:

```
Cash = [1500   4470   5280   -1299]
```

Scalar. A 1-by-1 matrix; that is, a single number.

Referencing Matrix Elements

To reference specific matrix elements, use (row, column) notation. For example:

```
Bonds(1,2)

ans =

          0.06

Cash(3)

ans =

       5280.00
```

You can enlarge matrices using small matrices or vectors as elements. For example,

```
AddBond = [1000   0.065   2];
Bonds = [Bonds; AddBond]
```

adds another row to the matrix and creates

```
Bonds =

       1000   0.06    2
        500   0.055   4
       1000   0.065   2
```

Likewise,

```
Prices = [987.50
          475.00
          995.00]

Bonds = [Prices, Bonds]
```

adds another column and creates

```
Bonds =

    987.50   1000   0.06    2
    475.00    500   0.055   4
    995.00   1000   0.065   2
```

Finally, the colon (:) is important in generating and referencing matrix elements. For example, to reference the par value, coupon rate, and coupon frequency of the second bond:

```
BondItems = Bonds(2, 2:4)

BondItems =

    500.00   0.055   4
```

Transposing Matrices

Sometimes matrices are in the wrong configuration for an operation. In MATLAB, the apostrophe or prime character (') transposes a matrix: columns become rows, rows become columns. For example,

```
Cash = [1500   4470   5280   -1299]'
```

produces

```
Cash =

        1500
        4470
        5280
       -1299
```

Matrix Algebra Refresher

In this section...

"Introduction" on page 1-8
"Adding and Subtracting Matrices" on page 1-8
"Multiplying Matrices" on page 1-9
"Dividing Matrices" on page 1-14
"Solving Simultaneous Linear Equations" on page 1-14
"Operating Element by Element" on page 1-18

Introduction

The explanations in the sections that follow should help refresh your skills for using matrix algebra and using MATLAB functions.

In addition, William Sharpe's *Macro-Investment Analysis* also provides an excellent explanation of matrix algebra operations using MATLAB. It is available on the Web at:

```
http://www.stanford.edu/~wfsharpe/mia/mia.htm
```

Tip When you are setting up a problem, it helps to "talk through" the units and dimensions associated with each input and output matrix. In the example under "Multiplying Matrices" on page 1-9, one input matrix has "five days' closing prices for three stocks," the other input matrix has "shares of three stocks in two portfolios," and the output matrix therefore has "five days' closing values for two portfolios." It also helps to name variables using descriptive terms.

Adding and Subtracting Matrices

Matrix addition and subtraction operate element-by-element. The two input matrices must have the same dimensions. The result is a new matrix of the same dimensions where each element is the sum or difference of each corresponding input element. For example, consider combining portfolios of

different quantities of the same stocks ("shares of stocks A, B, and C [the rows] in portfolios P and Q [the columns] plus shares of A, B, and C in portfolios R and S").

```
Portfolios_PQ = [100   200
                 500   400
                 300   150];

Portfolios_RS = [175   125
                 200   200
                 100   500];

NewPortfolios = Portfolios_PQ + Portfolios_RS

NewPortfolios =

        275.00        325.00
        700.00        600.00
        400.00        650.00
```

Adding or subtracting a scalar and a matrix is allowed and also operates element-by-element.

```
SmallerPortf = NewPortfolios-10

SmallerPortf =
        265.00        315.00
        690.00        590.00
        390.00        640.00
```

Multiplying Matrices

Matrix multiplication does *not* operate element-by-element. It operates according to the rules of linear algebra. In multiplying matrices, it helps to remember this key rule: the inner dimensions must be the same. That is, if the first matrix is *m*-by-3, the second must be 3-by-*n*. The resulting matrix is *m*-by-*n*. It also helps to "talk through" the units of each matrix, as mentioned in "Using Matrix Functions for Finance" on page 1-5.

Matrix multiplication also is *not* commutative; that is, it is not independent of order. A*B does *not* equal B*A. The dimension rule illustrates this property.

If A is 1-by-3 matrix and B is 3-by-1 matrix, A*B yields a scalar (1-by-1) matrix but B*A yields a 3-by-3 matrix.

Multiplying Vectors

Vector multiplication follows the same rules and helps illustrate the principles. For example, a stock portfolio has three different stocks and their closing prices today are:

```
ClosePrices = [42.5   15   78.875]
```

The portfolio contains these numbers of shares of each stock.

```
NumShares = [100
             500
             300]
```

To find the value of the portfolio, multiply the vectors

```
PortfValue = ClosePrices * NumShares
```

which yields:

```
PortfValue =

             35412.50
```

The vectors are 1-by-3 and 3-by-1; the resulting vector is 1-by-1, a scalar. Multiplying these vectors thus means multiplying each closing price by its respective number of shares and summing the result.

To illustrate order dependence, switch the order of the vectors

```
Values = NumShares * ClosePrices

Values =

       4250.00       1500.00       7887.50
      21250.00       7500.00      39437.50
      12750.00       4500.00      23662.50
```

which shows the closing values of 100, 500, and 300 shares of each stock, not the portfolio value, and meaningless for this example.

Computing Dot Products of Vectors

In matrix algebra, if X and Y are vectors of the same length

$$Y = [y_1, y_2, \ldots, y_n]$$

$$X = [x_1, x_2, \ldots, x_n]$$

then the dot product

$$X \bullet Y = x_1 y_1 + x_2 y_2 + \ldots + x_n y_n$$

is the scalar product of the two vectors. It is an exception to the commutative rule. To compute the dot product in MATLAB, use `sum(X .* Y)` or `sum(Y .* X)`. Just be sure the two vectors have the same dimensions. To illustrate, use the previous vectors.

```
Value = sum(NumShares .* ClosePrices')

Value =

      35412.50

Value = sum(ClosePrices .* NumShares')

Value =

      35412.50
```

As expected, the value in these cases matches the `PortfValue` computed previously.

Multiplying Vectors and Matrices

Multiplying vectors and matrices follows the matrix multiplication rules and process. For example, a portfolio matrix contains closing prices for a week. A second matrix (vector) contains the stock quantities in the portfolio.

```
WeekClosePr = [42.5     15      78.875
               42.125   15.5    78.75
               42.125   15.125  79
               42.625   15.25   78.875
               43       15.25   78.625];
PortQuan = [100
            500
            300];
```

To see the closing portfolio value for each day, simply multiply

```
WeekPortValue = WeekClosePr * PortQuan

WeekPortValue =

      35412.50
      35587.50
      35475.00
      35550.00
      35512.50
```

The prices matrix is 5-by-3, the quantity matrix (vector) is 3-by-1, so the resulting matrix (vector) is 5-by-1.

Multiplying Two Matrices

Matrix multiplication also follows the rules of matrix algebra. In matrix algebra notation, if A is an m-by-n matrix and B is an n-by-p matrix

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ \vdots & \vdots & & \vdots \\ a_{i1} & a_{i2} & \dots & a_{in} \\ \vdots & \vdots & & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}, \quad B = \begin{bmatrix} b_{11} & \dots & b_{1j} & \dots & b_{1p} \\ b_{21} & \dots & b_{2j} & \dots & b_{2p} \\ \vdots & & \vdots & & \vdots \\ b_{n1} & & b_{nj} & & b_{np} \end{bmatrix}$$

then $C = A*B$ is an m-by-p matrix; and the element c_{ij} in the ith row and jth column of C is

$$c_{ij} = a_{i1}b_{1j} + a_{i2}b_{2j} + \ldots + a_{in}b_{nj}$$

To illustrate, assume there are two portfolios of the same three stocks above but with different quantities.

```
Portfolios = [100   200
              500   400
              300   150];
```

Multiplying the 5-by-3 week's closing prices matrix by the 3-by-2 portfolios matrix yields a 5-by-2 matrix showing each day's closing value for both portfolios.

```
PortfolioValues = WeekClosePr * Portfolios

PortfolioValues =

      35412.50      26331.25
      35587.50      26437.50
      35475.00      26325.00
      35550.00      26456.25
      35512.50      26493.75
```

Monday's values result from multiplying each Monday closing price by its respective number of shares and summing the result for the first portfolio, then doing the same for the second portfolio. Tuesday's values result from multiplying each Tuesday closing price by its respective number of shares and summing the result for the first portfolio, then doing the same for the second portfolio. And so on through the rest of the week. With one simple command, MATLAB quickly performs many calculations.

Multiplying a Matrix by a Scalar

Multiplying a matrix by a scalar is an exception to the dimension and commutative rules. It just operates element-by-element.

```
Portfolios = [100   200
              500   400
              300   150];
```

```
DoublePort = Portfolios * 2

DoublePort =
        200.00        400.00
       1000.00        800.00
        600.00        300.00
```

Dividing Matrices

Matrix division is useful primarily for solving equations, and especially for solving simultaneous linear equations (see "Solving Simultaneous Linear Equations" on page 1-14). For example, you want to solve for X in $A*X = B$.

In ordinary algebra, you would divide both sides of the equation by A, and X would equal B/A. However, since matrix algebra is not commutative $(A*X \neq X*A)$, different processes apply. In formal matrix algebra, the solution involves matrix inversion. MATLAB, however, simplifies the process by providing two matrix division symbols, left and right (`\` and `/`). In general,

`X = A\B` solves for `X` in `A*X = B` and

`X = B/A` solves for `X` in `X*A = B`.

In general, matrix `A` must be a nonsingular square matrix; that is, it must be invertible and it must have the same number of rows and columns. (Generally, a matrix is invertible if the matrix times its inverse equals the identity matrix. To understand the theory and proofs, consult a textbook on linear algebra such as *Elementary Linear Algebra* by Hill listed in Appendix A, "Bibliography".) MATLAB gives a warning message if the matrix is singular or nearly so.

Solving Simultaneous Linear Equations

Matrix division is especially useful in solving simultaneous linear equations. Consider this problem: Given two portfolios of mortgage-based instruments, each with certain yields depending on the prime rate, how do you weight the portfolios to achieve certain annual cash flows? The answer involves solving two linear equations.

A linear equation is any equation of the form

$$a_1x + a_2y = b$$

where a_1, a_2, and b are constants (with a_1 and a_2 not both 0), and x and y are variables. (It's a linear equation because it describes a line in the xy-plane. For example, the equation $2x + y = 8$ describes a line such that if $x = 2$, then $y = 4$.)

A system of linear equations is a set of linear equations that you usually want to solve at the same time; that is, simultaneously. A basic principle for exact answers in solving simultaneous linear equations requires that there be as many equations as there are unknowns. To get exact answers for x and y, there must be two equations. For example, to solve for x and y in the system of linear equations

$$2x + y = 13$$

$$x - 3y = -18$$

there must be two equations, which there are. Matrix algebra represents this system as an equation involving three matrices: A for the left-side constants, X for the variables, and B for the right-side constants

$$A = \begin{bmatrix} 2 & 1 \\ 1 & -3 \end{bmatrix} \qquad X = \begin{bmatrix} x \\ y \end{bmatrix} \qquad B = \begin{bmatrix} 13 \\ -18 \end{bmatrix}$$

where $A*X = B$.

Solving the system simultaneously means solving for X. Using MATLAB,

```
A = [2  1
     1 -3];

B = [13
    -18];

X = A \ B
```

solves for `X` in `A * X = B`.

```
X = [3 7]
```

So $x = 3$ and $y = 7$ in this example. In general, you can use matrix algebra to solve any system of linear equations such as

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n &= b_1 \\ a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n &= b_2 \\ &\vdots \\ a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n &= b_m \end{aligned}$$

by representing them as matrices

$$A = \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \ldots & a_{mn} \end{bmatrix} \qquad X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} \qquad B = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_m \end{bmatrix}$$

and solving for X in $A*X = B$.

To illustrate, consider this situation. There are two portfolios of mortgage-based instruments, M1 and M2. They have current annual cash payments of $100 and $70 per unit, respectively, based on today's prime rate. If the prime rate moves down one percentage point, their payments would be $80 and $40. An investor holds 10 units of M1 and 20 units of M2. The investor's receipts equal cash payments times units, or R = C * U, for each prime-rate scenario. As word equations:

	M1	M2
Prime flat:	$100 * 10 units	+ $70 * 20 units = $2400 receipts
Prime down:	$80 * 10 units	+ $40 * 20 units = $1600 receipts

As MATLAB matrices:

```
Cash = [100  70
         80  40];

Units = [10
        20];

Receipts = Cash * Units

Receipts =

       2400.00
       1600.00
```

Now the investor asks this question: Given these two portfolios and their characteristics, how many units of each should I hold to receive $7000 if the prime rate stays flat and $5000 if the prime drops one percentage point? Find the answer by solving two linear equations.

	M1	M2
Prime flat:	$100 * *x* units	+ $70 * *y* units = $7000 receipts
Prime down:	$80 * *x* units	+ $40 * *y* units = $5000 receipts

In other words, solve for U (units) in the equation R (receipts) = C (cash) * U (units). Using MATLAB left division

```
Cash = [100  70
         80  40];

Receipts = [7000
            5000];

Units = Cash \ Receipts
Units =

         43.75
```

```
            37.50
```

The investor should hold 43.75 units of portfolio M1 and 37.5 units of portfolio M2 to achieve the annual receipts desired.

Operating Element by Element

Finally, element-by-element arithmetic operations are called *array* operations. To indicate a MATLAB array operation, precede the operator with a period (.). Addition and subtraction, and matrix multiplication and division by a scalar, are already array operations so no period is necessary. When using array operations on two matrices, the dimensions of the matrices must be the same. For example, given vectors of stock dividends and closing prices

```
Dividends = [1.90  0.40  1.56  4.50];
Prices = [25.625  17.75  26.125  60.50];

Yields = Dividends ./ Prices

Yields =

    0.0741    0.0225    0.0597    0.0744
```

Function Input and Output Arguments

In this section...

"Input Arguments" on page 1-19

"Output Arguments" on page 1-21

"Interest Rate Arguments" on page 1-22

Input Arguments

Matrix Input

MATLAB software was designed to be a large-scale array (vector or matrix) processor. In addition to its linear algebra applications, the general array-based processing facility can perform repeated operations on collections of data. When MATLAB code is written to operate simultaneously on collections of data stored in arrays, the code is said to be vectorized. Vectorized code is not only clean and concise, but is also efficiently processed by the underlying MATLAB engine.

Because MATLAB can process vectors and matrices easily, most Financial Toolbox functions allow vector or matrix input arguments, rather than just single (scalar) values. For example, the `irr` function computes the internal rate of return of a cash flow stream. It accepts a vector of cash flows and returns a scalar-valued internal rate of return. However, it also accepts a matrix of cash flow streams, a column in the matrix representing a different cash flow stream. In this case, `irr` returns a vector of internal rates of return, each entry in the vector corresponding to a column of the input matrix. Many other toolbox functions work similarly.

As an example, suppose you make an initial investment of $100, from which you then receive by a series of annual cash receipts of $10, $20, $30, $40, and $50. This cash flow stream may be stored in a vector

```
CashFlows = [-100 10 20 30 40 50]'
```

which MATLAB displays as

```
CashFlows =
```

```
  -100
    10
    20
    30
    40
    50
```

The `irr` function can compute the internal rate of return of this stream.

```
Rate = irr(CashFlows)
```

The internal rate of return of this investment is

```
Rate =

    0.1201
```

or 12.01%.

In this case, a single cash flow stream (written as an input vector) produces a scalar output – the internal rate of return of the investment.

Extending this example, if you process a matrix of identical cash flow streams

```
Rate = irr([CashFlows CashFlows CashFlows])
```

you should expect to see identical internal rates of return for each of the three investments.

```
Rate =

    0.1201    0.1201    0.1201
```

This simple example illustrates the power of vectorized programming. The example shows how to collect data into a matrix and then use a toolbox function to compute answers for the entire collection. This feature can be useful in portfolio management, for example, where you might want to organize multiple assets into a single collection. Place data for each asset in a different column or row of a matrix, then pass the matrix to a Financial Toolbox function. MATLAB performs the same computation on all of the assets at once.

Matrices of String Input

Enter MATLAB strings surrounded by single quotes (`'string'`).

Strings are stored as character arrays, one ASCII character per element. Thus, the date string

```
DateString = '9/16/2001'
```

is actually a 1-by-9 vector. Strings making up the rows of a matrix or vector all must have the same length. To enter several date strings, therefore, use a column vector and be sure all strings are the same length. Fill in with spaces or zeros. For example, to create a vector of dates corresponding to irregular cash flows

```
DateFields = ['01/12/2001'
              '02/14/2001'
              '03/03/2001'
              '06/14/2001'
              '12/01/2001'];
```

`DateFields` actually becomes a 5-by-10 character array.

Don't mix numbers and strings in a matrix. If you do, MATLAB treats all entries as characters. For example,

```
Item = [83  90  99 '14-Sep-1999']
```

becomes a 1-by-14 character array, not a 1-by-4 vector, and it contains

```
Item =

SZc14-Sep-1999
```

Output Arguments

Some functions return no arguments, some return just one, and some return multiple arguments. Functions that return multiple arguments use the syntax

```
[A, B, C] = function(variables...)
```

to return arguments A, B, and C. If you omit all but one, the function returns the first argument. Thus, for this example if you use the syntax

```
X = function(variables...)
```

function returns a value for A, but not for B or C.

Some functions that return vectors accept only scalars as arguments. Why could such functions not accept vectors as arguments and return matrices, where each column in the output matrix corresponds to an entry in the input vector? The answer is that the output vectors can be variable length and thus will not fit in a matrix without some convention to indicate that the shorter columns are missing data.

Functions that require asset life as an input, and return values corresponding to different periods over that life, cannot generally handle vectors or matrices as input arguments. Those functions are:

amortize	Amortization
depfixdb	Fixed declining-balance depreciation
depgendb	General declining-balance depreciation
depsoyd	Sum of years' digits depreciation

For example, suppose you have a collection of assets such as automobiles and you want to compute the depreciation schedules for them. The function depfixdb computes a stream of declining-balance depreciation values for an asset. You might want to set up a vector where each entry is the initial value of each asset. depfixdb also needs the lifetime of an asset. If you were to set up such a collection of automobiles as an input vector, and the lifetimes of those automobiles varied, the resulting depreciation streams would differ in length according to the life of each automobile, and the output column lengths would vary. A matrix must have the same number of rows in each column.

Interest Rate Arguments

One common argument, both as input and output, is interest rate. All Financial Toolbox functions expect and return interest rates as decimal fractions. Thus an interest rate of 9.5% is indicated as 0.095.

2

Performing Common Financial Tasks

- "Introduction" on page 2-2
- "Handling and Converting Dates" on page 2-4
- "Formatting Currency" on page 2-12
- "Charting Financial Data" on page 2-13
- "Analyzing and Computing Cash Flows" on page 2-17
- "Pricing and Computing Yields for Fixed-Income Securities" on page 2-22
- "Term Structure of Interest Rates" on page 2-37
- "Pricing and Analyzing Equity Derivatives" on page 2-40

Introduction

Financial Toolbox software contains functions that perform many common financial tasks, including:

- "Handling and Converting Dates" on page 2-4

  Calendar functions convert dates among different formats (including Excel® formats), determine future or past dates, find dates of holidays and business days, compute time differences between dates, find coupon dates and coupon periods for coupon bonds, and compute time periods based on 360-, 365-, or 366-day years.

- "Formatting Currency" on page 2-12

  The toolbox includes functions for handling decimal values in bank (currency) formats and as fractional prices.

- "Charting Financial Data" on page 2-13

  Charting functions produce a variety of financial charts including Bollinger bands, high-low-close charts, candlestick plots, point and figure plots, and moving-average plots.

- "Analyzing and Computing Cash Flows" on page 2-17

  Cash-flow evaluation and financial accounting functions compute interest rates, rates of return, payments associated with loans and annuities, future and present values, depreciation, and other standard accounting calculations associated with cash-flow streams.

- "Pricing and Computing Yields for Fixed-Income Securities" on page 2-22

  Securities Industry Association (SIA) compliant fixed-income functions compute prices, yields, accrued interest, and sensitivities for securities such as bonds, zero-coupon bonds, and Treasury bills. They handle odd first and last periods in price/yield calculations, compute accrued interest and discount rates, and calculate convexity and duration. Another set of functions analyzes term structure of interest rates, including pricing bonds from yield curves and bootstrapping yield curves from market prices.

- "Pricing and Analyzing Equity Derivatives" on page 2-40

  Derivatives analysis functions compute prices, yields, and sensitivities for derivative securities. They deal with both European and American options.

Black-Scholes functions work with European options. They compute delta, gamma, lambda, rho, theta, and vega, as well as values of call and put options.

Binomial functions work with American options, computing put and call prices.

- "Analyzing Portfolios" on page 3-2

  Portfolio analysis functions provide basic utilities to compute variances and covariance of portfolios, find combinations to minimize variance, compute Markowitz efficient frontiers, and calculate combined rates of return.

- Modeling volatility in time series.

  Generalized Autoregressive Conditional Heteroskedasticity (GARCH) functions model the volatility of univariate economic time series. (Econometrics Toolbox™ software provides a more comprehensive and integrated computing environment. For information, see the Econometrics Toolbox User's Guide documentation or the financial products Web page at `http://www.mathworks.com/products/finprod`.)

Handling and Converting Dates

In this section...

"Date Formats" on page 2-4

"Date Conversions" on page 2-5

"Current Date and Time" on page 2-8

"Determining Dates" on page 2-9

Date Formats

Since virtually all financial data is dated or derives from a time series, financial functions must have extensive date-handling capabilities. You most often work with date strings (14-Sep-1999) when dealing with dates. Financial Toolbox software works internally with *serial date numbers* (for example, 730377). A serial date number represents a calendar date as the number of days that has passed since a fixed base date. In MATLAB software, serial date number 1 is January 1, 0000 A.D. MATLAB also uses serial time to represent fractions of days beginning at midnight; for example, 6 p.m. equals 0.75 serial days. So 6:00 p.m. on 14-Sep-1999, in MATLAB, is date number `730377.75`.

Note If you specify a two-digit year, MATLAB assumes that the year lies within the 100-year period centered about the current year. See the function `datenum` for specific information. MATLAB internal date handling and calculations generate no ambiguous values. However, whenever possible, programmers should use serial date numbers or date strings containing four-digit years.

Many toolbox functions that require dates accept either date strings or serial date numbers. If you are dealing with a few dates at the MATLAB command-line level, date strings are more convenient. If you are using toolbox functions on large numbers of dates, as in analyzing large portfolios or cash flows, performance improves if you use date numbers.

The Financial Toolbox software provides functions that convert date strings to serial date numbers, and vice versa.

Date Conversions

Functions that convert between date formats are

`datedisp`	Displays a numeric matrix with date entries formatted as date strings
`datenum`	Converts a date string to a serial date number
`datestr`	Converts a serial date number to a date string
`m2xdate`	Converts MATLAB serial date number to Excel serial date number
`x2mdate`	Converts Excel serial date number to MATLAB serial date number

Another function, `datevec`, converts a date number or date string to a date vector whose elements are `[Year Month Day Hour Minute Second]`. Date vectors are mostly an internal format for some MATLAB functions; you would not often use them in financial calculations.

Input Conversions

The `datenum` function is important for using Financial Toolbox software efficiently. `datenum` takes an input string in any of several formats, with `'dd-mmm-yyyy'`, `'mm/dd/yyyy'` or `'dd-mmm-yyyy, hh:mm:ss.ss'` most common. The input string can have up to six fields formed by letters and numbers separated by any other characters:

- The day field is an integer from 1 through 31.
- The month field is either an integer from 1 through 12 or an alphabetical string with at least three characters.
- The year field is a nonnegative integer: if only two numbers are specified, then the year is assumed to lie within the 100-year period centered about the current year; if the year is omitted, the current year is used as the default.
- The hours, minutes, and seconds fields are optional. They are integers separated by colons or followed by `'am'` or `'pm'`.

For example, if the current year is 1999, then these are all equivalent

```
'17-May-1999'
'17-May-99'
'17-may'
'May 17, 1999'
'5/17/99'
'5/17'
```

and both of these represent the same time.

```
'17-May-1999, 18:30'
'5/17/99/6:30 pm'
```

Note that the default format for numbers-only input follows the American convention. Thus 3/6 is March 6, not June 3.

With `datenum` you can convert dates into serial date format, store them in a matrix variable, then later pass the variable to a function. Alternatively, you can use `datenum` directly in a function input argument list.

For example, consider the function `bndprice` that computes the price of a bond given the yield-to-maturity. First set up variables for the yield-to-maturity, coupon rate, and the necessary dates.

```
Yield       = 0.07;
CouponRate  = 0.08;
Settle      = datenum('17-May-2000');
Maturity    = datenum('01-Oct-2000');
```

Then call the function with the variables

```
bndprice(Yield, CouponRate, Settle, Maturity)
```

Alternatively, convert date strings to serial date numbers directly in the function input argument list.

```
bndprice(0.07, 0.08, datenum('17-May-2000'),...
datenum('01-Oct-2000'))
```

`bndprice` is an example of a function designed to detect the presence of date strings and make the conversion automatically. For these functions date strings may be passed directly.

```
bndprice(0.07, 0.08, '17-May-2000', '01-Oct-2000')
```

The decision to represent dates as either date strings or serial date numbers is often a matter of convenience. For example, when formatting data for visual display or for debugging date-handling code, it is often much easier to view dates as date strings because serial date numbers are difficult to interpret. Alternatively, serial date numbers are just another type of numeric data, and can be placed in a matrix along with any other numeric data for convenient manipulation.

Remember that if you create a vector of input date strings, use a column vector and be sure all strings are the same length. Fill with spaces or zeros. See "Matrices of String Input" on page 1-21.

Output Conversions

The function `datestr` converts a serial date number to one of 19 different date string output formats showing date, time, or both. The default output for dates is a day-month-year string, for example, 24-Aug-2000. This function is quite useful for preparing output reports.

Format	Description
`01-Mar-2000 15:45:17`	day-month-year hour:minute:second
`01-Mar-2000`	day-month-year
`03/01/00`	month/day/year
`Mar`	month, three letters
`M`	month, single letter
`3`	month
`03/01`	month/day
`1`	day of month
`Wed`	day of week, three letters
`W`	day of week, single letter
`2000`	year, four numbers
`99`	year, two numbers

Format	Description
Mar01	month year
15:45:17	hour:minute:second
03:45:17 PM	hour:minute:second AM or PM
15:45	hour:minute
03:45 PM	hour:minute AM or PM
Q1-99	calendar quarter-year
Q1	calendar quarter

Current Date and Time

The functions `today` and `now` return serial date numbers for the current date, and the current date and time, respectively.

```
today

ans =
      730693

now

ans =

      730693.48
```

The MATLAB function `date` returns a string for today's date.

```
date

ans =

26-Jul-2000
```

Determining Dates

The Financial Toolbox software provides many functions for determining specific dates, including functions which account for holidays and other nontrading days. For example, you schedule an accounting procedure for the last Friday of every month. The `lweekdate` function returns those dates for 2000; the 6 specifies Friday.

```
Fridates = lweekdate(6, 2000, 1:12);

Fridays = datestr(Fridates)

Fridays =

28-Jan-2000
25-Feb-2000
31-Mar-2000
28-Apr-2000
26-May-2000
30-Jun-2000
28-Jul-2000
25-Aug-2000
29-Sep-2000
27-Oct-2000
24-Nov-2000
29-Dec-2000
```

Or your company closes on Martin Luther King Jr. Day, which is the third Monday in January. The `nweekdate` function determines those dates for 2001 through 2004.

```
MLKDates = nweekdate(3, 2, 2001:2004, 1);

MLKDays = datestr(MLKDates)

MLKDays =

15-Jan-2001
21-Jan-2002
20-Jan-2003
19-Jan-2004
```

Accounting for holidays and other nontrading days is important when examining financial dates. The Financial Toolbox software provides the `holidays` function, which contains holidays and special nontrading days for the New York Stock Exchange between 1950 and 2030, inclusive. You can edit the `holidays.m` file to customize it with your own holidays and nontrading days. In this example, use it to determine the standard holidays in the last half of 2000.

```
LHHDates = holidays('1-Jul-2000', '31-Dec-2000');

LHHDays = datestr(LHHDates)

LHHDays =

04-Jul-2000
04-Sep-2000
23-Nov-2000
25-Dec-2000
```

Now use the toolbox `busdate` function to determine the next business day after these holidays.

```
LHNextDates = busdate(LHHDates);

LHNextDays = datestr(LHNextDates)

LHNextDays =

05-Jul-2000
05-Sep-2000
24-Nov-2000
26-Dec-2000
```

The toolbox also provides the `cfdates` function to determine cash-flow dates for securities with periodic payments. This function accounts for the coupons per year, the day-count basis, and the end-of-month rule. For example, to determine the cash-flow dates for a security that pays four coupons per year on the last day of the month, on an actual/365 day-count basis, just enter the settlement date, the maturity date, and the parameters.

```
PayDates = cfdates('14-Mar-2000', '30-Nov-2001', 4, 3, 1);
```

```
PayDays = datestr(PayDates)

PayDays =

31-May-2000
31-Aug-2000
30-Nov-2000
28-Feb-2001
31-May-2001
31-Aug-2001
30-Nov-2001
```

Formatting Currency

Financial Toolbox software provides several functions to format currency and chart financial data. The currency formatting functions are

`cur2frac`	Converts decimal currency values to fractional values
`cur2str`	Converts a value to Financial Toolbox bank format
`frac2cur`	Converts fractional currency values to decimal values

These examples show their use.

```
Dec = frac2cur('12.1', 8)
```

returns `Dec = 12.125`, which is the decimal equivalent of 12-1/8. The second input variable is the denominator of the fraction.

```
Str =  cur2str(-8264, 2)
```

returns the string `($8264.00)`. For this toolbox function, the output format is a numerical format with dollar sign prefix, two decimal places, and negative numbers in parentheses; for example, `($123.45)` and `$6789.01`. The standard MATLAB bank format uses two decimal places, no dollar sign, and a minus sign for negative numbers; for example, `-123.45` and `6789.01`.

Charting Financial Data

In this section...

"Introduction" on page 2-13
"High-Low-Close Chart Example" on page 2-14
"Bollinger Chart Example" on page 2-15

Introduction

The following toolbox financial charting functions plot financial data and produce presentation-quality figures quickly and easily.

`bolling`	Bollinger band chart
`bollinger`	Time series Bollinger band
`candle`	Candlestick chart
`candle`	Time series candle plot
`pointfig`	Point and figure chart
`highlow`	High, low, open, close chart
`highlow`	Time series High-Low plot
`movavg`	Leading and lagging moving averages chart

These functions work with standard MATLAB functions that draw axes, control appearance, and add labels and titles. The toolbox also provides a comprehensive set of charting functions that work with financial time series objects. For lists of these, see "Financial Data Charts" on page 13-6 and "Financial Time Series Indicator" on page 13-22.

Here are two plotting examples: a high-low-close chart of sample IBM® stock price data, and a Bollinger band chart of the same data. These examples load data from an external file (`ibm.dat`), then call the functions using subsets of the data. The MATLAB variable `ibm` , which is created by loading `ibm.dat`, is a six-column matrix where each row is a trading day's data and where columns 2, 3, and 4 contain the high, low, and closing prices, respectively.

Note The data in `ibm.dat` is fictional and for illustrative use only.

High-Low-Close Chart Example

First load the data and set up matrix dimensions. `load` and `size` are standard MATLAB functions.

```
load ibm.dat;
[ro, co] = size(ibm);
```

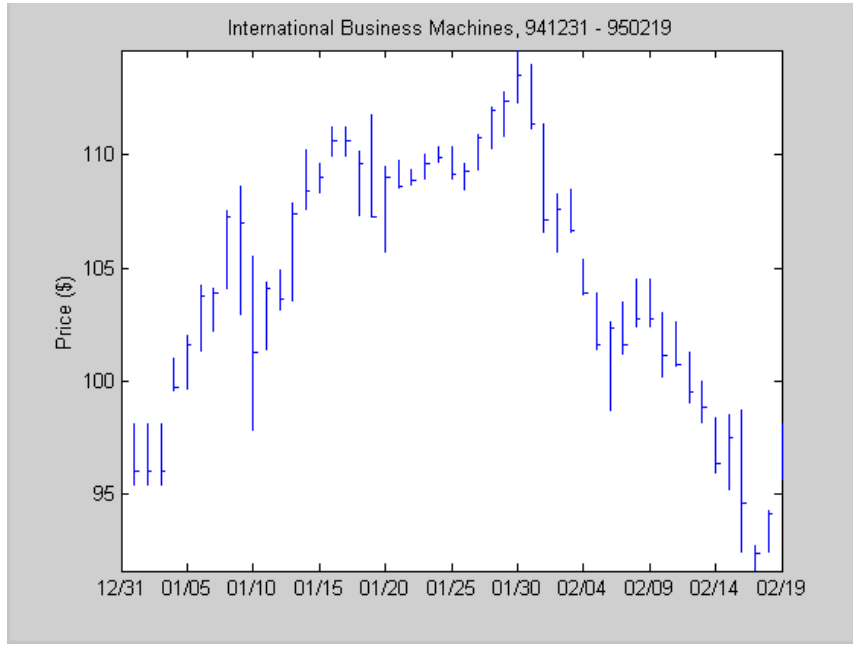
Open a figure window for the chart. Use the Financial Toolbox `highlow` function to plot high, low, and close prices for the last 50 trading days in the data file.

```
figure;
highlow(ibm(ro-50:ro,2),ibm(ro-50:ro,3),ibm(ro-50:ro,4),[],'b');
```

Add labels and title, and set axes with standard MATLAB functions. Use the Financial Toolbox `dateaxis` function to provide dates for the *x*-axis ticks.

```
xlabel('');
ylabel('Price ($)');
title('International Business Machines, 941231 - 950219');
axis([0 50 -inf inf]);
dateaxis('x',6,'31-Dec-1994')
```

MATLAB produces a figure like this. The plotted data and axes you see may differ. Viewed online, the high-low-close bars are blue.



Bollinger Chart Example

The `bolling` function in Financial Toolbox software produces a Bollinger band chart using all the closing prices in the same IBM stock price matrix. A Bollinger band chart plots actual data along with three other bands of data. The upper band is two standard deviations above a moving average; the lower band is two standard deviations below that moving average; and the middle band is the moving average itself. This example uses a 15-day moving average.

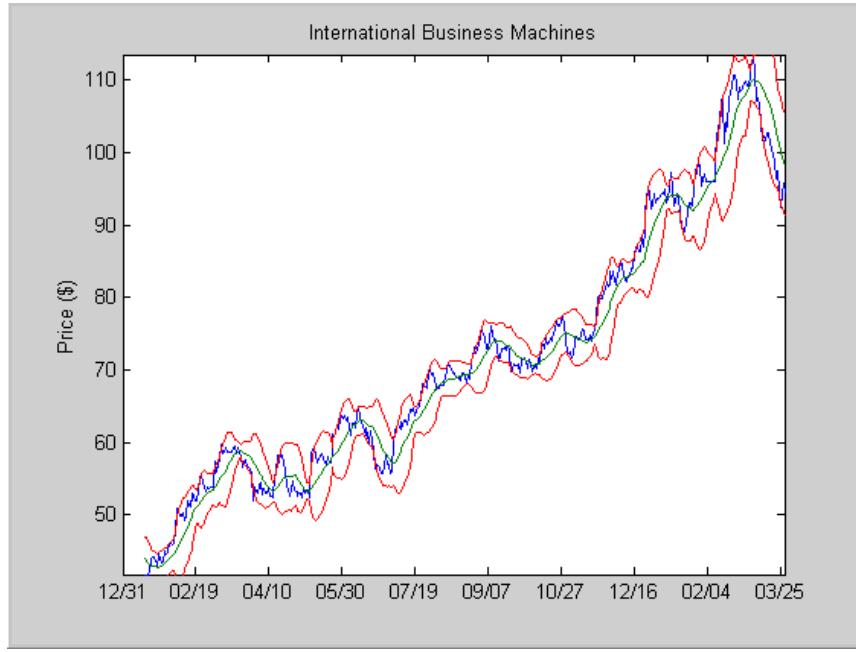
Assuming the previous IBM data is still loaded, execute the function.

```
bolling(ibm(:,4), 15, 0);
```

Specify the axes, labels, and titles. Again, use `dateaxis` to add the *x*-axis dates.

```
axis([0 ro min(ibm(:,4)) max(ibm(:,4))]);
ylabel('Price ($)');
```

```
title(['International Business Machines']);
dateaxis('x', 6,'31-Dec-1994')
```



For help using MATLAB plotting functions, see Creating Plots in the MATLAB documentation. See the MATLAB documentation for details on the `axis`, `title`, `xlabel`, and `ylabel` functions.

Analyzing and Computing Cash Flows

In this section...

"Introduction" on page 2-17

"Interest Rates/Rates of Return" on page 2-17

"Present or Future Values" on page 2-18

"Depreciation" on page 2-19

"Annuities" on page 2-19

Introduction

Financial Toolbox cash-flow functions compute interest rates and rates of return, present or future values, depreciation streams, and annuities.

Some examples in this section use this income stream: an initial investment of $20,000 followed by three annual return payments, a second investment of $5,000, then four more returns. Investments are negative cash flows, return payments are positive cash flows.

```
Stream = [-20000,  2000,  2500,  3500, -5000,  6500,...
            9500,  9500,  9500];
```

Interest Rates/Rates of Return

Several functions calculate interest rates involved with cash flows. To compute the internal rate of return of the cash stream, execute the toolbox function `irr`

```
ROR = irr(Stream)
```

which gives a rate of return of 11.72%.

Note that the internal rate of return of a cash flow may not have a unique value. Every time the sign changes in a cash flow, the equation defining `irr` can give up to two additional answers. An `irr` computation requires solving a polynomial equation, and the number of real roots of such an equation can depend on the number of sign changes in the coefficients. The equation for internal rate of return is

$$\frac{cf_1}{(1+r)} + \frac{cf_2}{(1+r)^2} + \ldots + \frac{cf_n}{(1+r)^n} + Investment = 0$$

where *Investment* is a (negative) initial cash outlay at time 0, cf_n is the cash flow in the *n*th period, and *n* is the number of periods. Basically, `irr` finds the rate *r* such that the net present value of the cash flow equals the initial investment. If all of the cf_ns are positive there is only one solution. Every time there is a change of sign between coefficients, up to two additional real roots are possible. There is usually only one answer that makes sense, but it is possible to get returns of both 5% and 11% (for example) from one income stream.

Another toolbox rate function, `effrr`, calculates the effective rate of return given an annual interest rate (also known as nominal rate or annual percentage rate, APR) and number of compounding periods per year. To find the effective rate of a 9% APR compounded monthly, enter

```
Rate = effrr(0.09, 12)
```

The answer is 9.38%.

A companion function `nomrr` computes the nominal rate of return given the effective annual rate and the number of compounding periods.

Present or Future Values

The toolbox includes functions to compute the present or future value of cash flows at regular or irregular time intervals with equal or unequal payments: `fvfix`, `fvvar`, `pvfix`, and `pvvar`. The `-fix` functions assume equal cash flows at regular intervals, while the `-var` functions allow irregular cash flows at irregular periods.

Now compute the net present value of the sample income stream for which you computed the internal rate of return. This exercise also serves as a check on that calculation because the net present value of a cash stream at its internal rate of return should be zero. Enter

```
NPV = pvvar(Stream, ROR)
```

which returns an answer very close to zero. The answer usually is not *exactly* zero due to rounding errors and the computational precision of the computer.

Note Other toolbox functions behave similarly. The functions that compute a bond's yield, for example, often must solve a nonlinear equation. If you then use that yield to compute the net present value of the bond's income stream, it usually does not *exactly* equal the purchase price, but the difference is negligible for practical applications.

Depreciation

The toolbox includes functions to compute standard depreciation schedules: straight line, general declining-balance, fixed declining-balance, and sum of years' digits. Functions also compute a complete amortization schedule for an asset, and return the remaining depreciable value after a depreciation schedule has been applied.

This example depreciates an automobile worth $15,000 over five years with a salvage value of $1,500. It computes the general declining balance using two different depreciation rates: 50% (or 1.5), and 100% (or 2.0, also known as double declining balance). Enter

```
Decline1 = depgendb(15000, 1500, 5, 1.5)
Decline2 = depgendb(15000, 1500, 5, 2.0)
```

which returns

```
Decline1 =
       4500.00       3150.00       2205.00       1543.50       2101.50
Decline2 =
       6000.00       3600.00       2160.00       1296.00        444.00
```

These functions return the actual depreciation amount for the first four years and the remaining depreciable value as the entry for the fifth year.

Annuities

Several toolbox functions deal with annuities. This first example shows how to compute the interest rate associated with a series of loan payments

when only the payment amounts and principal are known. For a loan whose original value was $5000.00 and which was paid back monthly over four years at $130.00/month

```
Rate = annurate(4*12, 130, 5000, 0, 0)
```

The function returns a rate of 0.0094 monthly, or about 11.28% annually.

The next example uses a present-value function to show how to compute the initial principal when the payment and rate are known. For a loan paid at $300.00/month over four years at 11% annual interest

```
Principal = pvfix(0.11/12, 4*12, 300, 0, 0)
```

The function returns the original principal value of $11,607.43.

The final example computes an amortization schedule for a loan or annuity. The original value was $5000.00 and was paid back over 12 months at an annual rate of 9%.

```
[Prpmt, Intpmt, Balance, Payment] = ...
        amortize(0.09/12, 12, 5000, 0, 0);
```

This function returns vectors containing the amount of principal paid,

```
Prpmt = [399.76 402.76  405.78  408.82  411.89  414.97
         418.09 421.22  424.38  427.56  430.77  434.00]
```

the amount of interest paid,

```
Intpmt = [37.50 34.50  31.48  28.44  25.37  22.28
          19.17 16.03  12.88   9.69   6.49   3.26]
```

the remaining balance for each period of the loan,

```
Balance = [4600.24  4197.49  3791.71  3382.89  2971.01
           2556.03  2137.94  1716.72  1292.34   864.77
            434.00     0.00]
```

and a scalar for the monthly payment.

```
Payment = 437.26
```

Pricing and Computing Yields for Fixed-Income Securities

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Introduction

The Financial Toolbox product provides functions for computing accrued interest, price, yield, convexity, and duration of fixed-income securities. Various conventions exist for determining the details of these computations. The Financial Toolbox software supports conventions specified by the Securities Industry and Financial Markets Association (SIFMA), used in the US markets, the International Capital Market Association (ICMA), used mainly in the European markets, and the International Swaps and Derivatives Association (ISDA). Note that for historical reasons, SIFMA is referred to in Financial Toolbox documentation as SIA and ICMA is referred to as International Securities Market Association (ISMA).

Terminology

Since terminology varies among texts on this subject, here are some basic definitions that apply to these Financial Toolbox functions. The "Glossary" on page Glossary-1 contains additional definitions.

The *settlement date* of a bond is the date when money first changes hands; that is, when a buyer pays for a bond. It need not coincide with the *issue date*, which is the date a bond is first offered for sale.

The *first coupon date* and *last coupon date* are the dates when the first and last coupons are paid, respectively. Although bonds typically pay periodic annual or semiannual coupons, the length of the first and last coupon periods may differ from the standard coupon period. The toolbox includes price and yield functions that handle these odd first and/or last periods.

Successive *quasi-coupon dates* determine the length of the standard coupon period for the fixed income security of interest, and do not necessarily coincide with actual coupon payment dates. The toolbox includes functions that calculate both actual and quasi-coupon dates for bonds with odd first and/or last periods.

Fixed-income securities can be purchased on dates that do not coincide with coupon payment dates. In this case, the bond owner is not entitled to the full value of the coupon for that period. When a bond is purchased between coupon dates, the buyer must compensate the seller for the pro-rata share of the coupon interest earned from the previous coupon payment date. This pro-rata share of the coupon payment is called *accrued interest*. The *purchase price*, the price actually paid for a bond, is the quoted market price plus accrued interest.

The *maturity date* of a bond is the date when the issuer returns the final face value, also known as the *redemption value* or *par value*, to the buyer. The *yield-to-maturity* of a bond is the nominal compound rate of return that equates the present value of all future cash flows (coupons and principal) to the current market price of the bond.

The *period* of a bond refers to the frequency with which the issuer of a bond makes coupon payments to the holder.

Period of a Bond

Period Value	Payment Schedule
0	No coupons (Zero coupon bond)
1	Annual
2	Semiannual
3	Tri-annual
4	Quarterly

Period of a Bond (Continued)

Period Value	Payment Schedule
6	Bi-monthly
12	Monthly

The *basis* of a bond refers to the basis or day-count convention for a bond. Basis is normally expressed as a fraction in which the numerator determines the number of days between two dates, and the denominator determines the number of days in the year. For example, the numerator of *actual/actual* means that when determining the number of days between two dates, count the actual number of days; the denominator means that you use the actual number of days in the given year in any calculations (either 365 or 366 days depending on whether the given year is a leap year).

The day count convention determines how accrued interest is calculated and determines how cash flows for the bond are discounted, thereby effecting price and yield calculations. Furthermore, the SIA convention is to use the actual/actual day count convention for discounting cash flows in all cases.

Basis of a Bond

Basis Value	Meaning	Description
0 (default)	actual/actual	Actual days held over actual days in coupon period. Denominator is 365 in most years and 366 in a leap year.
1	30/360 (SIA)	Each month contains 30 days; a year contains 360 days. Payments are adjusted for bonds that pay coupons on the last day of February.

Basis of a Bond (Continued)

Basis Value	Meaning	Description
2	actual/360	Actual days held over 360.
3	actual/365	Actual days held over 365, even in leap years.
4	30/360 PSA (Public Securities Association)	Each month contains 30 days; a year contains 360 days. If the last date of the period is the last day of February, the month is extended to 30 days.
5	30/360 ISDA (International Swap Dealers Association)	Variant of 30/360 with slight differences for calculating number of days in a month.
6	30/360 European	Variant of 30/360 used primarily in Europe.
7	actual/365 Japanese	All years contain 365 days. Leap days are ignored.
8	actual/actual (ISMA)	Actual days held over actual days in coupon period. Denominator is 365 in most years and 366 in a leap year. This basis assumes an annual compounding period.
9	actual/360 (ISMA)	Actual days held over 360. This basis assumes an annual compounding period.

Basis of a Bond (Continued)

Basis Value	Meaning	Description
10	actual/365 (ISMA)	Actual days held over 365, even in leap years. This basis assumes an annual compounding period.
11	30/360E (ISMA)	The number of days in every month is set to 30. If the start date or the end date of the period is the 31st of a month, that date is set to the 30th. The number of days in a year is 360.
12	actual/365 (ISDA)	This day count fraction is equal to the sum of number of interest accrual days falling with a leap year divided by 366 and the number of interest accrual days not falling within a leap year divided by 365.

Note Although the concept of day count sounds deceptively simple, the actual calculation of day counts can be quite complex. You can find a good discussion of day counts and the formulas for calculating them in Chapter 5 of Stigum and Robinson, *Money Market and Bond Calculations* in Appendix A, "Bibliography".

The *end-of-month rule* affects a bond's coupon payment structure. When the rule is in effect, a security that pays a coupon on the last actual day of a month will always pay coupons on the last day of the month. This means,

for example, that a semiannual bond that pays a coupon on February 28 in nonleap years will pay coupons on August 31 in all years and on February 29 in leap years.

End-of-Month Rule

End-of-Month Rule Value	Meaning
1 (default)	Rule in effect.
0	Rule not in effect.

Framework

Although not all Financial Toolbox functions require the same input arguments, they all accept the following common set of input arguments.

Common Input Arguments

Input	Meaning
`Settle`	Settlement date
`Maturity`	Maturity date
`Period`	Coupon payment period
`Basis`	Day-count basis
`EndMonthRule`	End-of-month payment rule
`IssueDate`	Bond issue date
`FirstCouponDate`	First coupon payment date
`LastCouponDate`	Last coupon payment date

Of the common input arguments, only `Settle` and `Maturity` are required. All others are optional. They will be set to the default values if you do not explicitly set them. Note that, by default, the `FirstCouponDate` and `LastCouponDate` are nonapplicable. In other words, if you do not specify `FirstCouponDate` and `LastCouponDate`, the bond is assumed to have no odd

first or last coupon periods. In this case, the bond is a standard bond with a coupon payment structure based solely on the maturity date.

Default Parameter Values

To illustrate the use of default values in Financial Toolbox functions, consider the `cfdates` function, which computes actual cash flow payment dates for a portfolio of fixed income securities regardless of whether the first and/or last coupon periods are normal, long, or short.

The complete calling syntax with the full input argument list is

```
CFlowDates = cfdates(Settle, Maturity, Period, Basis, ...
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)
```

while the minimal calling syntax requires only settlement and maturity dates

```
CFlowDates = cfdates(Settle, Maturity)
```

Single Bond Example

As an example, suppose you have a bond with these characteristics

```
Settle          = '20-Sep-1999'
Maturity        = '15-Oct-2007'
Period          = 2
Basis           = 0
EndMonthRule    = 1
IssueDate       = NaN
FirstCouponDate = NaN
LastCouponDate  = NaN
```

Note that `Period`, `Basis`, and `EndMonthRule` are set to their default values, and `IssueDate`, `FirstCouponDate`, and `LastCouponDate` are set to `NaN`.

Formally, a `NaN` is an IEEE® arithmetic standard for *Not-a-Number* and is used to indicate the result of an undefined operation (for example, zero divided by zero). However, `NaN` is also a very convenient placeholder. In the SIA functions of Financial Toolbox software, `NaN` indicates the presence of a nonapplicable value. It tells the Financial Toolbox functions to ignore the

input value and apply the default. Setting `IssueDate`, `FirstCouponDate`, and `LastCouponDate` to `NaN` in this example tells `cfdates` to assume that the bond has been issued before settlement and that no odd first or last coupon periods exist.

Having set these values, all these calls to `cfdates` produce the same result.

```
cfdates(Settle, Maturity)
cfdates(Settle, Maturity, Period)
cfdates(Settle, Maturity, Period, [])
cfdates(Settle, Maturity, [], Basis)
cfdates(Settle, Maturity, [], [])
cfdates(Settle, Maturity, Period, [], EndMonthRule)
cfdates(Settle, Maturity, Period, [], NaN)
cfdates(Settle, Maturity, Period, [], [], IssueDate)
cfdates(Settle, Maturity, Period, [], [], IssueDate, [], [])
cfdates(Settle, Maturity, Period, [], [], [], [],LastCouponDate)
cfdates(Settle, Maturity, Period, Basis, EndMonthRule, ...
IssueDate, FirstCouponDate, LastCouponDate)
```

Thus, leaving a particular input unspecified has the same effect as passing an empty matrix (`[]`) or passing a `NaN` – all three tell `cfdates` (and other Financial Toolbox functions) to use the default value for a particular input parameter.

Bond Portfolio Example

Since the previous example included only a single bond, there was no difference between passing an empty matrix or passing a `NaN` for an optional input argument. For a portfolio of bonds, however, using `NaN` as a placeholder is the only way to specify default acceptance for some bonds while explicitly setting nondefault values for the remaining bonds in the portfolio.

Now suppose you have a portfolio of two bonds.

```
Settle   = '20-Sep-1999'
Maturity = ['15-Oct-2007'; '15-Oct-2010']
```

These calls to `cfdates` all set the coupon period to its default value (`Period = 2`) for both bonds.

```
cfdates(Settle, Maturity, 2)
cfdates(Settle, Maturity, [2 2])
cfdates(Settle, Maturity, [])
cfdates(Settle, Maturity, NaN)
cfdates(Settle, Maturity, [NaN NaN])
cfdates(Settle, Maturity)
```

The first two calls explicitly set `Period = 2`. Since `Maturity` is a `2`-by-`1` vector of maturity dates, `cfdates` knows you have a two-bond portfolio.

The first call specifies a single (that is, scalar) 2 for `Period`. Passing a scalar tells `cfdates` to apply the scalar-valued input to all bonds in the portfolio. This is an example of implicit scalar-expansion. Note that the settlement date has been implicit scalar-expanded as well.

The second call also applies the default coupon period by explicitly passing a two-element vector of 2's. The third call passes an empty matrix, which `cfdates` interprets as an invalid period, for which the default value will be used. The fourth call is similar, except that a `NaN` has been passed. The fifth call passes two `NaN`'s, and has the same effect as the third. The last call passes the minimal input set.

Finally, consider the following calls to `cfdates` for the same two-bond portfolio.

```
cfdates(Settle, Maturity, [4 NaN])
cfdates(Settle, Maturity, [4 2])
```

The first call explicitly sets `Period = 4` for the first bond and implicitly sets the default `Period = 2` for the second bond. The second call has the same effect as the first but explicitly sets the periodicity for both bonds.

The optional input `Period` has been used for illustrative purpose only. The default-handling process illustrated in the examples applies to any of the optional input arguments.

Coupon Date Calculations

Calculating coupon dates, either actual or quasi dates, is notoriously complicated. Financial Toolbox software follows the SIA conventions in coupon date calculations.

The first step in finding the coupon dates associated with a bond is to determine the reference, or synchronization date (the *sync date*). Within the SIA framework, the order of precedence for determining the sync date is:

1. The first coupon date
2. The last coupon date
3. The maturity date

In other words, a Financial Toolbox function first examines the `FirstCouponDate` input. If `FirstCouponDate` is specified, coupon payment dates and quasi-coupon dates are computed with respect to `FirstCouponDate`; if `FirstCouponDate` is unspecified, empty (`[]`), or `NaN`, then the `LastCouponDate` is examined. If `LastCouponDate` is specified, coupon payment dates and quasi-coupon dates are computed with respect to `LastCouponDate`. If both `FirstCouponDate` and `LastCouponDate` are unspecified, empty (`[]`), or `NaN`, the `Maturity` (a required input argument) serves as the sync date.

Yield Conventions

There are two yield and time factor conventions that are used in the Financial Toolbox software – these are determined by the input `basis`. Specifically, bases `0` to `7` are assumed to have semiannual compounding, while bases `8` to `12` are assumed to have annual compounding regardless of the period of the bond's coupon payments (including zero-coupon bonds). In addition, any yield-related sensitivity (that is, duration and convexity), when quoted on a periodic basis, follows this same convention. (See `bndconvp`, `bndconvy`, `bnddurp`, `bnddury`, and `bndkrdur`.)

Pricing Functions

This example shows how easily you can compute the price of a bond with an odd first period using the function `bndprice`. Assume you have a bond with these characteristics:

```
Settle          = '11-Nov-1992';
Maturity        = '01-Mar-2005';
IssueDate       = '15-Oct-1992';
FirstCouponDate = '01-Mar-1993';
CouponRate      = 0.0785;
Yield           = 0.0625;
```

Allow coupon payment period (`Period = 2`), day-count basis (`Basis = 0`), and end-of-month rule (`EndMonthRule = 1`) to assume the default values. Also, assume there is no odd last coupon date and that the face value of the bond is $100. Calling the function

```
[Price, AccruedInt] = bndprice(Yield, CouponRate, Settle, ...
Maturity, [], [], [], IssueDate, FirstCouponDate)
```

returns a price of $113.60 and accrued interest of $0.59.

Similar functions compute prices with regular payments, odd first and last periods, and prices of Treasury bills and discounted securities such as zero-coupon bonds.

Note `bndprice` and other functions use nonlinear formulas to compute the price of a security. For this reason, Financial Toolbox software uses Newton's method when solving for an independent variable within a formula. See any elementary numerical methods textbook for the mathematics underlying Newton's method.

Yield Functions

To illustrate toolbox yield functions, compute the yield of a bond that has odd first and last periods and settlement in the first period. First set up variables for settlement, maturity date, issue, first coupon, and a last coupon date.

```
Settle          = '12-Jan-2000';
```

```
Maturity        = '01-Oct-2001';
IssueDate       = '01-Jan-2000';
FirstCouponDate = '15-Jan-2000';
LastCouponDate  = '15-Apr-2000';
```

Assume a face value of $100. Specify a purchase price of $95.70, a coupon rate of 4%, quarterly coupon payments, and a 30/360 day-count convention (`Basis = 1`).

```
Price        = 95.7;
CouponRate   = 0.04;
Period       = 4;
Basis        = 1;
EndMonthRule = 1;
```

Calling the function

```
Yield = bndyield(Price, CouponRate, Settle, Maturity, Period,...
Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)
```

returns

`Yield = 0.0659` (6.60%).

Fixed-Income Sensitivities

Financial Toolbox software supports the following options for managing interest-rate risk for one or more bonds:

- `bnddurp` and `bnddury` support duration and convexity analysis based on market quotes and assume parallel shifts in the bond yield curve.
- `bndkrdur` supports key rate duration based on a market yield curve and can model nonparallel shifts in the bond yield curve.

Calculating Duration and Convexity for Bonds

The toolbox includes functions to perform sensitivity analysis such as convexity and the Macaulay and modified durations for fixed-income securities. The Macaulay duration of an income stream, such as a coupon bond, measures how long, on average, the owner waits before receiving a

payment. It is the weighted average of the times payments are made, with the weights at time `T` equal to the present value of the money received at time `T`. The modified duration is the Macaulay duration discounted by the per-period interest rate; that is, divided by (1+rate/frequency).

To illustrate, the following example computes the annualized Macaulay and modified durations, and the periodic Macaulay duration for a bond with settlement (12-Jan-2000) and maturity (01-Oct-2001) dates as above, a 5% coupon rate, and a 4.5% yield to maturity. For simplicity, any optional input arguments assume default values (that is, semiannual coupons, and day-count `basis` = 0 (actual/actual), coupon payment structure synchronized to the maturity date, and end-of-month payment rule in effect).

```
CouponRate = 0.05;
Yield = 0.045;

[ModDuration, YearDuration, PerDuration] = bnddury(Yield,...
CouponRate, Settle, Maturity)
```

The durations are

```
ModDuration  = 1.6107 (years)
YearDuration = 1.6470 (years)
PerDuration  = 3.2940 (semiannual periods)
```

Note that the semiannual periodic Macaulay duration (`PerDuration`) is twice the annualized Macaulay duration (`YearDuration`).

Calculating Key Rate Durations for Bonds

Key rate duration enables you to evaluate the sensitivity and price of a bond to nonparallel changes in the spot or zero curve by decomposing the interest rate risk along the spot or zero curve. Key rate duration refers to the process of choosing a set of key rates and computing a duration for each rate. Specifically, for each key rate, while the other rates are held constant, the key rate is shifted up and down (and intermediate cash flow dates are interpolated), and then the present value of the security given the shifted curves is computed.

The calculation of `bndkrdur` supports:

$$\text{krdur_i} = \frac{(\text{PV_down - PV_up})}{(\text{PV x ShiftValue x 2})}$$

Where *PV* is the current value of the instrument, *PV_up* and *PV_down* are the new values after the discount curve has been shocked, and *ShiftValue* is the change in interest rate. For example, if key rates of 3 months, 1, 2, 3, 5, 7, 10, 15, 20, 25, 30 years were chosen, then a 30-year bond might have corresponding key rate durations of:

3M	1Y	2Y	3Y	5Y	7Y	10Y	15Y	20Y	25Y	30Y
.01	.04	.09	.21	.4	.65	1.27	1.71	1.68	1.83	7.03

The key rate durations add up to approximately equal the duration of the bond.

For example, compute the key rate duration of the U.S. Treasury Bond with maturity date of August 15, 2028 and coupon rate of 5.5%. (For further information on this bond, refer to .)

```
Settle = datenum('18-Nov-2008');
CouponRate = 5.500/100;
Maturity = datenum('15-Aug-2028');
Price = 114.83;
```

For the `ZeroData` information on the current spot curve for this bond, refer to :

```
ZeroDates = daysadd(Settle ,[30 90 180 360 360*2 360*3 360*5 ...
360*7 360*10 360*20 360*30]);
ZeroRates = ([0.06 0.12 0.81 1.08 1.22 1.53 2.32 2.92 3.68 4.42 4.20]/100)';
```

Compute the key rate duration for a specific set of rates (choose this based on the maturities of the available hedging instruments):

```
krd = bndkrdur([ZeroDates ZeroRates],CouponRate,Settle,Maturity,'keyrates',[2 5 10 20])

krd =

    0.2865    0.8729    2.6451    8.5778
```

Note, the sum of the key rate durations approximately equals the duration of the bond:

```
[sum(krd) bnddurp(Price,CouponRate,Settle,Maturity)]

ans =

   12.3823   12.3919
```

Term Structure of Interest Rates

In this section...

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"Deriving an Implied Zero Curve" on page 2-38

Introduction

The Financial Toolbox product contains several functions to derive and analyze interest rate curves, including data conversion and extrapolation, bootstrapping, and interest-rate curve conversion functions.

One of the first problems in analyzing the term structure of interest rates is dealing with market data reported in different formats. Treasury bills, for example, are quoted with bid and asked bank-discount rates. Treasury notes and bonds, on the other hand, are quoted with bid and asked prices based on $100 face value. To examine the full spectrum of Treasury securities, analysts must convert data to a single format. Financial Toolbox functions ease this conversion. This brief example uses only one security each; analysts often use 30, 100, or more of each.

First, capture Treasury bill quotes in their reported format

```
%        Maturity                Days  Bid     Ask     AskYield
TBill = [datenum('12/26/2000')  53    0.0503  0.0499  0.0510];
```

then capture Treasury bond quotes in their reported format

```
%        Coupon   Maturity           Bid       Ask       AskYield
TBond = [0.08875  datenum(2001,11,5) 103+4/32  103+6/32  0.0564];
```

and note that these quotes are based on a November 3, 2000 settlement date.

```
Settle = datenum('3-Nov-2000');
```

Next use the toolbox `tbl2bond` function to convert the Treasury bill data to Treasury bond format.

```
TBTBond = tbl2bond(TBill)
```

```
TBTBond =
         0     730846     99.26      99.27     0.05
```

(The second element of TBTBond is the serial date number for December 26, 2000.)

Now combine short-term (Treasury bill) with long-term (Treasury bond) data to set up the overall term structure.

```
TBondsAll = [TBTBond; TBond]

TBondsAll =
            0     730846     99.26     99.27     0.05
         0.09     731160    103.13    103.19     0.06
```

The Financial Toolbox software provides a second data-preparation function,tr2bonds, to convert the bond data into a form ready for the bootstrapping functions. tr2bonds generates a matrix of bond information sorted by maturity date, plus vectors of prices and yields.

```
[Bonds, Prices, Yields] = tr2bonds(TBondsAll);
```

Deriving an Implied Zero Curve

Using this market data, you can use one of the Financial Toolbox bootstrapping functions to derive an implied zero curve. Bootstrapping is a process whereby you begin with known data points and solve for unknown data points using an underlying arbitrage theory. Every coupon bond can be valued as a package of zero-coupon bonds which mimic its cash flow and risk characteristics. By mapping yields-to-maturity for each theoretical zero-coupon bond, to the dates spanning the investment horizon, you can create a theoretical zero-rate curve. The Financial Toolbox software provides two bootstrapping functions: zbtprice derives a zero curve from bond data and *prices*, and zbtyield derives a zero curve from bond data and *yields*. Using zbtprice

```
[ZeroRates, CurveDates] = zbtprice(Bonds, Prices, Settle)

ZeroRates =
```

```
        0.05
        0.06

CurveDates =

       730846
       731160
```

`CurveDates` gives the investment horizon.

```
datestr(CurveDates)

ans =

26-Dec-2000
05-Nov-2001
```

Additional Financial Toolbox functions construct discount, forward, and par yield curves from the zero curve, and vice versa.

```
[DiscRates, CurveDates] = zero2disc(ZeroRates, CurveDates,...
Settle);
[FwdRates, CurveDates] = zero2fwd(ZeroRates, CurveDates, Settle);
[PYldRates, CurveDates] = zero2pyld(ZeroRates, CurveDates,...
Settle);
```

Pricing and Analyzing Equity Derivatives

In this section...

"Introduction" on page 2-40

"Sensitivity Measures" on page 2-40

"Analysis Models" on page 2-41

Introduction

These toolbox functions compute prices, sensitivities, and profits for portfolios of options or other equity derivatives. They use the Black-Scholes model for European options and the binomial model for American options. Such measures are useful for managing portfolios and for executing collars, hedges, and straddles.

Sensitivity Measures

There are six basic sensitivity measures associated with option pricing: delta, gamma, lambda, rho, theta, and vega — the "greeks." The toolbox provides functions for calculating each sensitivity and for implied volatility.

Delta

Delta of a derivative security is the rate of change of its price relative to the price of the underlying asset. It is the first derivative of the curve that relates the price of the derivative to the price of the underlying security. When delta is large, the price of the derivative is sensitive to small changes in the price of the underlying security.

Gamma

Gamma of a derivative security is the rate of change of delta relative to the price of the underlying asset; that is, the second derivative of the option price relative to the security price. When gamma is small, the change in delta is small. This sensitivity measure is important for deciding how much to adjust a hedge position.

Lambda

Lambda, also known as the elasticity of an option, represents the percentage change in the price of an option relative to a 1% change in the price of the underlying security.

Rho

Rho is the rate of change in option price relative to the risk-free interest rate.

Theta

Theta is the rate of change in the price of a derivative security relative to time. Theta is usually very small or negative since the value of an option tends to drop as it approaches maturity.

Vega

Vega is the rate of change in the price of a derivative security relative to the volatility of the underlying security. When vega is large the security is sensitive to small changes in volatility. For example, options traders often must decide whether to buy an option to hedge against vega or gamma. The hedge selected usually depends upon how frequently one rebalances a hedge position and also upon the standard deviation of the price of the underlying asset (the volatility). If the standard deviation is changing rapidly, balancing against vega is usually preferable.

Implied Volatility

The implied volatility of an option is the standard deviation that makes an option price equal to the market price. It helps determine a market estimate for the future volatility of a stock and provides the input volatility (when needed) to the other Black-Scholes functions.

Analysis Models

Toolbox functions for analyzing equity derivatives use the Black-Scholes model for European options and the binomial model for American options. The Black-Scholes model makes several assumptions about the underlying securities and their behavior. The binomial model, on the other hand, makes far fewer assumptions about the processes underlying an option. For further

explanation, see Options, Futures, and Other Derivatives by John Hull in Appendix A, "Bibliography".

Black-Scholes Model

Using the Black-Scholes model entails several assumptions:

- The prices of the underlying asset follow an Ito process. (See Hull, page 222.)
- The option can be exercised only on its expiration date (European option).
- Short selling is permitted.
- There are no transaction costs.
- All securities are divisible.
- There is no riskless arbitrage.
- Trading is a continuous process.
- The risk-free interest rate is constant and remains the same for all maturities.

If any of these assumptions is untrue, Black-Scholes may not be an appropriate model.

To illustrate toolbox Black-Scholes functions, this example computes the call and put prices of a European option and its delta, gamma, lambda, and implied volatility. The asset price is $100.00, the exercise price is $95.00, the risk-free interest rate is 10%, the time to maturity is 0.25 years, the volatility is 0.50, and the dividend rate is 0. Simply executing the toolbox functions

```
[OptCall, OptPut] = blsprice(100, 95, 0.10, 0.25, 0.50, 0);
[CallVal, PutVal] = blsdelta(100, 95, 0.10, 0.25, 0.50, 0);
GammaVal = blsgamma(100, 95, 0.10, 0.25, 0.50, 0);
VegaVal = blsvega(100, 95, 0.10, 0.25, 0.50, 0);
[LamCall, LamPut] = blslambda(100, 95, 0.10, 0.25, 0.50, 0);
```

yields:

- The option call price `OptCall` = $13.70

- The option put price `OptPut` = $6.35
- delta for a call `CallVal` = 0.6665 and delta for a put `PutVal` = -0.3335
- gamma `GammaVal` = 0.0145
- vega `VegaVal` = 18.1843
- lambda for a call `LamCall` = 4.8664 and lambda for a put `LamPut` = –5.2528

Now as a computation check, find the implied volatility of the option using the call option price from `blsprice`.

```
Volatility = blsimpv(100, 95, 0.10, 0.25, OptCall);
```

The function returns an implied volatility of 0.500, the original `blsprice` input.

Binomial Model

The binomial model for pricing options or other equity derivatives assumes that the probability over time of each possible price follows a binomial distribution. The basic assumption is that prices can move to only two values, one up and one down, over any short time period. Plotting the two values, and then the subsequent two values each, and then the subsequent two values each, and so on over time, is known as "building a binomial tree." This model applies to American options, which can be exercised any time up to and including their expiration date.

This example prices an American call option using a binomial model. Again, the asset price is $100.00, the exercise price is $95.00, the risk-free interest rate is 10%, and the time to maturity is 0.25 years. It computes the tree in increments of 0.05 years, so there are 0.25/0.05 = 5 periods in the example. The volatility is 0.50, this is a call (`flag = 1`), the dividend rate is 0, and it pays a dividend of $5.00 after three periods (an ex-dividend date). Executing the toolbox function

```
[StockPrice, OptionPrice] = binprice(100, 95, 0.10, 0.25,...
0.05,  0.50, 1, 0, 5.0, 3);
```

returns the tree of prices of the underlying asset

```
StockPrice =
```

```
100.00     111.27     123.87     137.96     148.69     166.28
     0      89.97     100.05     111.32     118.90     132.96
     0          0      81.00      90.02      95.07     106.32
     0          0          0      72.98      76.02      85.02
     0          0          0          0      60.79      67.98
     0          0          0          0          0      54.36
```

and the tree of option values.

```
OptionPrice =

12.10      19.17      29.35      42.96      54.17      71.28
    0       5.31       9.41      16.32      24.37      37.96
    0          0       1.35       2.74       5.57      11.32
    0          0          0          0          0          0
    0          0          0          0          0          0
    0          0          0          0          0          0
```

The output from the binomial function is a binary tree. Read the `StockPrice` matrix this way: column 1 shows the price for period 0, column 2 shows the up and down prices for period 1, column 3 shows the up-up, up-down, and down-down prices for period 2, and so on. Ignore the zeros. The `OptionPrice` matrix gives the associated option value for each node in the price tree. Ignore the zeros that correspond to a zero in the price tree.

3

Portfolio Analysis

- "Analyzing Portfolios" on page 3-2
- "Portfolio Optimization Functions" on page 3-3
- "Portfolio Construction Examples" on page 3-5
- "Portfolio Selection and Risk Aversion" on page 3-8
- "Constraint Specification" on page 3-12
- "Active Returns and Tracking Error Efficient Frontier" on page 3-20

Analyzing Portfolios

Portfolio managers concentrate their efforts on achieving the best possible trade-off between risk and return. For portfolios constructed from a fixed set of assets, the risk/return profile varies with the portfolio composition. Portfolios that maximize the return, given the risk, or, conversely, minimize the risk for the given return, are called *optimal*. Optimal portfolios define a line in the risk/return plane called the *efficient frontier*.

A portfolio may also have to meet additional requirements to be considered. Different investors have different levels of risk tolerance. Selecting the adequate portfolio for a particular investor is a difficult process. The portfolio manager can hedge the risk related to a particular portfolio along the efficient frontier with partial investment in risk-free assets. The definition of the capital allocation line, and finding where the final portfolio falls on this line, if at all, is a function of:

- The risk/return profile of each asset
- The risk-free rate
- The borrowing rate
- The degree of risk aversion characterizing an investor

Financial Toolbox software includes a set of portfolio optimization functions designed to find the portfolio that best meets investor requirements.

Portfolio Optimization Functions

The portfolio optimization functions assist portfolio managers in constructing portfolios that optimize risk and return.

Capital Allocation	Description
`portalloc`	Computes the optimal risky portfolio on the efficient frontier, based on the risk-free rate, the borrowing rate, and the investor's degree of risk aversion. Also generates the capital allocation line, which provides the optimal allocation of funds between the risky portfolio and the risk-free asset.

Efficient Frontier Computation	Description
`frontcon`	Computes portfolios along the efficient frontier for a given group of assets. The computation is based on sets of constraints representing the maximum and minimum weights for each asset, and the maximum and minimum total weight for specified groups of assets.
`frontier`	Computes portfolios along the efficient frontier for a given group of assets. Generates a surface of efficient frontiers showing how asset allocation influences risk and return over time.
`portopt`	Computes portfolios along the efficient frontier for a given group of assets. The computation is based on a set of user-specified linear constraints. Typically, these constraints are generated using the constraint specification functions described below.

Constraint Specification	Description
`portcons`	Generates the portfolio constraints matrix for a portfolio of asset investments using linear inequalities. The inequalities are of the type `A*Wts' <= b`, where `Wts` is a row vector of weights.
`portvrisk`	Portfolio value at risk (VaR) returns the maximum potential loss in the value of a portfolio over one period of time, given the loss probability level `RiskThreshold`.
`pcalims`	Asset minimum and maximum allocation. Generates a constraint set to fix the minimum and maximum weight for each individual asset.
`pcgcomp`	Group-to-group ratio constraint. Generates a constraint set specifying the maximum and minimum ratios between pairs of groups.
`pcglims`	Asset group minimum and maximum allocation. Generates a constraint set to fix the minimum and maximum total weight for each defined group of assets.
`pcpval`	Total portfolio value. Generates a constraint set to fix the total value of the portfolio.

Constraint Conversion	Description
`abs2active`	Transforms a constraint matrix expressed in absolute weight format to an equivalent matrix expressed in active weight format.
`active2abs`	Transforms a constraint matrix expressed in active weight format to an equivalent matrix expressed in absolute weight format.

Portfolio Construction Examples

In this section...

"Introduction" on page 3-5

"Efficient Frontier Example" on page 3-5

Introduction

The efficient frontier computation functions require information about each asset in the portfolio. This data is entered into the function via two matrices: an expected return vector and a covariance matrix. The expected return vector contains the average expected return for each asset in the portfolio. The covariance matrix is a square matrix representing the interrelationships between pairs of assets. This information can be directly specified or can be estimated from an asset return time series with the function `ewstats`.

Efficient Frontier Example

This example computes the efficient frontier of portfolios consisting of three different assets using the function `frontcon`. To visualize the efficient frontier curve clearly, consider 10 different evenly spaced portfolios.

Assume that the expected return of the first asset is 10%, the second is 20%, and the third is 15%. The covariance is defined in the matrix `ExpCovariance`.

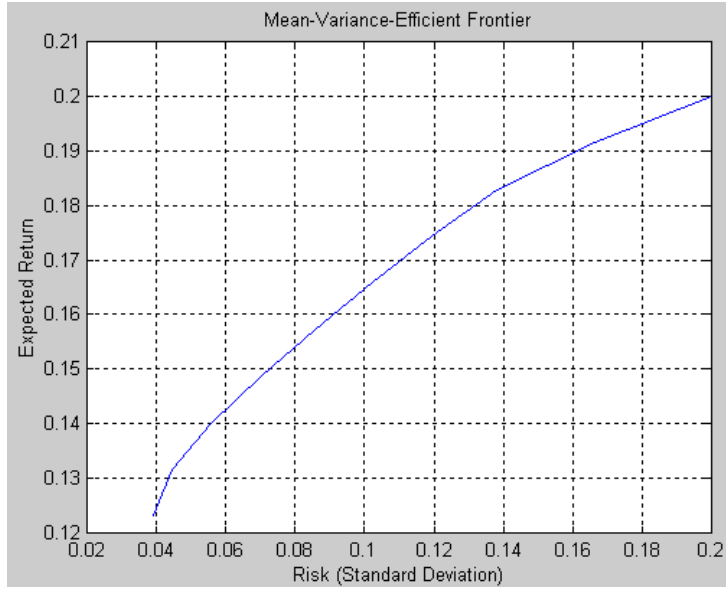
```
ExpReturn = [0.1 0.2 0.15];

ExpCovariance  = [ 0.005   -0.010    0.004;
                  -0.010    0.040   -0.002;
                   0.004   -0.002    0.023];

NumPorts = 10;
```

Since there are no constraints, you can call `frontcon` directly with the data you already have. If you call `frontcon` without specifying any output arguments, you get a graph representing the efficient frontier curve.

```
frontcon (ExpReturn, ExpCovariance, NumPorts);
```



Calling `frontcon` while specifying the output arguments returns the corresponding vectors and arrays representing the risk, return, and weights for each of the 10 points computed along the efficient frontier.

```
[PortRisk, PortReturn, PortWts] = frontcon(ExpReturn,...
ExpCovariance, NumPorts)

PortRisk =
    0.0392
    0.0445
    0.0559
    0.0701
    0.0858
    0.1023
    0.1192
    0.1383
    0.1661
    0.2000

PortReturn =
```

```
    0.1231
    0.1316
    0.1402
    0.1487
    0.1573
    0.1658
    0.1744
    0.1829
    0.1915
    0.2000

PortWts =

    0.7692    0.2308    0.0000
    0.6667    0.2991    0.0342
    0.5443    0.3478    0.1079
    0.4220    0.3964    0.1816
    0.2997    0.4450    0.2553
    0.1774    0.4936    0.3290
    0.0550    0.5422    0.4027
         0    0.6581    0.3419
         0    0.8291    0.1709
         0    1.0000    0.0000
```

The output data is represented row-wise. Each portfolio's risk, rate of return, and associated weights are identified as corresponding rows in the vectors and matrix.

For example, you can see from these results that the second portfolio has a risk of 0.0445, an expected return of 13.16%, and allocations of about 67% in the first asset, 30% in the second, and 3% in the third.

Portfolio Selection and Risk Aversion

In this section...

"Introduction" on page 3-8

"Optimal Risky Portfolio Example" on page 3-9

Introduction

One of the factors to consider when selecting the optimal portfolio for a particular investor is degree of risk aversion. This level of aversion to risk can be characterized by defining the investor's indifference curve. This curve consists of the family of risk/return pairs defining the trade-off between the expected return and the risk. It establishes the increment in return that a particular investor will require in order to make an increment in risk worthwhile. Typical risk aversion coefficients range between 2.0 and 4.0, with the higher number representing lesser tolerance to risk. The equation used to represent risk aversion in Financial Toolbox software is

```
U = E(r) - 0.005*A*sig^2
```

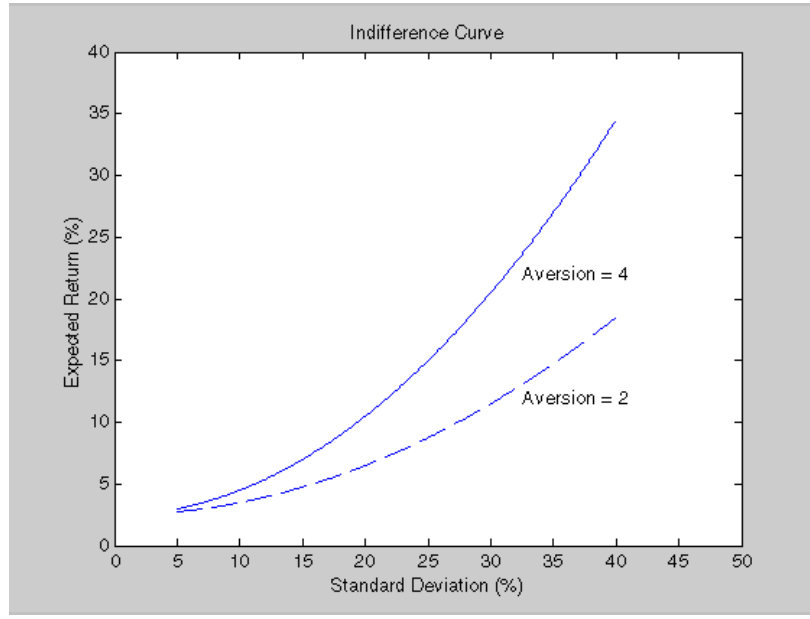
where:

`U` is the utility value.

`E(r)` is the expected return.

`A` is the index of investor's aversion.

`sig` is the standard deviation.



Optimal Risky Portfolio Example

This example computes the optimal risky portfolio on the efficient frontier based upon the risk-free rate, the borrowing rate, and the investor's degree of risk aversion. You do this with the function `portalloc`.

First generate the efficient frontier data using either `portopt` or `frontcon`. This example uses `portopt` and the same asset data from the previous example.

```
ExpReturn = [0.1 0.2 0.15];

ExpCovariance  = [ 0.005   -0.010    0.004;
                  -0.010    0.040   -0.002;
                   0.004   -0.002    0.023];
```

This time consider 20 different points along the efficient frontier.

```
NumPorts = 20;
```

```
[PortRisk, PortReturn, PortWts] = portopt(ExpReturn,...
ExpCovariance, NumPorts);
```

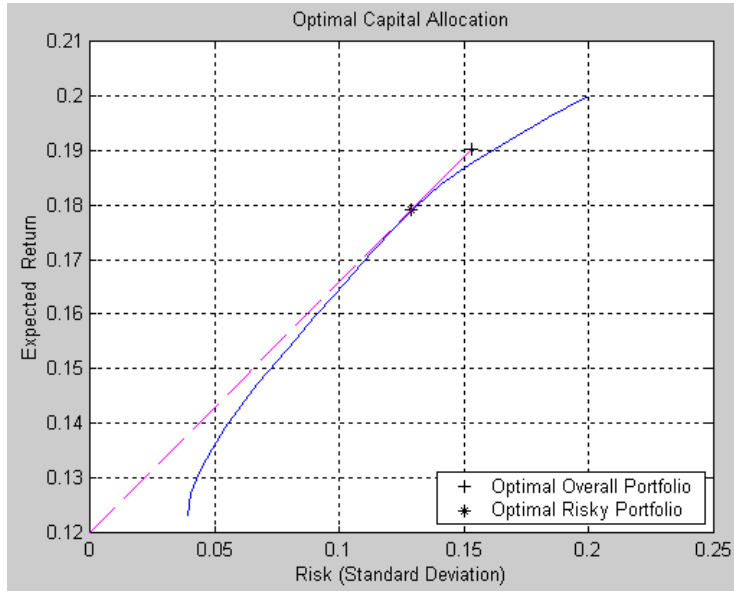
As with `frontcon`, calling `portopt` while specifying output arguments returns the corresponding vectors and arrays representing the risk, return, and weights for each of the portfolios along the efficient frontier. Use them as the first three input arguments to the function `portalloc`.

Now find the optimal risky portfolio and the optimal allocation of funds between the risky portfolio and the risk-free asset, using these values for the risk-free rate, borrowing rate and investor's degree of risk aversion.

```
RisklessRate  =  0.08
BorrowRate    =  0.12
RiskAversion  =  3
```

Calling `portalloc` without specifying any output arguments gives a graph displaying the critical points.

```
portalloc (PortRisk, PortReturn, PortWts, RisklessRate,...
BorrowRate, RiskAversion);
```



Calling `portalloc` while specifying the output arguments returns the variance (`RiskyRisk`), the expected return (`RiskyReturn`), and the weights (`RiskyWts`) allocated to the optimal risky portfolio. It also returns the fraction (`RiskyFraction`) of the complete portfolio allocated to the risky portfolio, and the variance (`OverallRisk`) and expected return (`OverallReturn`) of the optimal overall portfolio. The overall portfolio combines investments in the risk-free asset and in the risky portfolio. The actual proportion assigned to each of these two investments is determined by the degree of risk aversion characterizing the investor.

```
[RiskyRisk, RiskyReturn, RiskyWts,RiskyFraction, OverallRisk,...
OverallReturn] = portalloc (PortRisk, PortReturn, PortWts,...
RisklessRate, BorrowRate, RiskAversion)

RiskyRisk = 0.1288
RiskyReturn = 0.1791
RiskyWts = 0.0057 0.5879 0.4064
RiskyFraction = 1.1869
OverallRisk = 0.1529
OverallReturn = 0.1902
```

The value of `RiskyFraction` exceeds 1 (100%), implying that the risk tolerance specified allows borrowing money to invest in the risky portfolio, and that no money will be invested in the risk-free asset. This borrowed capital is added to the original capital available for investment. In this example the customer will tolerate borrowing 18.69% of the original capital amount.

Constraint Specification

In this section...

"Example" on page 3-12

"Linear Constraint Equations" on page 3-14

"Specifying Additional Constraints" on page 3-17

Example

This example computes the efficient frontier of portfolios consisting of three different assets, INTC, XON, and RD, given a list of constraints. The expected returns for INTC, XON, and RD are respectively as follows:

```
ExpReturn = [0.1 0.2 0.15];
```

The covariance matrix is

```
ExpCovariance  =  [ 0.005   -0.010    0.004;
                   -0.010    0.040   -0.002;
                    0.004   -0.002    0.023];
```

- Constraint 1
  - Allow short selling up to 10% of the portfolio value in any asset, but limit the investment in any one asset to 110% of the portfolio value.
- Constraint 2
  - Consider two different sectors, technology and energy, with the following table indicating the sector each asset belongs to.

Asset	INTC	XON	RD
Sector	Technology	Energy	Energy

Constrain the investment in the Energy sector to 80% of the portfolio value, and the investment in the Technology sector to 70%.

To solve this problem, use `frontcon`, passing in a list of asset constraints. Consider eight different portfolios along the efficient frontier:

```
NumPorts = 8;
```

To introduce the asset bounds constraints specified in Constraint 1, create the matrix `AssetBounds`, where each column represents an asset. The upper row represents the lower bounds, and the lower row represents the upper bounds.

```
AssetBounds = [-0.10, -0.10, -0.10;
                1.10,  1.10,  1.10];
```

Constraint 2 needs to be entered in two parts, the first part defining the groups, and the second part defining the constraints for each group. Given the information above, you can build a matrix of 1s and 0s indicating whether a specific asset belongs to a group. Each column represents an asset, and each row represents a group. This example has two groups: the technology group, and the energy group. Create the matrix `Groups` as follows.

```
Groups =  [0   1   1;
           1   0   0];
```

The `GroupBounds` matrix allows you to specify an upper and lower bound for each group. Each row in this matrix represents a group. The first column represents the minimum allocation, and the second column represents the maximum allocation to each group. Since the investment in the Energy sector is capped at 80% of the portfolio value, and the investment in the Technology sector is capped at 70%, create the `GroupBounds` matrix using this information.

```
GroupBounds = [0   0.80;
               0   0.70];
```

Now use `frontcon` to obtain the vectors and arrays representing the risk, return, and weights for each of the eight portfolios computed along the efficient frontier.

```
[PortRisk, PortReturn, PortWts] =  frontcon(ExpReturn,...
ExpCovariance, NumPorts, [], AssetBounds, Groups, GroupBounds)

PortRisk =
```

```
    0.0416
    0.0499
    0.0624
    0.0767
    0.0920
    0.1100
    0.1378
    0.1716

PortReturn  =

   0.1279
   0.1361
   0.1442
   0.1524
   0.1605
   0.1687
   0.1768
   0.1850

PortWts  =

    0.7000    0.2582    0.0418
    0.6031    0.3244    0.0725
    0.4864    0.3708    0.1428
    0.3696    0.4172    0.2132
    0.2529    0.4636    0.2835
    0.2000    0.5738    0.2262
    0.2000    0.7369    0.0631
    0.2000    0.9000   -0.1000
```

The output data is represented row-wise, where each portfolio's risk, rate of return, and associated weight is identified as corresponding rows in the vectors and matrix.

Linear Constraint Equations

While `frontcon` allows you to enter a fixed set of constraints related to minimum and maximum values for groups and individual assets, you often need to specify a larger and more general set of constraints when finding

the optimal risky portfolio. The function `portopt` addresses this need, by accepting an arbitrary set of constraints as an input matrix.

The auxiliary function `portcons` can be used to create the matrix of constraints, with each row representing an inequality. These inequalities are of the type `A*Wts' <= b`, where `A` is a matrix, `b` is a vector, and `Wts` is a row vector of asset allocations. The number of columns of the matrix `A`, and the length of the vector `Wts` correspond to the number of assets. The number of rows of the matrix `A`, and the length of vector `b` correspond to the number of constraints. This method allows you to specify any number of linear inequalities to the function `portopt`.

In actuality, `portcons` is an entry point to a set of functions that generate matrices for specific types of constraints. `portcons` allows you to specify all the constraints data at once, while the specific portfolio constraint functions allow you to build the constraints incrementally. These constraint functions are `pcpval`, `pcalims`, `pcglims`, and `pcgcomp`.

Consider an example to help understand how to specify constraints to `portopt` while bypassing the use of `portcons`. This example requires specifying the minimum and maximum investment in various groups.

Maximum and Minimum Group Exposure

Group	Minimum Exposure	Maximum Exposure
North America	0.30	0.75
Europe	0.10	0.55
Latin America	0.20	0.50
Asia	0.50	0.50

Note that the minimum and maximum exposure in Asia is the same. This means that you require a fixed exposure for this group.

Also assume that the portfolio consists of three different funds. The correspondence between funds and groups is shown in the table below.

Group Membership

Group	Fund 1	Fund 2	Fund 3
North America	X	X	
Europe			X
Latin America	X		
Asia		X	X

Using the information in these two tables, build a mathematical representation of the constraints represented. Assume that the vector of weights representing the exposure of each asset in a portfolio is called `Wts = [W1 W2 W3]`.

Specifically

1.	$W1 + W2$	$\geq$	0.30
2.	$W1 + W2$	$\leq$	0.75
3.	$W3$	$\geq$	0.10
4.	$W3$	$\leq$	0.55
5.	$W1$	$\geq$	0.20
6.	$W1$	$\leq$	0.50
7.	$W2 + W3$	$=$	0.50

Since you need to represent the information in the form `A*Wts <= b`, multiply equations 1, 3 and 5 by –1. Also turn equation 7 into a set of two inequalities: $W2 + W3 \geq 0.50$ and $W2 + W3 \leq 0.50$. (The intersection of these two inequalities is the equality itself.) Thus

1.	$-W1 - W2$	$\leq$	-0.30
2.	$W1 + W2$	$\leq$	0.75
3.	$-W3$	$\leq$	-0.10

4.	$W3$	$\leq$	0.55
5.	$-W1$	$\leq$	-0.20
6.	$W1$	$\leq$	0.50
7.	$-W2 - W3$	$\leq$	-0.50
8.	$W2 + W3$	$\leq$	0.50

Bringing these equations into matrix notation gives

```
A = [-1    -1     0;
      1     1     0;
      0     0    -1;
      0     0     1;
     -1     0     0;
      1     0     0;
      0    -1    -1;
      0     1     1]

b = [-0.30;
      0.75;
     -0.10;
      0.55;
     -0.20;
      0.50;
     -0.50;
      0.50]
```

Build the constraint matrix `ConSet` by concatenating the matrix `A` to the vector `b`.

```
ConSet = [A, b]
```

Specifying Additional Constraints

The example above defined a constraints matrix that specified a set of typical scenarios. It defined groups of assets, specified upper and lower bounds for total allocation in each of these groups, and it set the total allocation of one of the groups to a fixed value. Constraints like these are common occurrences.

The function portcons was created to simplify the creation of the constraint matrix for these and other common portfolio requirements. portcons takes as input arguments a list of constraint-specifier strings, followed by the data necessary to build the constraint specified by the strings.

Assume that you need to add more constraints to the previous example. Specifically, add a constraint indicating that the sum of weights in any portfolio should be equal to 1, and another set of constraints (one per asset) indicating that the weight for each asset must greater than 0. This translates into five more constraint rows: two for the new equality, and three indicating that each weight must be greater or equal to 0. The total number of inequalities in the example is now 13. Clearly, creating the constraint matrix can turn into a tedious task.

To create the new constraint matrix using portcons, use two separate constraint-specifier strings:

- 'Default', which indicates that each weight is greater than 0 and that the total sum of the weights adds to 1
- 'GroupLims', which defines the minimum and maximum allocation on each group

The only data requirement for the constraint-specifier string 'Default' is NumAssets (the total number of assets). The constraint-specifier string 'GroupLims' requires three different arguments: a Groups matrix indicating the assets that belong to each group, the GroupMin vector indicating the minimum bounds for each group, and the GroupMax vector indicating the maximum bounds for each group. Based on the table Group Membership on page 3-16, build the Group matrix, with each row representing a group, and each column representing an asset.

```
Group = [1    1    0;
         0    0    1;
         1    0    0;
         0    1    1]
```

The table Maximum and Minimum Group Exposure on page 3-15 has the information to build GroupMin and GroupMax.

```
GroupMin = [0.30  0.10  0.20  0.50];
```

```
GroupMax = [0.75  0.55  0.50  0.50];
```

Given that the number of assets is three, build the constraint matrix by calling `portcons`.

```
ConSet = portcons('Default', 3, 'GroupLims', Group, GroupMin,...
GroupMax);
```

In most cases, `portcons('Default')` returns the minimal set of constraints required for calling `portopt`. If `ConSet` is not specified in the call to `portopt`, the function calls `portcons` passing `'Default'` as its only specifier.

Now use `portopt` to obtain the vectors and arrays representing the risk, return, and weights for the portfolios computed along the efficient frontier.

```
[PortRisk, PortReturn, PortWts] = portopt(ExpReturn,...
ExpCovariance, [], [], ConSet)

PortRisk = 0.0586
Port Return = 0.1375
PortWts = 0.5 0.25 0.25
```

In this case, the constraints allow only one optimum portfolio.

Active Returns and Tracking Error Efficient Frontier

Suppose you want to identify an efficient set of portfolios that minimize the variance of the difference in returns with respect to a given target portfolio, subject to a given expected excess return. The mean and standard deviation of this excess return are often called the active return and active risk, respectively. Active risk is sometimes referred to as the tracking error. Since the objective is to track a given target portfolio as closely as possible, the resulting set of portfolios is sometimes referred to as the tracking error efficient frontier.

Specifically, assume that the target portfolio is expressed as an index weight vector, such that the index return series may be expressed as a linear combination of the available assets. This example illustrates how to construct a frontier that minimizes the active risk (tracking error) subject to attaining a given level of return. That is, it computes the tracking error efficient frontier.

One way to construct the tracking error efficient frontier is to explicitly form the target return series and subtract it from the return series of the individual assets. In this manner, you specify the expected mean and covariance of the active returns, and compute the efficient frontier subject to the usual portfolio constraints.

This example works directly with the mean and covariance of the absolute (unadjusted) returns but converts the constraints from the usual absolute weight format to active weight format.

Consider a portfolio of five assets with the following expected returns, standard deviations, and correlation matrix based on absolute weekly asset returns.

```
NumAssets    =  5;

ExpReturn    = [0.2074  0.1971  0.2669  0.1323  0.2535]/100;

Sigmas       = [2.6570  3.6297  3.9916  2.7145  2.6133]/100;

Correlations = [1.0000  0.6092  0.6321  0.5833  0.7304
                0.6092  1.0000  0.8504  0.8038  0.7176
                0.6321  0.8504  1.0000  0.7723  0.7236
```

```
                    0.5833  0.8038  0.7723  1.0000  0.7225
                    0.7304  0.7176  0.7236  0.7225  1.0000];
```

Convert the correlations and standard deviations to a covariance matrix using `corr2cov`.

```
ExpCovariance = corr2cov(Sigmas, Correlations);
```

Next, assume that the target index portfolio is an equally-weighted portfolio formed from the five assets. Note that the sum of index weights equals 1, satisfying the standard full investment budget equality constraint.

```
Index = ones(NumAssets, 1)/NumAssets;
```

Generate an asset constraint matrix using `portcons`. The constraint matrix `AbsConSet` is expressed in absolute format (unadjusted for the index), and is formatted as `[A b]`, corresponding to constraints of the form `A*w <= b`. Each row of `AbsConSet` corresponds to a constraint, and each column corresponds to an asset. Allow no short-selling and full investment in each asset (lower and upper bounds of each asset are 0 and 1, respectively). In particular, note that the first two rows correspond to the budget equality constraint; the remaining rows correspond to the upper/lower investment bounds.

```
AbsConSet = portcons('PortValue', 1, NumAssets, ...
'AssetLims', zeros(NumAssets,1), ones(NumAssets,1));
```

Now transform the absolute constraints to active constraints with `abs2active`.

```
ActiveConSet = abs2active(AbsConSet, Index);
```

An examination of the absolute and active constraint matrices reveals that they are differ only in the last column (the columns corresponding to the `b` in `A*w <= b`).

```
[AbsConSet(:,end)  ActiveConSet(:,end)]

ans =

    1.0000         0
   -1.0000         0
```

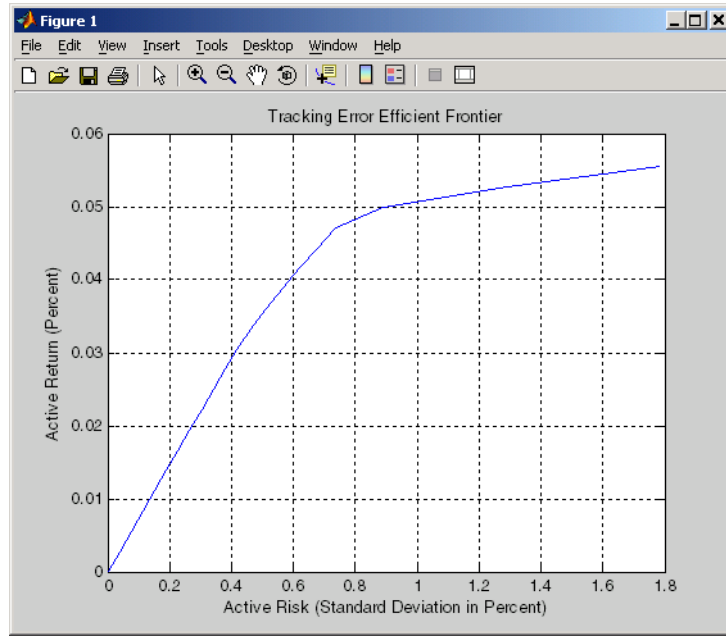
```
    1.0000    0.8000
    1.0000    0.8000
    1.0000    0.8000
    1.0000    0.8000
    1.0000    0.8000
         0    0.2000
         0    0.2000
         0    0.2000
         0    0.2000
         0    0.2000
```

In particular, note that the sum-to-one absolute budget constraint becomes a sum-to-zero active budget constraint. The general transformation is as follows:

$$b_{active} = b_{absolute} - A \cdot Index$$

Now construct and plot the tracking error efficient frontier with 21 portfolios.

```
[ActiveRisk, ActiveReturn, ActiveWeights] = ...
portopt(ExpReturn,ExpCovariance, 21, [], ActiveConSet);
ActiveRisk = real(ActiveRisk);
plot(ActiveRisk*100, ActiveReturn*100, 'blue')
grid('on')
xlabel('Active Risk (Standard Deviation in Percent)')
ylabel('Active Return (Percent)')
title('Tracking Error Efficient Frontier')
```



Of particular interest is the lower-left portfolio along the frontier. This zero-risk/zero-return portfolio has a practical economic significance. It represents a full investment in the index portfolio itself. Note that each tracking error efficient portfolio (each row in the array `ActiveWeights`) satisfies the active budget constraint, and thus represents portfolio investment allocations with respect to the index portfolio. To convert these allocations to absolute investment allocations, add the index to each efficient portfolio.

```
AbsoluteWeights  =  ActiveWeights + repmat(Index', 21, 1);
```

4

Investment Performance Metrics

- "Overview of Performance Metrics" on page 4-2
- "Using the Sharpe Ratio" on page 4-6
- "Using the Information Ratio" on page 4-8
- "Tracking Error" on page 4-10
- "Risk-Adjusted Return" on page 4-11
- "Sample and Expected Lower Partial Moments" on page 4-13
- "Maximum and Expected Maximum Drawdown" on page 4-16

Overview of Performance Metrics

In this section...

"Performance Metrics Classes" on page 4-2

"Performance Metrics Example" on page 4-3

Performance Metrics Classes

Sharpe first proposed a ratio of excess return to total risk as an investment performance metric. Subsequent work by Sharpe, Lintner, and Mossin extended these ideas to entire asset markets in what is called the Capital Asset Pricing Model (CAPM). Since the development of the CAPM, a variety of investment performance metrics has evolved.

This chapter presents four classes of investment performance metrics:

- The first class of metrics are absolute investment performance metrics that can be called "classic" metrics since they are based on the CAPM. They include the Sharpe ratio, the information ratio, and tracking error. To compute the Sharpe ratio from data, use the function `sharpe` to calculate the ratio for one or more asset return series. To compute the information ratio and associated tracking error, use the function `inforatio` to calculate these quantities for one or more asset return series.
- The second class of metrics are relative investment performance metrics to compute risk-adjusted returns. These metrics are also based on the CAPM and include Beta, Jensen's Alpha, the Security Market Line (SML), Modigliani and Modigliani Risk-Adjusted Return, and the Graham-Harvey measures. To calculate risk-adjusted alpha and return, use `portalpha`.
- The third class of metrics are alternative investment performance metrics based on lower partial moments. To calculate lower partial moments, use the functions `lpm` for sample lower partial moments and `elpm` for expected lower partial moments.
- The fourth class of metrics are performance metrics based on maximum drawdown and expected maximum drawdown. To calculate maximum or expected maximum drawdowns, use the functions `maxdrawdown` and `emaxdrawdown`.

Performance Metrics Example

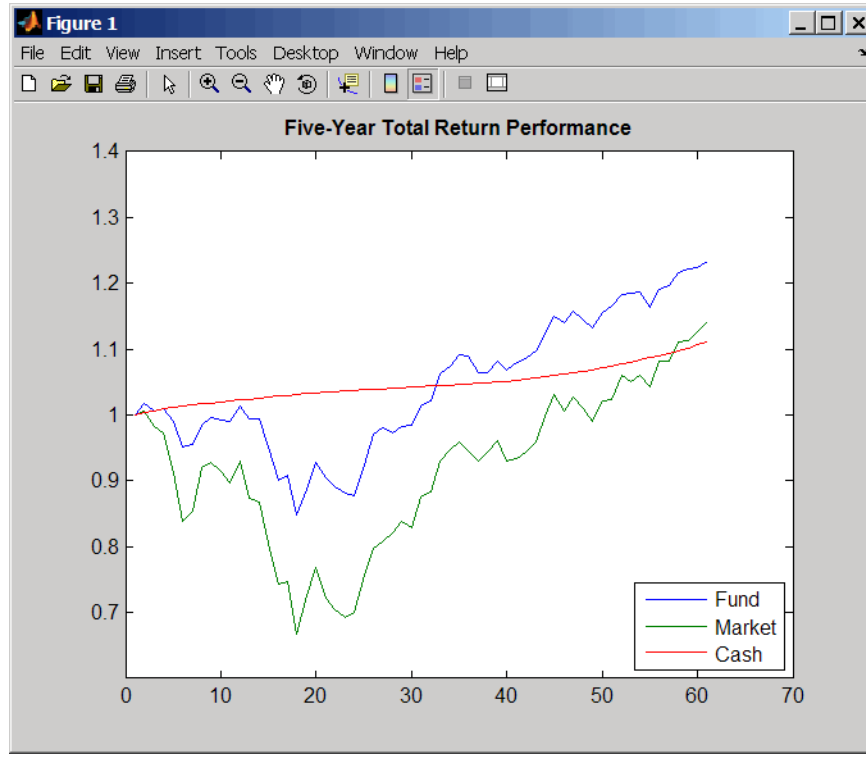
To illustrate the functions for investment performance metrics, you will work with three financial time series objects using performance data for:

- An actively managed, large-cap value mutual fund
- A large-cap market index
- 90-day Treasury bills

The data is monthly total return prices that cover a span of 5 years.

The following plot illustrates the performance of each series in terms of total returns to an initial $1 invested at the start of this 5-year period:

```
load FundMarketCash
plot(TestData)
hold all
title('\bfFive-Year Total Return Performance');
legend('Fund','Market','Cash','Location','SouthEast');
hold off
```



The mean (`Mean`) and standard deviation (`Sigma`) of returns for each series are

```
Returns = tick2ret(TestData);
Assets
Mean = mean(Returns)
Sigma = std(Returns, 1)
```

which gives the following result:

```
Assets =
    'Fund'    'Market'    'Cash'
Mean =
    0.0038    0.0030    0.0017
Sigma =
    0.0229    0.0389    0.0009
```

In this chapter, you will work with this data to demonstrate that the example fund has done well in absolute, relative, and risk-adjusted terms with respect to the investment performance metrics.

Note Functions for investment performance metrics use total return price and total returns. To convert between total return price and total returns, use `ret2tick` and `tick2ret`.

Using the Sharpe Ratio

In this section...

"Introduction" on page 4-6

"Sharpe Ratio Example" on page 4-6

Introduction

The Sharpe ratio is the ratio of the excess return of an asset divided by the asset's standard deviation of returns. The Sharpe ratio has the form:

```
(Mean - Riskless) / Sigma
```

Here `Mean` is the mean of asset returns, `Riskless` is the return of a riskless asset, and `Sigma` is the standard deviation of asset returns. A higher Sharpe ratio is better than a lower Sharpe ratio. A negative Sharpe ratio indicates "anti-skill" since the performance of the riskless asset is superior.

Sharpe Ratio Example

To compute the Sharpe ratio, the mean return of the cash asset will be used as the return for the riskless asset. Thus, given asset return data and the riskless asset return, the Sharpe ratio is calculated with

```
Riskless = mean(Returns(:,3))
Sharpe = sharpe(Returns, Riskless)
```

which gives the following result:

```
Riskless =
    0.0017
Sharpe =
    0.0886    0.0315         0
```

The Sharpe ratio of the example fund is significantly higher than the Sharpe ratio of the market. As will be demonstrated with `portalpha`, this translates into a strong risk-adjusted return. Since the `Cash` asset is the same as `Riskless`, it makes sense that its Sharpe ratio is 0. The Sharpe ratio was

calculated with the mean of cash returns. It can also be calculated with the cash return series as input for the riskless asset

```
Sharpe = sharpe(Returns, Returns(:,3))
```

which gives the following result:

```
Sharpe =
    0.0886    0.0315         0
```

Using the Information Ratio

In this section...

"Introduction" on page 4-8

"Information Ratio Example" on page 4-8

Introduction

Although originally called the "appraisal ratio" by Treynor and Black, the information ratio is the ratio of relative return to relative risk (known as "tracking error"). Whereas the Sharpe ratio looks at returns relative to a riskless asset, the information ratio is based on returns relative to a risky benchmark which is known colloquially as a "bogey." Given an asset or portfolio of assets with random returns designated by `Asset` and a benchmark with random returns designated by `Benchmark`, the information ratio has the form:

```
Mean(Asset - Benchmark) / Sigma (Asset - Benchmark)
```

Here `Mean(Asset - Benchmark)` is the mean of `Asset` minus `Benchmark` returns, and `Sigma(Asset - Benchmark)` is the standard deviation of `Asset` minus `Benchmark` returns. A higher information ratio is considered better than a lower information ratio.

Information Ratio Example

To calculate the information ratio using the example data, the mean return of the market series will be used as the return of the benchmark. Thus, given asset return data and the riskless asset return, compute the information ratio with

```
Benchmark = Returns(:,2);
InfoRatio = inforatio(Returns, Benchmark)
```

which gives the following result:

```
InfoRatio =
    0.0432       NaN   -0.0315
```

Since the market series has no risk relative to itself, the information ratio for the second series is undefined (which is represented as `NaN` in MATLAB software). Its standard deviation of relative returns in the denominator is 0.

Tracking Error

In this section...

"Introduction" on page 4-10

"Tracking Error Example" on page 4-10

Introduction

Given an asset or portfolio of assets and a benchmark, the relative standard deviation of returns between the asset or portfolio of assets and the benchmark is called tracking error.

Tracking Error Example

The function `inforatio` computes tracking error and returns it as a second argument

```
Benchmark = Returns(:,2);
[InfoRatio, TrackingError] = inforatio(Returns, Benchmark)
```

which gives the following results:

```
InfoRatio =
    0.0432       NaN   -0.0315
TrackingError =
    0.0187         0    0.0390
```

Tracking error is a useful measure of performance relative to a benchmark since it is in units of asset returns. For example, the tracking error of 1.87% for the fund relative to the market in this example is reasonable for an actively managed, large-cap value fund.

Risk-Adjusted Return

In this section...

"Introduction" on page 4-11

"Risk-Adjusted Return Example" on page 4-11

Introduction

Risk-adjusted return either shifts the risk (which is the standard deviation of returns) of a portfolio to match the risk of a market portfolio or shifts the risk of a market portfolio to match the risk of a fund. According to the Capital Asset Pricing Model (CAPM), the market portfolio and a riskless asset are points on a Security Market Line (SML). The return of the resultant shifted portfolio, levered or unlevered, to match the risk of the market portfolio, is the risk-adjusted return. The SML provides another measure of risk-adjusted return, since the difference in return between the fund and the SML, return at the same level of risk.

Risk-Adjusted Return Example

Given our example data with a fund, a market, and a cash series, you can calculate the risk-adjusted return and compare it with the fund and market's mean returns

```
Fund = Returns(:,1);
Market = Returns(:,2);
Cash = Returns(:,3);
MeanFund = mean(Fund)
MeanMarket = mean(Market)

[MM, aMM] = portalpha(Fund, Market, Cash)
[GH1, aGH1] = portalpha(Fund, Market, Cash, 'gh1')
[GH2, aGH2] = portalpha(Fund, Market, Cash, 'gh2')
[SML, aSML] = portalpha(Fund, Market, Cash, 'sml')
```

which gives the following results:

```
MeanFund =
    0.0038
```

```
MeanMarket =
    0.0030
MM =
    0.0052
aMM =
    0.0022
GH1 =
    0.0025
aGH1 =
    0.0013
GH2 =
    0.0052
aGH2 =
    0.0022
SML =
    0.0025
aSML =
    0.0013
```

Since the fund's risk is much less than the market's risk, the risk-adjusted return of the fund is much higher than both the nominal fund and market returns.

Sample and Expected Lower Partial Moments

In this section...

"Introduction" on page 4-13

"Sample Lower Partial Moments Example" on page 4-13

"Expected Lower Partial Moments Example" on page 4-14

Introduction

Use lower partial moments to examine what is colloquially known as "downside risk." The main idea of the lower partial moment framework is to model moments of asset returns that fall below a minimum acceptable level of return. To compute lower partial moments from data, use `lpm` to calculate lower partial moments for multiple asset return series and for multiple moment orders. To compute expected values for lower partial moments under several assumptions about the distribution of asset returns, use `elpm` to calculate lower partial moments for multiple assets and for multiple orders.

Sample Lower Partial Moments Example

The following example demonstrates `lpm` to compute the zero-order, first-order, and second-order lower partial moments for the three time series, where the mean of the third time series is used to compute `MAR` (with the so-called risk-free rate).

```
Assets
MAR = mean(Returns(:,3))
LPM = lpm(Returns, MAR, [0 1 2])
```

which gives the following results:

```
Assets =
    'Fund'    'Market'    'Cash'
MAR =
    0.0017
LPM =
    0.4333    0.4167    0.6167
    0.0075    0.0140    0.0004
```

```
    0.0003    0.0008    0.0000
```

The first row of LPM contains zero-order lower partial moments of the three series. The fund and market index fall below MAR about 40% of the time and cash returns fall below its own mean about 60% of the time.

The second row contains first-order lower partial moments of the three series. The fund and market have large expected shortfall returns relative to MAR by 75 and 140 basis points per month. On the other hand, cash underperforms MAR by about only 4 basis points per month on the downside.

The third row contains second-order lower partial moments of the three series. The square root of these quantities provides an idea of the dispersion of returns that fall below the MAR. The market index has a much larger variation on the downside when compared to the fund.

Expected Lower Partial Moments Example

To compare realized values with expected values, use elpm to compute expected lower partial moments based on the mean and standard deviations of normally distributed asset returns. The elpm function works with the mean and standard deviations for multiple assets and multiple orders

```
Assets
ELPM = elpm(Mean, Sigma, MAR, [0 1 2])
```

which gives the following results:

```
Assets =
    'Fund'    'Market'    'Cash'
ELPM =
    0.4647    0.4874    0.5000
    0.0082    0.0149    0.0004
    0.0002    0.0007    0.0000
```

Based on the moments of each asset, the expected values for lower partial moments imply better than expected performance for the fund and market and worse than expected performance for cash. Note that this function works with either degenerate or nondegenerate normal random variables. For

example, if cash were truly riskless, its standard deviation would be 0. You can examine the difference in expected shortfall.

```
RisklessCash = elpm(Mean(3), 0, MAR, 1)
```

which gives the following result:

```
RisklessCash =
     0
```

Maximum and Expected Maximum Drawdown

In this section...

"Introduction" on page 4-16

"Maximum Drawdown Example" on page 4-16

"Expected Maximum Drawdown Example" on page 4-18

Introduction

Although additional metrics exist that are used in the hedge fund and commodity trading communities (see Pederson and Rudholm-Alfvin in Appendix A, "Bibliography"), the original definition and subsequent implementation of these metrics is not yet standardized. The "traditional" return form for maximum drawdown is the drop from maximum to minimum return over a period of time. Given returns that have been transformed into a linear Brownian motion with drift, it is possible to compute the expected maximum drawdown (see Magdon-Ismail, Atiya, Pratap, and Abu-Mostafa in Appendix A, "Bibliography"). Use `maxdrawdown` and `emaxdrawdown` to calculate the maximum and expected maximum drawdowns.

Maximum Drawdown Example

This example demonstrates computing `MaxDD` for three types of returns: fund, market, and cash

```
load FundMarketCash
MaxDD = maxdrawdown(TestData)
```

which gives the following results:

```
MaxDD =
    0.1658    0.3381         0
```

Most academic research on maximum drawdown focuses on the underlying stochastic processes that generate asset returns. Convert price data to geometric Brownian motion and compute maximum drawdown

```
Returns = TestData(2:end,:) ./ TestData(1:end - 1,:);
MaxDD = maxdrawdown(Returns,'geometric')
```

which gives the following results:

```
MaxDD =
    0.1007    0.1890    0.0023
```

Convert price data to arithmetic Brownian motion and compute maximum drawdown (the answer should match the previous result).

```
Returns = log(Returns);
MaxDD = maxdrawdown(Returns,'arithmetic')
```

which gives the following results:

```
MaxDD =
    0.1007    0.1890    0.0023
```

The maximum drawdown function has been enhanced to return the indices of the maximum drawdown periods for each series

```
[MaxDD, MaxDDIndex] = maxdrawdown(TestData)
Start = MaxDDIndex(1,:)
End = MaxDDIndex(2,:)
```

which gives the following results:

```
MaxDD =

    0.1658    0.3381         0

MaxDDIndex =

     2     2   NaN
    18    18   NaN

Start =

     2     2   NaN

End =
```

```
    18    18   NaN
```

The first two series have the same periods for maximum drawdown from the 2nd to the 18th month in the data. Note that the third series never has a drawdown, so that the indices are NaNs.

Expected Maximum Drawdown Example

This example demonstrates using the return moments of the fund to compute the expected MaxDD and then compare it with the realized MaxDD

```
load FundMarketCash
Returns = TestData(2:end,:) ./ TestData(1:end - 1,:);
Returns = log(Returns);
MaxDD = maxdrawdown(Returns(:,1),'arithmetic')
Mu = mean(Returns(:,1));
Sigma = std(Returns(:,1),1);
EMaxDD = emaxdrawdown(Mu, Sigma, 100)
```

which gives the following results:

```
MaxDD =
    0.1007
EMaxDD =
    0.1852
```

5

Regression with Missing Data

- "Multivariate Normal Regression" on page 5-2
- "Maximum Likelihood Estimation with Missing Data" on page 5-9
- "Multivariate Normal Regression Types" on page 5-17
- "Valuation with Missing Data" on page 5-34

Multivariate Normal Regression

In this section...

"Introduction" on page 5-2
"Multivariate Normal Linear Regression" on page 5-3
"Maximum Likelihood Estimation" on page 5-4
"Special Case of a Multiple Linear Regression Model" on page 5-5
"Least-Squares Regression" on page 5-5
"Mean and Covariance Estimation" on page 5-5
"Convergence" on page 5-6
"Fisher Information" on page 5-6
"Statistical Tests" on page 5-7

Introduction

This section focuses on using likelihood-based methods for multivariate normal regression. The parameters of the regression model are estimated via maximum likelihood estimation. For multiple series, this requires iteration until convergence. The complication due to the possibility of missing data is incorporated into the analysis with a variant of the EM algorithm known as the ECM algorithm.

The underlying theory of maximum likelihood estimation and the definition and significance of the Fisher information matrix can be found in Caines [1] and Cramér [2]. The underlying theory of the ECM algorithm can be found in Meng and Rubin [8] and Sexton and Swensen [9].

In addition, these two examples of maximum likelihood estimation are presented:

- "Example of Portfolios with Missing Data" on page 5-26
- "Estimation of Some Technology Stock Betas" on page 5-36

Multivariate Normal Linear Regression

Suppose you have a multivariate normal linear regression model in the form

$$\begin{bmatrix} \mathbf{Z}_1 \\ \vdots \\ \mathbf{Z}_m \end{bmatrix} \sim N\left(\begin{bmatrix} \mathbf{H}_1\mathbf{b} \\ \vdots \\ \mathbf{H}_m\mathbf{b} \end{bmatrix}, \begin{bmatrix} \mathbf{C} & \cdots & \mathbf{0} \\ \vdots & & \vdots \\ \mathbf{0} & \cdots & \mathbf{C} \end{bmatrix} \right)$$

where the model has m observations of n-dimensional random variables $\mathbf{Z}_1$, ..., $\mathbf{Z}_m$ with a linear regression model that has a p-dimensional model parameter vector $\mathbf{b}$. In addition, the model has a sequence of m design matrices $\mathbf{H}_1$, ..., $\mathbf{H}_m$, where each design matrix is a known n-by-p matrix.

Given a parameter vector $\mathbf{b}$ and a collection of design matrices, the collection of m independent variables $\mathbf{Z}_k$ is assumed to have independent identically distributed multivariate normal residual errors $\mathbf{Z}_k - \mathbf{H}_k\,\mathbf{b}$ with n-vector mean $\mathbf{0}$ and n-by-n covariance matrix $\mathbf{C}$ for each $k = 1, ..., m$.

A concise way to write this model is

$$\mathbf{Z}_k \sim N(\mathbf{H}_k\,\mathbf{b}, \mathbf{C})$$

for $k = 1, ..., m$.

The goal of multivariate normal regression is to obtain maximum likelihood estimates for $\mathbf{b}$ and $\mathbf{C}$ given a collection of m observations $\mathbf{z}_1$, ..., $\mathbf{z}_m$ of the random variables $\mathbf{Z}_1$, ..., $\mathbf{Z}_m$. The estimated parameters are the p distinct elements of $\mathbf{b}$ and the $n\,(n + 1)/2$ distinct elements of $\mathbf{C}$ (the lower-triangular elements of $\mathbf{C}$).

Note Quasi-maximum likelihood estimation works with the same models but with a relaxation of the assumption of normally distributed residuals. In this case, however, the parameter estimates are asymptotically optimal.

Maximum Likelihood Estimation

To estimate the parameters of the multivariate normal linear regression model using maximum likelihood estimation, it is necessary to maximize the log-likelihood function over the estimation parameters given observations $\mathbf{z}_1$, ... , $\mathbf{z}_m$.

Given the multivariate normal model to characterize residual errors in the regression model, the log-likelihood function is

$$L(\mathbf{z}_1, \ldots, \mathbf{z}_m; \mathbf{b}, \mathbf{C}) = \frac{1}{2} mn \log(2\pi) + \frac{1}{2} m \log(\det(\mathbf{C})) + \frac{1}{2} \sum_{k=1}^{m} (\mathbf{z}_k - \mathbf{H}_k \mathbf{b})^T \mathbf{C}^{-1} (\mathbf{z}_k - \mathbf{H}_k \mathbf{b})$$

Although the cross-sectional residuals must be independent, you can use this log-likelihood function for quasi-maximum likelihood estimation. In this case, the estimates for the parameters **b** and **C** provide estimates to characterize the first and second moments of the residuals. See Caines [1] for details.

Except for a special case (see "Special Case of a Multiple Linear Regression Model" on page 5-5), if both the model parameters in **b** and the covariance parameters in **C** are to be estimated, the estimation problem is intractably nonlinear and a solution must use iterative methods. Denote estimates for the parameters **b** and **C** for iteration $t = 0, 1, \ldots$ with the superscript notation $\mathbf{b}^{(t)}$ and $\mathbf{C}^{(t)}$.

Given initial estimates $\mathbf{b}^{(0)}$ and $\mathbf{C}^{(0)}$ for the parameters, the maximum likelihood estimates for **b** and **C** are obtained using a two-stage iterative process with

$$\mathbf{b}^{(t+1)} = \left(\sum_{k=1}^{m} \mathbf{H}_k^T (\mathbf{C}^{(t)})^{-1} \mathbf{H}_k \right)^{-1} \left(\sum_{k=1}^{m} \mathbf{H}_k^T (\mathbf{C}^{(t)})^{-1} \mathbf{z}_k \right)$$

and

$$\mathbf{C}^{(t+1)} = \frac{1}{m} \sum_{k=1}^{m} (\mathbf{z}_k - \mathbf{H}_k \mathbf{b}^{(t+1)})(\mathbf{z}_k - \mathbf{H}_k \mathbf{b}^{(t+1)})^T$$

for $t = 0, 1, \ldots$.

Special Case of a Multiple Linear Regression Model

The special case mentioned in "Maximum Likelihood Estimation" on page 5-4 occurs if $n = 1$ so that the sequence of observations is a sequence of scalar observations. This model is known as a multiple linear regression model. In this case, the covariance matrix **C** is a 1-by-1 matrix that drops out of the maximum likelihood iterates so that a single-step estimate for **b** and **C** can be obtained with converged estimates $\mathbf{b}^{(1)}$ and $\mathbf{C}^{(1)}$.

Least-Squares Regression

Another simplification of the general model is called least-squares regression. If $\mathbf{b}^{(0)} = \mathbf{0}$ and $\mathbf{C}^{(0)} = \mathbf{I}$, then $\mathbf{b}^{(1)}$ and $\mathbf{C}^{(1)}$ from the two-stage iterative process are least-squares estimates for **b** and **C**, where

$$\mathbf{b}^{LS} = \left(\sum_{k=1}^{m} \mathbf{H}_k{}^T \mathbf{H}_k \right)^{-1} \left(\sum_{k=1}^{m} \mathbf{H}_k{}^T \mathbf{z}_k \right)$$

and

$$\mathbf{C}^{LS} = \frac{1}{m} \sum_{k=1}^{m} (\mathbf{z}_k - \mathbf{H}_k \mathbf{b}^{LS})(\mathbf{z}_k - \mathbf{H}_k \mathbf{b}^{LS})^T$$

Mean and Covariance Estimation

A final simplification of the general model is to estimate the mean and covariance of a sequence of n-dimensional observations $\mathbf{z}_1, \ldots, \mathbf{z}_m$. In this case, the number of series is equal to the number of model parameters with $n = p$ and the design matrices are identity matrices with $\mathbf{H}_k = \mathbf{I}$ for $i = 1, \ldots, m$ so that **b** is an estimate for the mean and **C** is an estimate of the covariance of the collection of observations $\mathbf{z}_1, \ldots, \mathbf{z}_m$.

Convergence

If the iterative process continues until the log-likelihood function increases by no more than a specified amount, the resultant estimates are said to be maximum likelihood estimates $\mathbf{b}^{ML}$ and $\mathbf{C}^{ML}$.

Note that if $n = 1$ (which implies a single data series), convergence occurs after only one iterative step, which, in turn, implies that the least-squares and maximum likelihood estimates are identical. If, however, $n > 1$, the least-squares and maximum likelihood estimates are usually distinct.

In Financial Toolbox software, both the changes in the log-likelihood function and the norm of the change in parameter estimates are monitored. Whenever both changes fall below specified tolerances (which should be something between machine precision and its square root), the toolbox functions terminate under an assumption that convergence has been achieved.

Fisher Information

Since maximum likelihood estimates are formed from samples of random variables, their estimators are random variables; an estimate derived from such samples has an uncertainty associated with it. To characterize these uncertainties, which are called standard errors, two quantities are derived from the total log-likelihood function.

The Hessian of the total log-likelihood function is

$$\nabla^2 L(\mathbf{z}_1, \ldots, \mathbf{z}_m; \theta)$$

and the Fisher information matrix is

$$\mathbf{I}(\theta) = -E[\nabla^2 L(\mathbf{z}_1, \ldots, \mathbf{z}_m; \theta)]$$

where the partial derivatives of the ∇^2 operator are taken with respect to the combined parameter vector Θ that contains the distinct components of $\mathbf{b}$ and $\mathbf{C}$ with a total of $q = p + n(n + 1)/2$ parameters.

Since maximum likelihood estimation is concerned with large-sample estimates, the central limit theorem applies to the estimates and the Fisher

information matrix plays a key role in the sampling distribution of the parameter estimates. Specifically, maximum likelihood parameter estimates are asymptotically normally distributed such that

$$(\theta^{(t)} - \theta) \sim N(0, \mathbf{I}^{-1}(\theta^{(t)})) \text{ as } t \to \infty$$

where Θ is the combined parameter vector and $\Theta^{(t)}$ is the estimate for the combined parameter vector at iteration $t = 0, 1, \ldots$.

The Fisher information matrix provides a lower bound, called a Cramér-Rao lower bound, for the standard errors of estimates of the model parameters.

Statistical Tests

Given an estimate for the combined parameter vector Θ, the squared standard errors are the diagonal elements of the inverse of the Fisher information matrix

$$s^2(\hat{\theta}_i) = (\mathbf{I}^{-1}(\hat{\theta}))_{ii}$$

for $i = 1, \ldots, q$.

Since the standard errors are estimates for the standard deviations of the parameter estimates, you can construct confidence intervals so that, for example, a 95% interval for each parameter estimate is approximately

$$\hat{\theta}_i \pm 1.96\, s(\hat{\theta}_i)$$

for $i = 1, \ldots, q$.

Error ellipses at a level-of-significance $\alpha \in [0, 1]$ for the parameter estimates satisfy the inequality

$$(\theta - \hat{\theta})^T \mathbf{I}(\hat{\theta})(\theta - \hat{\theta}) \leq \chi^2_{1-\alpha,q}$$

and follow a χ^2 distribution with q degrees-of-freedom. Note that similar inequalities can be formed for any subcollection of the parameters.

In general, given parameter estimates, the computed Fisher information matrix, and the log-likelihood function, you can perform numerous statistical tests on the parameters, the model, and the regression.

Maximum Likelihood Estimation with Missing Data

In this section...

"Introduction" on page 5-9

"ECM Algorithm" on page 5-10

"Standard Errors" on page 5-11

"Data Augmentation" on page 5-11

"Multivariate Normal Regression Functions" on page 5-12

"Multivariate Normal Regression Without Missing Data" on page 5-14

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"Least-Squares Regression with Missing Data" on page 5-15

"Multivariate Normal Parameter Estimation with Missing Data" on page 5-15

"Support Functions" on page 5-16

Introduction

Suppose that a portion of the sample data is missing, where missing values are represented as `NaN`s. If the missing values are missing-at-random and ignorable, where Little and Rubin [7] have precise definitions for these terms, it is possible to use a version of the Expectation Maximization, or EM, algorithm of Dempster, Laird, and Rubin [3] to estimate the parameters of the multivariate normal regression model. The algorithm used in Financial Toolbox software is the ECM (Expectation Conditional Maximization) algorithm of Meng and Rubin [8] with enhancements by Sexton and Swensen [9].

Each sample $\mathbf{z}_k$ for $k = 1, ..., m$, is either complete with no missing values, empty with no observed values, or incomplete with both observed and missing values. Empty samples are ignored since they contribute no information.

To understand the missing-at-random and ignorabable conditions, consider an example of stock price data before an IPO. For a counterexample, censored data, in which all values greater than some cutoff are replaced with `NaN`s, does not satisfy these conditions.

In sample k, let $\mathbf{x}_k$ represent the missing values in $\mathbf{z}_k$, and $\mathbf{y}_k$ represent the observed values. Define a permutation matrix $\mathbf{P}_k$ so that

$$\mathbf{z}_k = \mathbf{P}_k \begin{bmatrix} \mathbf{x}_k \\ \mathbf{y}_k \end{bmatrix}$$

for $k = 1, \ldots, m$.

ECM Algorithm

The ECM algorithm has two steps – an E, or expectation step, and a CM, or conditional maximization, step. As with maximum likelihood estimation, the parameter estimates evolve according to an iterative process, where estimates for the parameters after t iterations are denoted as $\mathbf{b}^{(t)}$ and $\mathbf{C}^{(t)}$.

The E step forms conditional expectations for the elements of missing data with

$$E\left[\mathbf{X}_k \,\middle|\, \mathbf{Y}_k = \mathbf{y}_k; \mathbf{b}^{(t)}, \mathbf{C}^{(t)}\right]$$

$$cov\left[\mathbf{X}_k \,\middle|\, \mathbf{Y}_k = \mathbf{y}_k; \mathbf{b}^{(t)}, \mathbf{C}^{(t)}\right]$$

for each sample $k \in \{1, \ldots, m\}$ that has missing data.

The CM step proceeds in the same manner as the maximum likelihood procedure without missing data. The main difference is that missing data moments are imputed from the conditional expectations obtained in the E step.

The E and CM steps are repeated until the log-likelihood function ceases to increase. One of the important properties of the ECM algorithm is that it is always guaranteed to find a maximum of the log-likelihood function and, under suitable conditions, this maximum can be a global maximum.

Standard Errors

The negative of the expected Hessian of the log-likelihood function and the Fisher information matrix are identical if no data is missing. However, if data is missing, the Hessian, which is computed over available samples, accounts for the loss of information due to missing data. Consequently, the Fisher information matrix provides standard errors that are a Cramér-Rao lower bound whereas the Hessian matrix provides standard errors that may be greater if there is missing data.

Data Augmentation

The ECM functions do not "fill in" missing values as they estimate model parameters. In some cases, you may want to fill in the missing values. Although you can fill in the missing values in your data with conditional expectations, you would get optimistic and unrealistic estimates because conditional estimates are not random realizations.

Several approaches are possible, including resampling methods and multiple imputation (see Little and Rubin [7] and Shafer [10] for details). A somewhat informal sampling method for data augmentation is to form random samples for missing values based on the conditional distribution for the missing values. Given parameter estimates for $\hat{\mathbf{b}}$ and $\hat{\mathbf{C}}$, each observation has moments

$$E[\,\mathbf{Z}_k\,] = \mathbf{H}_k\hat{\mathbf{b}}$$

and

$$cov(\mathbf{Z}_k) = \mathbf{H}_k^T\hat{\mathbf{C}}\mathbf{H}_k^T$$

for $k = 1, \ldots, m$, where you have dropped the parameter dependence on the left sides for notational convenience.

For observations with missing values partitioned into missing values $\mathbf{X}_k$ and observed values $\mathbf{Y}_k = \mathbf{y}_k$, you can form conditional estimates for any subcollection of random variables within a given observation. Thus, given estimates $\boldsymbol{E}[\,\mathbf{Z}_k\,]$ and $cov(\mathbf{Z}_k)$ based on the parameter estimates, you can create conditional estimates

$$E[\mathbf{X}_k \mid \mathbf{y}_k]$$

and

$$cov(\mathbf{X}_k \mid \mathbf{y}_k)$$

using standard multivariate normal distribution theory. Given these conditional estimates, you can simulate random samples for the missing values from the conditional distribution

$$\mathbf{X}_k \sim N(E[\mathbf{X}_k \mid \mathbf{y}_k], cov(\mathbf{X}_k \mid \mathbf{y}_k))$$

The samples from this distribution reflect the pattern of missing and nonmissing values for observations $k = 1, ..., m$. You must sample from conditional distributions for each observation to preserve the correlation structure with the nonmissing values at each observation.

If you follow this procedure, the resultant filled-in values are random and generate mean and covariance estimates that are asymptotically equivalent to the ECM-derived mean and covariance estimates. Note, however, that the filled-in values are random and reflect likely samples from the distribution estimated over all the data and may not reflect "true" values for a particular observation.

Multivariate Normal Regression Functions

Financial Toolbox software has a number of functions for multivariate normal regression with or without missing data. The toolbox functions solve four classes of regression problems with functions to estimate parameters, standard errors, log-likelihood functions, and Fisher information matrices. The four classes of regression problems are:

- "Multivariate Normal Regression Without Missing Data" on page 5-14
- "Multivariate Normal Regression With Missing Data" on page 5-14
- "Least-Squares Regression with Missing Data" on page 5-15
- "Multivariate Normal Parameter Estimation with Missing Data" on page 5-15

Additional support functions are also provided, see "Support Functions" on page 5-16.

In all functions, the MATLAB representation for the number of observations (or samples) is `NumSamples = m`, the number of data series is `NumSeries = n`, and the number of model parameters is `NumParams = p`. Note that the moment estimation functions have `NumSeries = NumParams`.

The collection of observations (or samples) is stored in a MATLAB matrix `Data` such that

$$\mathrm{Data}(k,\ :) = \mathbf{z}_k^T$$

for `k = 1, ..., NumSamples`, where `Data` is a `NumSamples`-by-`NumSeries` matrix.

For the multivariate normal regression or least-squares functions, an additional required input is the collection of design matrices that is stored as either a MATLAB matrix or a vector of cell arrays denoted as `Design`.

If $\mathrm{Numseries} = 1$, `Design` can be a `NumSamples`-by-`NumParams` matrix. This is the "standard" form for regression on a single data series.

If $\mathrm{Numseries} = 1$, `Design` can be either a cell array with a single cell or a cell array with `NumSamples` cells. Each cell in the cell array contains a `NumSeries`-by-`NumParams` matrix such that

$$\mathrm{Design}\{k\} = \mathbf{H}_k$$

for `k = 1, ..., NumSamples`. If `Design` has a single cell, it is assumed to be the same `Design` matrix for each sample such that

$$\mathrm{Design}\{1\} = \mathbf{H}_1 = \ldots = \mathbf{H}_m$$

Otherwise, `Design` must contain individual design matrices for each and every sample.

The main distinction among the four classes of regression problems depends upon how missing values are handled and where missing values are

represented as the MATLAB value `NaN`. If a sample is to be ignored given any missing values in the sample, the problem is said to be a problem "without missing data." If a sample is to be ignored if and only if every element of the sample is missing, the problem is said to be a problem "with missing data" since the estimation must account for possible `NaN` values in the data.

In general, `Data` may or may not have missing values and `Design` should have no missing values. In some cases, however, if an observation in `Data` is to be ignored, the corresponding elements in `Design` are also ignored. Consult the function reference pages for details.

Multivariate Normal Regression Without Missing Data

You can use the following functions for multivariate normal regression without missing data.

`mvnrmle`	Estimate model parameters, residuals, and the residual covariance.
`mvnrstd`	Estimate standard errors of model and covariance parameters.
`mvnrfish`	Estimate the Fisher information matrix.
`mvnrobj`	Calculate the log-likelihood function.

The first two functions are the main estimation functions. The second two are supporting functions that can be used for more detailed analyses.

Multivariate Normal Regression With Missing Data

You can use the following functions for multivariate normal regression with missing data.

`ecmmvnrmle`	Estimate model parameters, residuals, and the residual covariance.
`ecmmvnrstd`	Estimate standard errors of model and covariance parameters.

`ecmmvnrfish`	Estimate the Fisher information matrix.
`ecmmvnrobj`	Calculate the log-likelihood function.

The first two functions are the main estimation functions. The second two are supporting functions used for more detailed analyses.

Least-Squares Regression with Missing Data

You can use the following functions for least-squares regression with missing data or for covariance-weighted least-squares regression with a fixed covariance matrix.

`ecmlsrmle`	Estimate model parameters, residuals, and the residual covariance.
`ecmlsrobj`	Calculate the least-squares objective function (pseudo log-likelihood).

To compute standard errors and estimates for the Fisher information matrix, the multivariate normal regression functions with missing data are used.

`ecmmvnrstd`	Estimate standard errors of model and covariance parameters.
`ecmmvnrfish`	Estimate the Fisher information matrix.

Multivariate Normal Parameter Estimation with Missing Data

You can use the following functions to estimate the mean and covariance of multivariate normal data.

`ecmnmle`	Estimate the mean and covariance of the data.
`ecmnstd`	Estimate standard errors of the mean and covariance of the data.

`ecmnfish`	Estimate the Fisher information matrix.
`ecmnhess`	Estimate the Fisher information matrix using the Hessian.
`ecmnobj`	Calculate the log-likelihood function.

These functions behave slightly differently from the more general regression functions since they solve a specialized problem. Consult the function reference pages for details.

Support Functions

Two support functions are included.

`convert2sur`	Convert a multivariate normal regression model into an SUR model.
`ecmninit`	Obtain initial estimates for the mean and covariance of a `Data` matrix.

The `convert2sur` function converts a multivariate normal regression model into a seemingly unrelated regression, or SUR, model. The second function `ecmninit` is a specialized function to obtain initial ad hoc estimates for the mean and covariance of a `Data` matrix with missing data. (If there are no missing values, the estimates are the maximum likelihood estimates for the mean and covariance.)

Multivariate Normal Regression Types

In this section...

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"Multivariate Normal Regression" on page 5-17
"Least-Squares Regression" on page 5-18
"Covariance-Weighted Least Squares" on page 5-19
"Feasible Generalized Least Squares" on page 5-20
"Seemingly Unrelated Regression" on page 5-21
"Mean and Covariance Parameter Estimation" on page 5-23
"Troubleshooting Multivariate Normal Regression" on page 5-23
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"Nonrandom Residuals" on page 5-24
"Nonconvergence" on page 5-25
"Example of Portfolios with Missing Data" on page 5-26

Regressions

Each regression function has a specific operation. This section shows how to use these functions to perform specific types of regressions. To illustrate use of the functions for various regressions, "typical" usage is shown with optional arguments kept to a minimum. For a typical regression, you estimate model parameters and residual covariance matrices with the `mle` functions and estimate the standard errors of model parameters with the `std` functions. The regressions "without missing data" essentially ignore samples with any missing values, and the regressions "with missing data" ignore samples with every value missing.

Multivariate Normal Regression

Multivariate normal regression, or MVNR, is the "standard" implementation of the regression functions in Financial Toolbox software.

Multivariate Normal Regression Without Missing Data

Estimate Parameters

```
[Parameters, Covariance] = mvnrmle(Data, Design);
```

Estimate Standard Errors

```
StdParameters = mvnrstd(Data, Design, Covariance);
```

Multivariate Normal Regression with Missing Data

Estimate Parameters

```
[Parameters, Covariance] = ecmmvnrmle(Data, Design);
```

Estimate Standard Errors

```
StdParameters = ecmmvnrstd(Data, Design, Covariance);
```

Least-Squares Regression

Least-squares regression, or LSR, sometimes called ordinary least-squares or multiple linear regression, is the simplest linear regression model. It also enjoys the property that, independent of the underlying distribution, it is a best linear unbiased estimator (BLUE).

Given m = `NumSamples` observations, the typical least-squares regression model seeks to minimize the objective function

$$\sum_{k=1}^{m} (\mathbf{Z}_k - \mathbf{H}_k\mathbf{b})^T(\mathbf{Z}_k - \mathbf{H}_k\mathbf{b})$$

which, within the maximum likelihood framework of the multivariate normal regression routine `mvnrmle`, is equivalent to a single-iteration estimation of just the parameters to obtain `Parameters` with the initial covariance matrix `Covariance` held fixed as the identity matrix. In the case of missing data, however, the internal algorithm to handle missing data requires a separate routine `ecmlsrmle` to do least-squares instead of multivariate normal regression.

Least-Squares Regression Without Missing Data

Estimate Parameters

```
[Parameters, Covariance] = mvnrmle(Data, Design, 1);
```

Estimate Standard Errors

```
StdParameters = mvnrstd(Data, Design, Covariance);
```

Least-Squares Regression with Missing Data

Estimate Parameters

```
[Parameters, Covariance] = ecmlsrmle(Data, Design);
```

Estimate Standard Errors

```
StdParameters = ecmmvnrstd(Data, Design, Covariance);
```

Covariance-Weighted Least Squares

Given m = `NUMSAMPLES` observations, the typical covariance-weighted least squares, or CWLS, regression model seeks to minimize the objective function

$$\sum_{k=1}^{m} (\mathbf{Z}_k - \mathbf{H}_k\mathbf{b})^T \mathbf{C}_0 (\mathbf{Z}_k - \mathbf{H}_k\mathbf{b})$$

with fixed covariance $\mathbf{C}_0$.

In most cases, $\mathbf{C}_0$ is a diagonal matrix. The inverse matrix $\mathbf{W} = \mathbf{C}_0^{-1}$ has diagonal elements that can be considered relative “weights” for each series. Thus, CWLS is a form of weighted least squares with the weights applied across series.

Covariance-Weighted Least Squares Without Missing Data

Estimate Parameters

```
[Parameters, Covariance] = mvnrmle(Data, Design, 1, [], [], [],
                                   Covar0);
```

Estimate Standard Errors

```
StdParameters = mvnrstd(Data, Design, Covariance);
```

Covariance-Weighted Least Squares with Missing Data

Estimate Parameters

```
[Parameters, Covariance] = ecmlsrmle(Data, Design, [], [], [], [],
                                     Covar0);
```

Estimate Standard Errors

```
StdParameters = ecmmvnrstd(Data, Design, Covariance);
```

Feasible Generalized Least Squares

An ad hoc form of least squares that has surprisingly good properties for misspecified or nonnormal models is known as feasible generalized least squares, or FGLS. The basic procedure is to do least-squares regression and then to do covariance-weighted least-squares regression with the resultant residual covariance from the first regression.

Feasible Generalized Least Squares Without Missing Data

Estimate Parameters

```
[Parameters, Covariance] = mvnrmle(Data, Design, 2, 0, 0);
```

or (to illustrate the FGLS process explicitly)

```
[Parameters, Covar0] = mvnrmle(Data, Design, 1);
[Parameters, Covariance] = mvnrmle(Data, Design, 1, [], [], [],
                                   Covar0);
```

Estimate Standard Errors

```
StdParameters = mvnrstd(Data, Design, Covariance);
```

Feasible Generalized Least Squares with Missing Data

Estimate Parameters

```
[Parameters, Covar0] = ecmlsrmle(Data, Design);
[Parameters, Covariance] = ecmlsrmle(Data, Design, [], [], [], [],
                                     Covar0);
```

Estimate Standard Errors

```
StdParameters = ecmmvnrstd(Data, Design, Covariance);
```

Seemingly Unrelated Regression

Given a multivariate normal regression model in standard form with a `Data` matrix and a `Design` array, it is possible to convert the problem into a seemingly unrelated regression (SUR) problem by a simple transformation of the `Design` array. The main idea of SUR is that instead of having a common parameter vector over all data series, you have a separate parameter vector associated with each separate series or with distinct groups of series that, nevertheless, share a common residual covariance. It is this ability to aggregate and disaggregate series and to perform comparative tests on each design that is the power of SUR.

To make the transformation, use the function `convert2sur`, which converts a standard-form design array into an equivalent design array to do SUR with a specified mapping of the series into `NUMGROUPS` groups. The regression functions are used in the usual manner, but with the SUR design array instead of the original design array. Instead of having `NUMPARAMS` elements, the SUR output parameter vector has `NUMGROUPS` of stacked parameter estimates, where the first `NUMPARAMS` elements of `Parameters` contain parameter estimates associated with the first group of series, the next `NUMPARAMS` elements of `Parameters` contain parameter estimates associated with the second group of series, and so on. If the model has only one series, for example, `NUMSERIES` = 1, then the SUR design array is the same as the original design array since SUR requires two or more series to generate distinct parameter estimates.

Given `NUMPARAMS` parameters and `NUMGROUPS` groups with a parameter vector `Parameters` with `NUMGROUPS * NUMPARAMS` elements from any of the regression routines, the following MATLAB code fragment shows how to print a table of SUR parameter estimates with rows that correspond to each parameter and columns that correspond to each group or series:

```
fprintf(1,'Seemingly Unrelated Regression Parameter
```

```
   Estimates\n');
fprintf(1,'   %7s ',' ');
fprintf(1,'  Group(%3d) ',1:NumGroups);
fprintf(1,'\n');
for i = 1:NumParams
 fprintf(1,'   %7d ',i);
 ii = i;
     for j = 1:NumGroups
      fprintf(1,'%12g ',Param(ii));
      ii = ii + NumParams;
      end
      fprintf(1,'\n');
end
fprintf(1,'\n');
```

Seemingly Unrelated Regression Without Missing Data

Form an SUR Design

```
DesignSUR = convert2sur(Design, Group);
```

Estimate Parameters

```
[Parameters, Covariance] = mvnrmle(Data, DesignSUR);
```

Estimate Standard Errors

```
StdParameters = mvnrstd(Data, DesignSUR, Covariance);
```

Seemingly Unrelated Regression with Missing Data

Form an SUR Design

```
DesignSUR = convert2sur(Design, Group);
```

Estimate Parameters

```
[Parameters, Covariance] = ecmmvnrmle(Data, DesignSUR);
```

Estimate Standard Errors

```
StdParameters = ecmmvnrstd(Data, DesignSUR, Covariance);
```

Mean and Covariance Parameter Estimation

Without missing data, you can estimate the mean of your `Data` with the function `mean` and the covariance with the function `cov`. Nevertheless, the function `ecmnmle` does this for you if it detects an absence of missing values. Otherwise, it uses the ECM algorithm to handle missing values.

Estimate Parameters

```
[Mean, Covariance] = ecmnmle(Data);
```

Estimate Standard Errors

```
StdMean = ecmnstd(Data, Mean, Covariance);
```

Troubleshooting Multivariate Normal Regression

This section provides a few pointers to handle various technical and operational difficulties that might occur.

Biased Estimates

If samples are ignored, the number of samples used in the estimation is less than `NumSamples`. Clearly the actual number of samples used must be sufficient to obtain estimates. In addition, although the model parameters `Parameters` (or mean estimates `Mean`) are unbiased maximum likelihood estimates, the residual covariance estimate `Covariance` is biased. To convert to an unbiased covariance estimate, multiply `Covariance` by

$$\mathrm{Count}/(\mathrm{Count}-1)$$

where `Count` is the actual number of samples used in the estimation with $\mathrm{Count} \leq \mathrm{NumSamples}$. Note that none of the regression functions perform this adjustment.

Requirements

The regression functions, particularly the estimation functions, have several requirements. First, they must have consistent values for `NumSamples`, `NumSeries`, and `NumParams`. As a general rule, the multivariate normal regression functions require

$$\text{Count} * \text{NumSeries} \leq \max\{\text{NumParams}, \text{NumSeries} * (\text{NumSeries} + 1)/2\}$$

and the least-squares regression functions require

$$\text{Count} * \text{NumSeries} \leq \text{NumParams}$$

where `Count` is the actual number of samples used in the estimation with

$$\text{Count} \leq \text{NumSamples}$$

Second, they must have enough nonmissing values to converge. Third, they must have a nondegenerate covariance matrix.

Although some necessary and sufficient conditions can be found in the references, general conditions for existence and uniqueness of solutions in the missing-data case do not exist. Nonconvergence is usually due to an ill-conditioned covariance matrix estimate, which is discussed in greater detail in "Nonconvergence" on page 5-25.

Slow Convergence

Since worst-case convergence of the ECM algorithm is linear, it is possible to execute hundreds and even thousands of iterations before termination of the algorithm. If you are estimating with the ECM algorithm on a regular basis with regular updates, you can use prior estimates as initial guesses for the next period's estimation. This approach often speeds things up since the default initialization in the regression functions sets the initial parameters **b** to zero and the initial covariance **C** to be the identity matrix.

Other ad hoc approaches are possible although most approaches are problem-dependent. In particular, for mean and covariance estimation, the estimation function `ecmnmle` uses a function `ecmninit` to obtain an initial estimate.

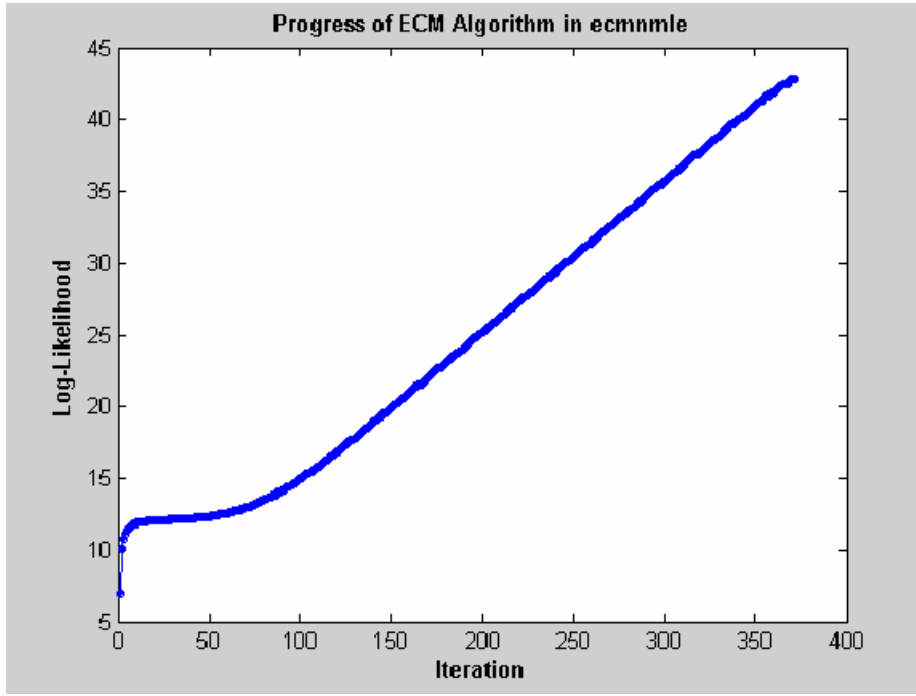
Nonrandom Residuals

Simultaneous estimates for parameters **b** and covariances **C** require **C** to be positive-definite. Consequently, the general multivariate normal regression routines require nondegenerate residual errors. If you are faced with a model that has exact results, the least-squares routine `ecmlsrmle` still

works, although it provides a least-squares estimate with a singular residual covariance matrix. The other regression functions will fail.

Nonconvergence

Although the regression functions are robust and work for most "typical" cases, they can fail to converge. The main failure mode is an ill-conditioned covariance matrix, where failures are either soft or hard. A soft failure wanders endlessly toward a nearly singular covariance matrix and can be spotted if the algorithm fails to converge after about 100 iterations. If `MaxIterations` is increased to 500 and display mode is initiated (with no output arguments), a typical soft failure looks like this.



This case, which is based on 20 observations of 5 assets with 30% of data missing, shows that the log-likelihood goes linearly to infinity as the likelihood function goes to 0. In this case, the function converges but the covariance

matrix is effectively singular with a smallest eigenvalue on the order of machine precision (`eps`).

For the function `ecmnmle`, a hard error looks like this:

```
> In ecmninit at 60
  In ecmnmle at 140
??? Error using ==> ecmnmle
Full covariance not positive-definite in iteration 218.
```

From a practical standpoint, if in doubt, test your residual covariance matrix from the regression routines to ensure that it is positive-definite. This is important because a soft error has a matrix that appears to be positive-definite but actually has a near-zero-valued eigenvalue to within machine precision. To do this with a covariance estimate `Covariance`, use `cond(Covariance)`, where any value greater than `1/eps` should be considered suspect.

If either type of failure occurs, however, note that the regression routine is indicating that something is probably wrong with the data. (Even with no missing data, two time series that are proportional to one another produce a singular covariance matrix.)

Example of Portfolios with Missing Data

This example illustrates how to use the missing data algorithms for portfolio optimization and for valuation. This example works with 5 years of daily total return data for 12 computer technology stocks, with 6 hardware and 6 software companies. The example estimates the mean and covariance matrix for these stocks, forms efficient frontiers with both a naïve approach and the ECM approach, and compares results.

You can run the example directly with the M-file `ecmtechdemo.m`.

1. Load the following data file:

   ```
   load ecmtechdemo
   ```

   This file contains these three quantities:

   - `Assets` is a cell array of the tickers for the twelve stocks in the example.

- `Data` is a `1254`-by-`12` matrix of 1254 daily total returns for each of the 12 stocks.
- `Dates` is a `1254`-by-`1` column vector of the dates associated with the data.

The time period for the data extends from April 19, 2000 to April 18, 2005.

The sixth stock in `Assets` is Google (GOOG), which started trading on August 19, 2004. Consequently, all returns before August 20, 2004 are missing and represented as `NaNs`. Also, Amazon (AMZN) had a few days with missing values scattered throughout the past 5 years.

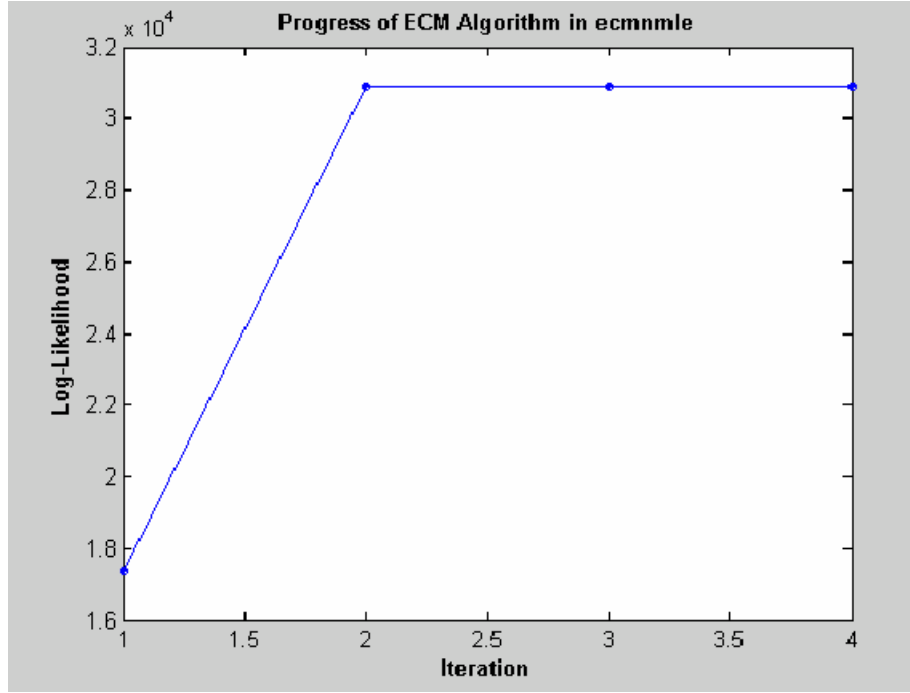
2 A naïve approach to the estimation of the mean and covariance for these 12 assets is to eliminate all days that have missing values for any of the 12 assets. Use the function `ecmninit` with the `nanskip` option to do this.

```
[NaNMean, NaNCovar] = ecmninit(Data,'nanskip');
```

3 Contrast the result of this approach with using all available data and the function `ecmnmle` to compute the mean and covariance. First, call `ecmnmle` with no output arguments to establish that enough data is available to obtain meaningful estimates.

```
ecmnmle(Data);
```

The following figure shows that, even with almost 87% of the Google data being `NaN` values, the algorithm converges after only four iterations.



4 Estimate the mean and covariance as computed by `ecmnmle`.

```
>> [ECMMean, ECMCovar] = ecmnmle(Data)

ECMMean =

    0.0008
    0.0008
   -0.0005
    0.0002
    0.0011
    0.0038
   -0.0003
   -0.0000
   -0.0003
   -0.0000
   -0.0003
```

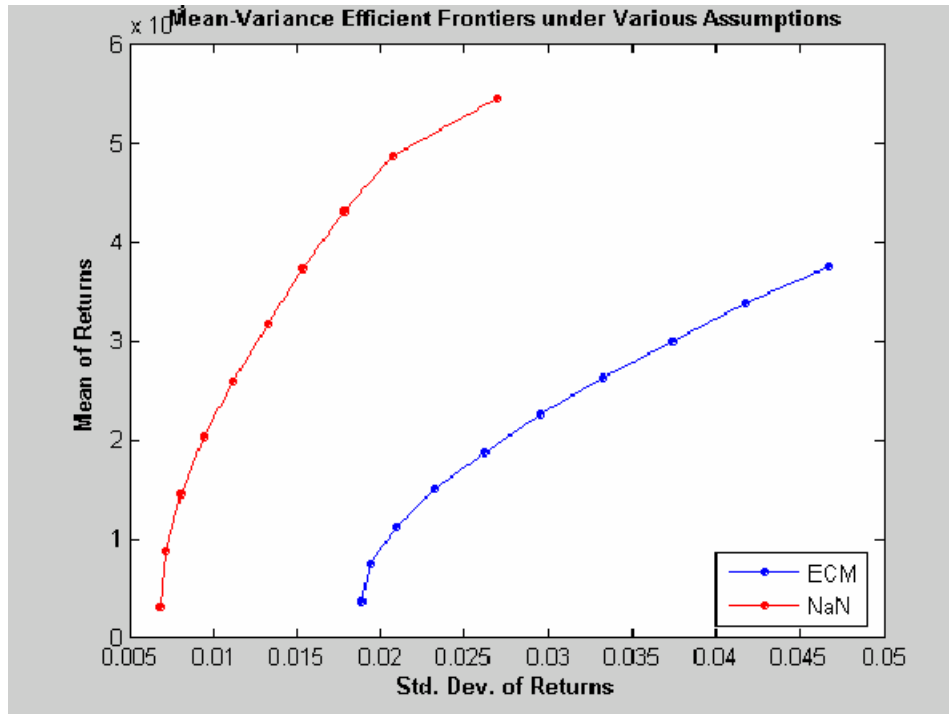
```
    0.0004

ECMCovar =

    0.0012    0.0005    0.0006    0.0005    0.0005    0.0003
    0.0005    0.0024    0.0007    0.0006    0.0010    0.0004
    0.0006    0.0007    0.0013    0.0007    0.0007    0.0003
    0.0005    0.0006    0.0007    0.0009    0.0006    0.0002
    0.0005    0.0010    0.0007    0.0006    0.0016    0.0006
    0.0003    0.0004    0.0003    0.0002    0.0006    0.0022
    0.0005    0.0005    0.0006    0.0005    0.0005    0.0001
    0.0003    0.0003    0.0004    0.0003    0.0003    0.0002
    0.0006    0.0006    0.0008    0.0007    0.0006    0.0002
    0.0003    0.0004    0.0005    0.0004    0.0004    0.0001
    0.0005    0.0006    0.0008    0.0005    0.0007    0.0003
    0.0006    0.0012    0.0008    0.0007    0.0011    0.0016

ECMCovar (continued)

    0.0005    0.0003    0.0006    0.0003    0.0005    0.0006
    0.0005    0.0003    0.0006    0.0004    0.0006    0.0012
    0.0006    0.0004    0.0008    0.0005    0.0008    0.0008
    0.0005    0.0003    0.0007    0.0004    0.0005    0.0007
    0.0005    0.0003    0.0006    0.0004    0.0007    0.0011
    0.0001    0.0002    0.0002    0.0001    0.0003    0.0016
    0.0009    0.0003    0.0005    0.0004    0.0005    0.0006
    0.0003    0.0005    0.0004    0.0003    0.0004    0.0004
    0.0005    0.0004    0.0011    0.0005    0.0007    0.0007
    0.0004    0.0003    0.0005    0.0006    0.0004    0.0005
    0.0005    0.0004    0.0007    0.0004    0.0013    0.0007
    0.0006    0.0004    0.0007    0.0005    0.0007    0.0020
```

5 Given estimates for the mean and covariance of asset returns derived from the naïve and ECM approaches, estimate portfolios, and associated expected returns and risks on the efficient frontier for both approaches.

```
[ECMRisk, ECMReturn, ECMWts] = portopt(ECMMean',ECMCovar,10);
[NaNRisk, NaNReturn, NaNWts] = portopt(NaNMean',NaNCovar,10);
```

6 Plot the results on the same graph to illustrate the differences.

```
figure(gcf)
plot(ECMRisk,ECMReturn,'-bo','MarkerFaceColor','b','MarkerSize', 3);
hold all
plot(NaNRisk,NaNReturn,'-ro','MarkerFaceColor','r','MarkerSize', 3);
title('\bfMean-Variance Efficient Frontiers under Various Assumptions');
legend('ECM','NaN','Location','SouthEast');
xlabel('\bfStd. Dev. of Returns');
ylabel('\bfMean of Returns');
hold off
```



7 Clearly, the naïve approach is optimistic about the risk-return trade-offs for this universe of 12 technology stocks. The proof, however, lies in the portfolio weights. To view the weights, enter

```
Assets
ECMWts
NaNWts
```

which generates

```
>> Assets

ans =

    'AAPL'    'AMZN'    'CSCO'    'DELL'    'EBAY'    'GOOG'

>> ECMWts

ans =

    0.0358    0.0011   -0.0000    0.0000    0.0000    0.0989
    0.0654    0.0110    0.0000    0.0000    0.0000    0.1877
    0.0923    0.0194    0.0000    0.0000    0.0000    0.2784
    0.1165    0.0264    0.0000   -0.0000    0.0000    0.3712
    0.1407    0.0334   -0.0000         0    0.0000    0.4639
    0.1648    0.0403    0.0000         0   -0.0000    0.5566
    0.1755    0.0457    0.0000   -0.0000   -0.0000    0.6532
    0.1845    0.0509    0.0000    0.0000   -0.0000    0.7502
    0.1093    0.0174   -0.0000    0.0000         0    0.8733
         0         0   -0.0000    0.0000         0    1.0000

>> NaNWts

ans =

   -0.0000    0.0000   -0.0000    0.1185    0.0000    0.0522
    0.0576   -0.0000   -0.0000    0.1219    0.0000    0.0854
    0.1248   -0.0000   -0.0000    0.0952   -0.0000    0.1195
    0.1969   -0.0000   -0.0000    0.0529   -0.0000    0.1551
    0.2690   -0.0000   -0.0000    0.0105    0.0000    0.1906
    0.3414    0.0000   -0.0000   -0.0000   -0.0000    0.2265
    0.4235    0.0000   -0.0000   -0.0000   -0.0000    0.2639
    0.5245    0.0000   -0.0000   -0.0000   -0.0000    0.3034
    0.6269   -0.0000   -0.0000   -0.0000   -0.0000    0.3425
    1.0000   -0.0000   -0.0000    0.0000   -0.0000         0

Assets (continued)
```

```
    'HPQ'    'IBM'    'INTC'    'MSFT'    'ORCL'    'YHOO'

ECMWts (continued)

    0.0535    0.4676    0.0000    0.3431   -0.0000    0.0000
    0.0179    0.3899   -0.0000    0.3282    0.0000   -0.0000
         0    0.3025   -0.0000    0.3074    0.0000   -0.0000
    0.0000    0.2054   -0.0000    0.2806    0.0000    0.0000
    0.0000    0.1083   -0.0000    0.2538   -0.0000    0.0000
    0.0000    0.0111   -0.0000    0.2271   -0.0000    0.0000
    0.0000    0.0000   -0.0000    0.1255   -0.0000    0.0000
    0.0000         0   -0.0000    0.0143   -0.0000   -0.0000
    0.0000   -0.0000   -0.0000   -0.0000   -0.0000    0.0000
    0.0000   -0.0000   -0.0000   -0.0000   -0.0000    0.0000

NaNWts (continued)

    0.0824    0.1779    0.0000    0.5691   -0.0000    0.0000
    0.1274    0.0460    0.0000    0.5617   -0.0000   -0.0000
    0.1674   -0.0000    0.0000    0.4802    0.0129   -0.0000
    0.2056   -0.0000    0.0000    0.3621    0.0274   -0.0000
    0.2438   -0.0000    0.0000    0.2441    0.0419   -0.0000
    0.2782   -0.0000    0.0000    0.0988    0.0551   -0.0000
    0.2788   -0.0000    0.0000   -0.0000    0.0337   -0.0000
    0.1721   -0.0000    0.0000   -0.0000   -0.0000   -0.0000
    0.0306   -0.0000    0.0000    0.0000         0   -0.0000
         0    0.0000    0.0000   -0.0000   -0.0000   -0.0000
```

The naïve portfolios in `NaNWts` tend to favor Apple® Computer (AAPL), which happened to do well over the period from the Google IPO to the end of the estimation period, while the ECM portfolios in `ECMWts` tend to underweight Apple Computer and to recommend increased weights in Google relative to the naïve weights.

8 To evaluate the impact of estimation error and, in particular, the effect of missing data, use `ecmnstd` to calculate standard errors. Although it is possible to estimate the standard errors for both the mean and covariance, the standard errors for the mean estimates alone are usually the main quantities of interest.

```
StdMeanF = ecmnstd(Data,ECMMean,ECMCovar,'fisher');
```

9 Calculate standard errors that use the data-generated Hessian matrix (which accounts for the possible loss of information due to missing data) with the option `HESSIAN`.

```
StdMeanH = ecmnstd(Data,ECMMean,ECMCovar,'hessian');
```

The difference in the standard errors shows the increase in uncertainty of estimation of asset expected returns due to missing data. This can be viewed by entering

```
Assets
StdMeanH'
StdMeanF'
StdMeanH' - StdMeanF'
```

The two assets with `missing data`, AMZN and GOOG, are the only assets to have differences due to missing information.

Valuation with Missing Data

In this section...

"Introduction" on page 5-34
"Capital Asset Pricing Model" on page 5-34
"Estimation of the CAPM" on page 5-35
"Estimation with Missing Data" on page 5-36
"Estimation of Some Technology Stock Betas" on page 5-36
"Grouped Estimation of Some Technology Stock Betas" on page 5-39
"References" on page 5-42

Introduction

The Capital Asset Pricing Model (CAPM) is a venerable but often maligned tool to characterize comovements between asset and market prices. Although many issues arise in CAPM implementation and interpretation, one problem that practitioners face is to estimate the coefficients of the CAPM with incomplete stock price data.

This example shows how to use the missing data regression functions to estimate the coefficients of the CAPM. You can run the example directly with the M-file `CAPMdemo.m`.

Capital Asset Pricing Model

Given a host of assumptions that can be found in the references (see Sharpe [11], Lintner [6], Jarrow [5], and Sharpe, et. al. [12]), the CAPM concludes that asset returns have a linear relationship with market returns. Specifically, given the return of all stocks that constitute a market denoted as M and the return of a riskless asset denoted as C, the CAPM states that the return of each asset R_i in the market has the expectational form

$$E[R_i] = \alpha_i + C + \beta_i(E[M] - C)$$

for assets $i = 1, ..., n$, where β_i is a parameter that specifies the degree of comovement between a given asset and the underlying market. In other words, the expected return of each asset is equal to the return on a riskless asset plus a risk-adjusted expected market return net of riskless asset returns. The collection of parameters $\beta_1, \ldots, \beta_n$ is called asset betas.

Note that the beta of an asset has the form

$$\beta_i = \frac{\mathrm{cov}(R_i, M)}{\mathrm{var}(M)}$$

which is the ratio of the covariance between asset and market returns divided by the variance of market returns. If an asset has a beta = 1, the asset is said to move with the market; if an asset has a beta > 1, the asset is said to be more volatile than the market. Conversely, if an asset has a beta < 1, the asset is said to be less volatile than the market.

Estimation of the CAPM

The standard CAPM model is a linear model with additional parameters for each asset to characterize residual errors. For each of n assets with m samples of observed asset returns $R_{k,i}$, market returns M_k, and riskless asset returns C_k, the estimation model has the form

$$R_{k,i} = \alpha_i + C_k + \beta_i(M_k - C_k) + V_{k,i}$$

for samples $k = 1, ..., m$ and assets $i = 1, ..., n$, where α_i is a parameter that specifies the nonsystematic return of an asset, β_i is the asset beta, and $V_{k,i}$ is the residual error for each asset with associated random variable V_i.

The collection of parameters $\alpha_1, \ldots, \alpha_n$ are called asset alphas. The strict form of the CAPM specifies that alphas must be zero and that deviations from zero are the result of temporary disequilibria. In practice, however, assets may have nonzero alphas, where much of active investment management is devoted to the search for assets with exploitable nonzero alphas.

To allow for the possibility of nonzero alphas, the estimation model generally seeks to estimate alphas and to perform tests to determine if the alphas are statistically equal to zero.

The residual errors V_i are assumed to have moments

$$E[V_i] = 0$$

and

$$E[V_i V_j] = S_{ij}$$

for assets $i, j = 1, \ldots, n$, where the parameters $S_{11}, \ldots, S_{nn}$ are called residual or nonsystematic variances/covariances.

The square root of the residual variance of each asset, for example, $\mathrm{sqrt}(S_{ii})$ for $i = 1, \ldots, n$, is said to be the residual or nonsystematic risk of the asset since it characterizes the residual variation in asset prices that are not explained by variations in market prices.

Estimation with Missing Data

Although betas can be estimated for companies with sufficiently long histories of asset returns, it is difficult to estimate betas for recent IPOs. However, if a collection of sufficiently observable companies exists that can be expected to have some degree of correlation with the new company's stock price movements, that is, companies within the same industry as the new company, it is possible to obtain imputed estimates for new company betas with the missing-data regression routines.

Estimation of Some Technology Stock Betas

To illustrate how to use the missing-data regression routines, estimate betas for 12 technology stocks, where a single stock (GOOG) is an IPO.

1. Load dates, total returns, and ticker symbols for the 12 stocks from the MAT-file `CAPMuniverse`.

```
load CAPMuniverse
whos Assets Data Dates
```

```
  Name         Size                    Bytes  Class

  Assets       1x14                      952  cell array
  Data      1471x14                   164752  double array
  Dates     1471x1                     11768  double array

Grand total is 22135 elements using 177472 bytes
```

The assets in the model have the following symbols, where the last two series are proxies for the market and the riskless asset:

```
Assets(1:7)
Assets(8:14)

ans =

  'AAPL'    'AMZN'    'CSCO'    'DELL'    'EBAY'    'GOOG'    'HPQ'

ans =

  'IBM'    'INTC'    'MSFT'    'ORCL'    'YHOO'    'MARKET'    'CASH'
```

The data covers the period from January 1, 2000 to November 7, 2005 with daily total returns. Two stocks in this universe have missing values that are represented by `NaNs`. One of the two stocks had an IPO during this period and, consequently, has significantly less data than the other stocks.

2 Compute separate regressions for each stock, where the stocks with missing data will have estimates that reflect their reduced observability.

```
[NumSamples, NumSeries] = size(Data);
NumAssets = NumSeries - 2;

StartDate = Dates(1);
EndDate = Dates(end);

fprintf(1,'Separate regressions with ');
fprintf(1,'daily total return data from %s to %s ...\n', ...
    datestr(StartDate,1),datestr(EndDate,1));
```

```
fprintf(1,'  %4s %-20s %-20s %-20s\n','','Alpha','Beta','Sigma');
fprintf(1,'  ---- -------------------- ');
fprintf(1,'-------------------- --------------------\n');

for i = 1:NumAssets
% Set up separate asset data and design matrices
  TestData = zeros(NumSamples,1);
  TestDesign = zeros(NumSamples,2);

  TestData(:) = Data(:,i) - Data(:,14);
  TestDesign(:,1) = 1.0;
  TestDesign(:,2) = Data(:,13) - Data(:,14);

% Estimate CAPM for each asset separately
  [Param, Covar] = ecmmvnrmle(TestData, TestDesign);

 % Estimate ideal standard errors for covariance parameters
  [StdParam, StdCovar] = ecmmvnrstd(TestData, TestDesign, ...
      Covar, 'fisher');

% Estimate sample standard errors for model parameters
  StdParam = ecmmvnrstd(TestData, TestDesign, Covar, 'hessian');

% Set up results for output
  Alpha = Param(1);
  Beta = Param(2);
  Sigma = sqrt(Covar);

  StdAlpha = StdParam(1);
  StdBeta = StdParam(2);
  StdSigma = sqrt(StdCovar);

% Display estimates
  fprintf('  %4s %9.4f (%8.4f) %9.4f (%8.4f) %9.4f (%8.4f)\n', ...
     Assets{i},Alpha(1),abs(Alpha(1)/StdAlpha(1)), ...
     Beta(1),abs(Beta(1)/StdBeta(1)),Sigma(1),StdSigma(1));
end
```

This code fragment generates the following table.

```
Separate regressions with daily total return data from 03-Jan-2000
to 07-Nov-2005 ...
      Alpha                Beta                 Sigma
-------------------- -------------------- --------------------
AAPL    0.0012 (  1.3882)    1.2294 ( 17.1839)    0.0322 (  0.0062)
AMZN    0.0006 (  0.5326)    1.3661 ( 13.6579)    0.0449 (  0.0086)
CSCO   -0.0002 (  0.2878)    1.5653 ( 23.6085)    0.0298 (  0.0057)
DELL   -0.0000 (  0.0368)    1.2594 ( 22.2164)    0.0255 (  0.0049)
EBAY    0.0014 (  1.4326)    1.3441 ( 16.0732)    0.0376 (  0.0072)
GOOG    0.0046 (  3.2107)    0.3742 (  1.7328)    0.0252 (  0.0071)
HPQ     0.0001 (  0.1747)    1.3745 ( 24.2390)    0.0255 (  0.0049)
IBM    -0.0000 (  0.0312)    1.0807 ( 28.7576)    0.0169 (  0.0032)
INTC    0.0001 (  0.1608)    1.6002 ( 27.3684)    0.0263 (  0.0050)
MSFT   -0.0002 (  0.4871)    1.1765 ( 27.4554)    0.0193 (  0.0037)
ORCL    0.0000 (  0.0389)    1.5010 ( 21.1855)    0.0319 (  0.0061)
YHOO    0.0001 (  0.1282)    1.6543 ( 19.3838)    0.0384 (  0.0074)
```

The `Alpha` column contains alpha estimates for each stock that are near zero as expected. In addition, the t-statistics (which are enclosed in parentheses) generally reject the hypothesis that the alphas are nonzero at the 99.5% level of significance.

The `Beta` column contains beta estimates for each stock that also have t-statistics enclosed in parentheses. For all stocks but GOOG, the hypothesis that the betas are nonzero is accepted at the 99.5% level of significance. It seems, however, that GOOG does not have enough data to obtain a meaningful estimate for beta since its t-statistic would imply rejection of the hypothesis of a nonzero beta.

The `Sigma` column contains residual standard deviations, that is, estimates for nonsystematic risks. Instead of t-statistics, the associated standard errors for the residual standard deviations are enclosed in parentheses.

Grouped Estimation of Some Technology Stock Betas

To estimate stock betas for all 12 stocks, set up a joint regression model that groups all 12 stocks within a single design. (Since each stock has the same design matrix, this model is actually an example of seemingly unrelated regression.) The routine to estimate model parameters is `ecmmvnrmle`, and the routine to estimate standard errors is `ecmmvnrstd`.

Because GOOG has a significant number of missing values, a direct use of the missing data routine `ecmmvnrmle` takes 482 iterations to converge. This can take a long time to compute. For the sake of brevity, the parameter and covariance estimates after the first 480 iterations are contained in a MAT-file and are used as initial estimates to compute stock betas.

```
load CAPMgroupparam
whos Param0 Covar0

Name         Size                    Bytes  Class

Covar0      12x12                     1152  double array
Param0      24x1                       192  double array

Grand total is 168 elements using 1344 bytes
```

Now estimate the parameters for the collection of 12 stocks.

```
fprintf(1,'\n');
fprintf(1,'Grouped regression with ');
fprintf(1,'daily total return data from %s to %s ...\n', ...
    datestr(StartDate,1),datestr(EndDate,1));
fprintf(1,'  %4s %-20s %-20s %-20s\n','','Alpha','Beta','Sigma');
fprintf(1,'  ---- -------------------- ');
fprintf(1,'-------------------- --------------------\n');

NumParams = 2 * NumAssets;

% Set up grouped asset data and design matrices
TestData = zeros(NumSamples, NumAssets);
TestDesign = cell(NumSamples, 1);
Design = zeros(NumAssets, NumParams);

for k = 1:NumSamples
    for i = 1:NumAssets
        TestData(k,i) = Data(k,i) - Data(k,14);
        Design(i,2*i - 1) = 1.0;
        Design(i,2*i) = Data(k,13) - Data(k,14);
    end
    TestDesign{k} = Design;
```

```
end

% Estimate CAPM for all assets together with initial parameter
% estimates
[Param, Covar] = ecmmvnrmle(TestData, TestDesign, [], [], [],...
    Param0, Covar0);

% Estimate ideal standard errors for covariance parameters
[StdParam, StdCovar] = ecmmvnrstd(TestData, TestDesign, Covar,...
    'fisher');

% Estimate sample standard errors for model parameters
StdParam = ecmmvnrstd(TestData, TestDesign, Covar, 'hessian');

% Set up results for output
Alpha = Param(1:2:end-1);
Beta = Param(2:2:end);
Sigma = sqrt(diag(Covar));

StdAlpha = StdParam(1:2:end-1);
StdBeta = StdParam(2:2:end);
StdSigma = sqrt(diag(StdCovar));

% Display estimates
for i = 1:NumAssets
  fprintf('  %4s %9.4f (%8.4f) %9.4f (%8.4f) %9.4f (%8.4f)\n', ...
  Assets{i},Alpha(i),abs(Alpha(i)/StdAlpha(i)), ...
  Beta(i),abs(Beta(i)/StdBeta(i)),Sigma(i),StdSigma(i));
end
```

This code fragment generates the following table.

```
Grouped regression with daily total return data from 03-Jan-2000
to 07-Nov-2005 ...
       Alpha                 Beta              Sigma
---------------------- ---------------------------------------
AAPL    0.0012 (  1.3882)    1.2294 ( 17.1839)    0.0322 (  0.0062)
AMZN    0.0007 (  0.6086)    1.3673 ( 13.6427)    0.0450 (  0.0086)
CSCO   -0.0002 (  0.2878)    1.5653 ( 23.6085)    0.0298 (  0.0057)
DELL   -0.0000 (  0.0368)    1.2594 ( 22.2164)    0.0255 (  0.0049)
```

```
EBAY    0.0014 (  1.4326)    1.3441 ( 16.0732)    0.0376 (  0.0072)
GOOG    0.0041 (  2.8907)    0.6173 (  3.1100)    0.0337 (  0.0065)
HPQ     0.0001 (  0.1747)    1.3745 ( 24.2390)    0.0255 (  0.0049)
IBM    -0.0000 (  0.0312)    1.0807 ( 28.7576)    0.0169 (  0.0032)
INTC    0.0001 (  0.1608)    1.6002 ( 27.3684)    0.0263 (  0.0050)
MSFT   -0.0002 (  0.4871)    1.1765 ( 27.4554)    0.0193 (  0.0037)
ORCL    0.0000 (  0.0389)    1.5010 ( 21.1855)    0.0319 (  0.0061)
YHOO    0.0001 (  0.1282)    1.6543 ( 19.3838)    0.0384 (  0.0074)
```

Although the results for complete-data stocks are the same, note that the beta estimates for AMZN and GOOG (the two stocks with missing values) are different from the estimates derived for each stock separately. Since AMZN has few missing values, the differences in the estimates are small. With GOOG, however, the differences are more pronounced.

The t-statistic for the beta estimate of GOOG is now significant at the 99.5% level of significance. Note, however, that the t-statistics for beta estimates are based on standard errors from the sample Hessian which, in contrast to the Fisher information matrix, accounts for the increased uncertainty in an estimate due to missing values. If the t-statistic is obtained from the more optimistic Fisher information matrix, the t-statistic for GOOG is 8.25. Thus, despite the increase in uncertainty due to missing data, GOOG nonetheless has a statistically significant estimate for beta.

Finally, note that the beta estimate for GOOG is 0.62 —a value that may require some explanation. Although the market has been volatile over this period with sideways price movements, GOOG has steadily appreciated in value. Consequently, it is less tightly correlated with the market, implying that it is less volatile than the market (beta < 1).

References

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6

Solving Sample Problems

- "Introduction" on page 6-2
- "Common Problems in Finance" on page 6-3
- "Producing Graphics with the Toolbox" on page 6-21

Introduction

This section shows how Financial Toolbox functions solve real-world problems. The examples ship with the toolbox as M-files. Try them by entering the commands directly or by executing the M-files.

This chapter contains two major topics:

- "Common Problems in Finance" on page 6-3

  Shows how the toolbox solves real-world financial problems, specifically:

  - "Sensitivity of Bond Prices to Changes in Interest Rates" on page 6-3
  - "Constructing a Bond Portfolio to Hedge Against Duration and Convexity" on page 6-6
  - "Sensitivity of Bond Prices to Parallel Shifts in the Yield Curve" on page 6-9
  - "Constructing Greek-Neutral Portfolios of European Stock Options" on page 6-14
  - "Term Structure Analysis and Interest Rate Swap Pricing" on page 6-18
- "Producing Graphics with the Toolbox" on page 6-21

  Shows how the toolbox produces presentation-quality graphics by solving these problems:

  - "Plotting an Efficient Frontier" on page 6-21
  - "Plotting Sensitivities of an Option" on page 6-24
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Common Problems in Finance

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Sensitivity of Bond Prices to Changes in Interest Rates

Macaulay and *modified duration* measure the sensitivity of a bond's price to changes in the level of interest rates. *Convexity* measures the change in duration for small shifts in the yield curve, and thus measures the second-order price sensitivity of a bond. Both measures can gauge the vulnerability of a bond portfolio's value to changes in the level of interest rates.

Alternatively, analysts can use duration and convexity to construct a bond portfolio that is partly hedged against small shifts in the term structure. If you combine bonds in a portfolio whose duration is zero, the portfolio is insulated, to some extent, against interest rate changes. If the portfolio convexity is also zero, this insulation is even better. However, since hedging costs money or reduces expected return, you need to know how much protection results from hedging duration alone compared to hedging both duration and convexity.

This example demonstrates a way to analyze the relative importance of duration and convexity for a bond portfolio using some of the SIA-compliant bond functions in Financial Toolbox software. Using duration, it constructs a first-order approximation of the change in portfolio price to a level shift in interest rates. Then, using convexity, it calculates a second-order approximation. Finally, it compares the two approximations with the true

price change resulting from a change in the yield curve. The example M-file is `ftspex1.m`.

Step 1. Define three bonds using values for the settlement date, maturity date, face value, and coupon rate. For simplicity, accept default values for the coupon payment periodicity (semiannual), end-of-month payment rule (rule in effect), and day-count basis (actual/actual). Also, synchronize the coupon payment structure to the maturity date (no odd first or last coupon dates). Any inputs for which defaults are accepted are set to empty matrices (`[]`) as placeholders where appropriate.

```
Settle     = '19-Aug-1999';
Maturity   = ['17-Jun-2010'; '09-Jun-2015'; '14-May-2025'];
Face       = [100; 100; 1000];
CouponRate = [0.07; 0.06; 0.045];
```

Also, specify the yield curve information.

```
Yields = [0.05; 0.06; 0.065];
```

Step 2. Use Financial Toolbox functions to calculate the price, modified duration in years, and convexity in years of each bond.

The true price is quoted (clean) price plus accrued interest.

```
[CleanPrice, AccruedInterest] = bndprice(Yields, CouponRate,...
Settle, Maturity, 2, 0, [], [], [], [], [], Face);

Durations = bnddury(Yields, CouponRate, Settle, Maturity, 2, 0,...
[], [], [], [], [], Face);

Convexities = bndconvy(Yields, CouponRate, Settle, Maturity, 2, 0,...
[], [], [], [], [], Face);

Prices  =  CleanPrice + AccruedInterest;
```

Step 3. Choose a hypothetical amount by which to shift the yield curve (here, 0.2 percentage point or 20 basis points).

```
dY = 0.002;
```

Weight the three bonds equally, and calculate the actual quantity of each bond in the portfolio, which has a total value of $100,000.

```
PortfolioPrice   = 100000;
PortfolioWeights = ones(3,1)/3;
PortfolioAmounts = PortfolioPrice * PortfolioWeights ./ Prices;
```

Step 4. Calculate the modified duration and convexity of the portfolio. Note that the portfolio duration or convextity is a weighted average of the durations or convexities of the individual bonds. Calculate the first- and second-order approximations of the percent price change as a function of the change in the level of interest rates.

```
PortfolioDuration  = PortfolioWeights' * Durations;
PortfolioConvexity = PortfolioWeights' * Convexities;
PercentApprox1 = -PortfolioDuration * dY * 100;

PercentApprox2 =  PercentApprox1 + ...
PortfolioConvexity*dY^2*100/2.0;
```

Step 5. Estimate the new portfolio price using the two estimates for the percent price change.

```
PriceApprox1  =  PortfolioPrice + ...
PercentApprox1 * PortfolioPrice/100;

PriceApprox2  =  PortfolioPrice + ...
PercentApprox2 * PortfolioPrice/100;
```

Step 6. Calculate the true new portfolio price by shifting the yield curve.

```
[CleanPrice, AccruedInterest] = bndprice(Yields + dY,...
CouponRate, Settle, Maturity, 2, 0, [], [], [], [], [],...
Face);

NewPrice = PortfolioAmounts' * (CleanPrice + AccruedInterest);
```

Step 7. Compare the results. The analysis results are as follows (verify these results by running the example M-file `ftspex1.m`):

- The original portfolio price was $100,000.

- The yield curve shifted up by 0.2 percentage point or 20 basis points.
- The portfolio duration and convexity are 10.3181 and 157.6346, respectively. These will be needed for "Constructing a Bond Portfolio to Hedge Against Duration and Convexity" on page 6-6.
- The first-order approximation, based on modified duration, predicts the new portfolio price (`PriceApprox1`) will be $97,936.37.
- The second-order approximation, based on duration and convexity, predicts the new portfolio price (`PriceApprox2`) will be $97,967.90.
- The true new portfolio price (`NewPrice`) for this yield curve shift is $97,967.51.
- The estimate using duration and convexity is quite good (at least for this fairly small shift in the yield curve), but only slightly better than the estimate using duration alone. The importance of convexity increases as the magnitude of the yield curve shift increases. Try a larger shift (`dY`) to see this effect.

The approximation formulas in this example consider only parallel shifts in the term structure, because both formulas are functions of `dY`, the change in yield. The formulas are not well-defined unless each yield changes by the same amount. In actual financial markets, changes in yield curve level typically explain a substantial portion of bond price movements. However, other changes in the yield curve, such as slope, may also be important and are not captured here. Also, both formulas give local approximations whose accuracy deteriorates as `dY` increases in size. You can demonstrate this by running the program with larger values of `dY`.

Constructing a Bond Portfolio to Hedge Against Duration and Convexity

This example constructs a bond portfolio to hedge the portfolio of "Sensitivity of Bond Prices to Changes in Interest Rates" on page 6-3 It assumes a long position in (holding) the portfolio, and that three other bonds are available for hedging. It chooses weights for these three other bonds in a new portfolio so that the duration and convexity of the new portfolio match those of the original portfolio. Taking a short position in the new portfolio, in an amount equal to the value of the first portfolio, partially hedges against parallel shifts in the yield curve.

Recall that portfolio duration or convexity is a weighted average of the durations or convexities of the individual bonds in a portfolio. As in the previous example, this example uses modified duration in years and convexity in years. The hedging problem therefore becomes one of solving a system of linear equations, which is an easy to do in MATLAB software. The M-file for this example is `ftspex2.m`.

Step 1. Define three bonds available for hedging the original portfolio. Specify values for the settlement date, maturity date, face value, and coupon rate. For simplicity, accept default values for the coupon payment periodicity (semiannual), end-of-month payment rule (rule in effect), and day-count basis (actual/actual). Also, synchronize the coupon payment structure to the maturity date (that is, no odd first or last coupon dates). Set any inputs for which defaults are accepted to empty matrices (`[]`) as placeholders where appropriate. The intent is to hedge against duration and convexity and constrain total portfolio price.

```
Settle     = '19-Aug-1999';
Maturity   = ['15-Jun-2005'; '02-Oct-2010'; '01-Mar-2025'];
Face       = [500; 1000; 250];
CouponRate = [0.07; 0.066; 0.08];
```

Also, specify the yield curve for each bond.

```
Yields = [0.06; 0.07; 0.075];
```

Step 2. Use Financial Toolbox functions to calculate the price, modified duration in years, and convexity in years of each bond.

The true price is quoted (clean price plus accrued interest.

```
[CleanPrice, AccruedInterest] = bndprice(Yields,CouponRate,...
Settle, Maturity, 2, 0, [], [], [], [], [], Face);

Durations = bnddury(Yields, CouponRate, Settle, Maturity,...
2, 0, [], [], [], [], [], Face);

Convexities = bndconvy(Yields, CouponRate, Settle,...
Maturity, 2, 0, [], [], [], [], [], Face);

Prices  =  CleanPrice + AccruedInterest;
```

Step 3. Set up and solve the system of linear equations whose solution is the weights of the new bonds in a new portfolio with the same duration and convexity as the original portfolio. In addition, scale the weights to sum to 1; that is, force them to be portfolio weights. You can then scale this unit portfolio to have the same price as the original portfolio. Recall that the original portfolio duration and convexity are 10.3181 and 157.6346, respectively. Also, note that the last row of the linear system ensures that the sum of the weights is unity.

```
A = [Durations'
     Convexities'
     1 1 1];

b = [ 10.3181
     157.6346
       1];

Weights = A\b;
```

Step 4. Compute the duration and convexity of the hedge portfolio, which should now match the original portfolio.

```
PortfolioDuration  = Weights' * Durations;
PortfolioConvexity = Weights' * Convexities;
```

Step 5. Finally, scale the unit portfolio to match the value of the original portfolio and find the number of bonds required to insulate against small parallel shifts in the yield curve.

```
PortfolioValue = 100000;
HedgeAmounts   = Weights ./ Prices * PortfolioValue;
```

Step 6. Compare the results. (Verify the analysis results by running the example M-file ftspex2.m.)

- As required, the duration and convexity of the new portfolio are 10.3181 and 157.6346, respectively.
- The hedge amounts for bonds 1, 2, and 3 are -57.37, 71.70, and 216.27, respectively.

Notice that the hedge matches the duration, convexity, and value ($100,000) of the original portfolio. If you are holding that first portfolio, you can hedge by taking a short position in the new portfolio.

Just as the approximations of the first example are appropriate only for small parallel shifts in the yield curve, the hedge portfolio is appropriate only for reducing the impact of small level changes in the term structure.

Sensitivity of Bond Prices to Parallel Shifts in the Yield Curve

Often bond portfolio managers want to consider more than just the sensitivity of a portfolio's price to a small shift in the yield curve, particularly if the investment horizon is long. This example shows how MATLAB software can help you to visualize the price behavior of a portfolio of bonds over a wide range of yield curve scenarios, and as time progresses toward maturity.

This example uses Financial Toolbox bond pricing functions to evaluate the impact of time-to-maturity and yield variation on the price of a bond portfolio. It plots the portfolio value and shows the behavior of bond prices as yield and time vary. This example M-file is `ftspex3.m`.

Step 1. Specify values for the settlement date, maturity date, face value, coupon rate, and coupon payment periodicity of a four-bond portfolio. For simplicity, accept default values for the end-of-month payment rule (rule in effect) and day-count basis (actual/actual). Also, synchronize the coupon payment structure to the maturity date (no odd first or last coupon dates). Any inputs for which defaults are accepted are set to empty matrices (`[]`) as placeholders where appropriate.

```
Settle     = '15-Jan-1995';
Maturity   = datenum(['03-Apr-2020'; '14-May-2025'; ...
                      '09-Jun-2019'; '25-Feb-2019']);
Face       = [1000; 1000; 1000; 1000];
CouponRate = [0; 0.05; 0; 0.055];
Periods    = [0; 2; 0; 2];
```

Also, specify the points on the yield curve for each bond.

```
Yields = [0.078; 0.09; 0.075; 0.085];
```

Step 2. Use Financial Toolbox functions to calculate the true bond prices as the sum of the quoted price plus accrued interest.

```
[CleanPrice, AccruedInterest] = bndprice(Yields,...
CouponRate,Settle, Maturity, Periods,...
[], [], [], [], [], [], Face);

Prices  =  CleanPrice + AccruedInterest;
```

Step 3. Assume the value of each bond is $25,000, and determine the quantity of each bond such that the portfolio value is $100,000.

```
BondAmounts = 25000 ./ Prices;
```

Step 4. Compute the portfolio price for a rolling series of settlement dates over a range of yields. The evaluation dates occur annually on January 15, beginning on 15-Jan-1995 (settlement) and extending out to 15-Jan-2018. Thus, this step evaluates portfolio price on a grid of time of progression (`dT`) and interest rates (`dY`).

```
dy = -0.05:0.005:0.05;               % Yield changes

D  = datevec(Settle);                % Get date components
dt = datenum(D(1):2018, D(2), D(3)); % Get evaluation dates

[dT, dY]  =  meshgrid(dt, dy); % Create grid

NumTimes  =  length(dt);       % Number of time steps
NumYields =  length(dy);       % Number of yield changes
NumBonds  =  length(Maturity); % Number of bonds

% Preallocate vector
Prices = zeros(NumTimes*NumYields, NumBonds);
```

Now that the grid and price vectors have been created, compute the price of each bond in the portfolio on the grid one bond at a time.

```
for i = 1:NumBonds

   [CleanPrice, AccruedInterest] = bndprice(Yields(i)+...
```

```
    dY(:), CouponRate(i), dT(:), Maturity(i), Periods(i),...
    [], [], [], [], [], [], Face(i));

    Prices(:,i) = CleanPrice + AccruedInterest;

end
```

Scale the bond prices by the quantity of bonds.

```
Prices = Prices * BondAmounts;
```

Reshape the bond values to conform to the underlying evaluation grid.

```
Prices = reshape(Prices, NumYields, NumTimes);
```

Step 5. Plot the price of the portfolio as a function of settlement date and a range of yields, and as a function of the change in yield (`dY`). This plot illustrates the interest rate sensitivity of the portfolio as time progresses (`dT`), under a range of interest rate scenarios. With the following graphics commands, you can visualize the three-dimensional surface relative to the current portfolio value (that is, $100,000).

```
figure                    % Open a new figure window
surf(dt, dy, Prices)      % Draw the surface
```

Add the base portfolio value to the existing surface plot.

```
hold on                   % Add the current value for reference
basemesh = mesh(dt, dy, 100000*ones(NumYields, NumTimes));
```

Make it transparent, plot it so the price surface shows through, and draw a box around the plot.

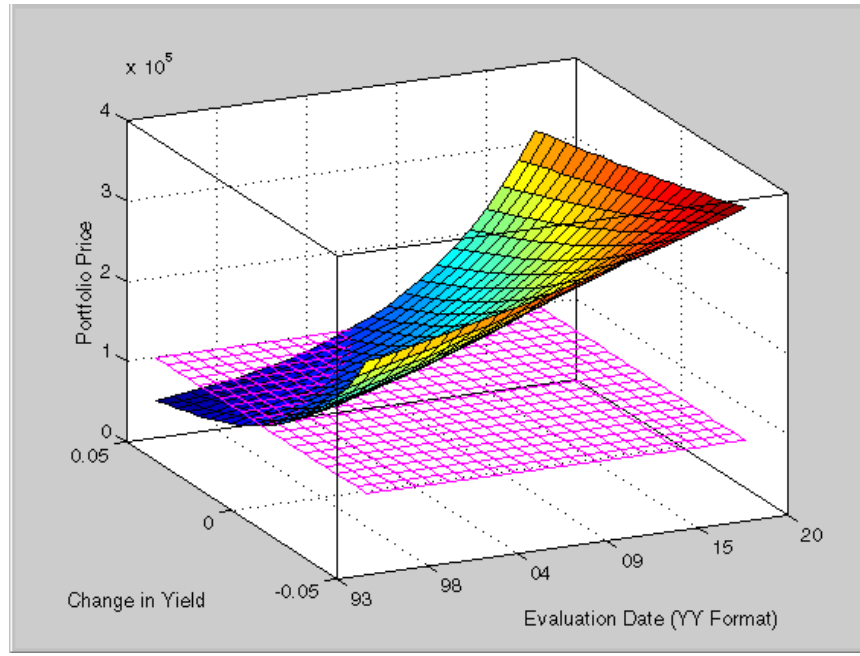
```
set(basemesh, 'facecolor', 'none');
set(basemesh, 'edgecolor', 'm');
set(gca, 'box', 'on');
```

Plot the *x*-axis using two-digit year (YY format) labels for ticks.

```
dateaxis('x', 11);
```

Add axis labels and set the three-dimensional viewpoint. MATLAB produces the figure.

```
xlabel('Evaluation Date (YY Format)');
ylabel('Change in Yield');
zlabel('Portfolio Price');
hold off
view(-25,25);
```



MATLAB three-dimensional graphics allow you to visualize the interest rate risk experienced by a bond portfolio over time. This example assumed parallel shifts in the term structure, but it might similarly have allowed other components to vary, such as the level and slope.

Sensitivity of Bond Prices to Nonparallel Shifts in the Yield Curve

Key rate duration enables you to determine the sensitivity of the price of a bond to nonparallel shifts in the yield curve. This example uses `bndkrdur` to

construct a portfolio to hedge the interest rate risk of a U.S. Treasury bond maturing in 20 years. For more information on this bond, see .

```
Settle = datenum('2-Dec-2008');
CouponRate = 5.500/100;
Maturity = datenum('15-Aug-2028');
Price = 128.68;
```

The interest rate risk of this bond is hedged with the following four on-the-run Treasury bonds:

The 30-year bond. For more information, see .

```
Maturity_30 = datenum('15-May-2038');
Coupon_30 = .045;
Price_30 = 124.69;
```

The ten-year note. For more information, see .

```
Maturity_10 = datenum('15-Nov-2018');
Coupon_10 = .0375;
Price_10 = 109.35;
```

The five-year note. For more information, see .

```
Maturity_05 = datenum('30-Nov-2013');
Coupon_05 = .02;
Price_05 = 101.67;
```

The two-year note. For more information, see .

```
Maturity_02 = datenum('30-Nov-2010');
Coupon_02 = .01250;
Price_02 =  100.72;
```

You can get the Treasury spot or zero curve from: .

```
ZeroDates = daysadd(Settle,[30 90 180 360 360*2 360*3 360*5 ...
360*7 360*10 360*20 360*30]);
ZeroRates = ([0.09 0.07 0.44 0.81 0.90 1.16 1.71 2.13 2.72 3.51 3.22]/100)';
```

Step 1. Compute the key rate durations for both the bond and the hedging portfolio:

```
BondKRD = bndkrdur([ZeroDates ZeroRates], CouponRate, Settle,...
Maturity,'keyrates',[2 5 10 20]);
HedgeMaturity = [Maturity_02;Maturity_05;Maturity_10;Maturity_30];
HedgeCoupon = [Coupon_02;Coupon_05;Coupon_10;Coupon_30];
HedgeKRD = bndkrdur([ZeroDates ZeroRates], HedgeCoupon,...
Settle, HedgeMaturity, 'keyrates',[2 5 10 20]);
```

Step 2. Compute the dollar durations for each of the instruments and each of the key rates (assuming holding 100 bonds):

```
PortfolioDD = 100*Price* BondKRD;
HedgeDD = bsxfun(@times, HedgeKRD,[Price_30;Price_10;Price_05;Price_02]);
```

Step 3. Compute the number of bonds to sell short to obtain a key rate duration that is 0 for the entire portfolio:

```
NumBonds = PortfolioDD/HedgeDD;

NumBonds =

    3.8973    6.1596   23.0282   80.0522
```

These results indicate selling 4, 6, 23 and 80 bonds respectively of the 2-, 5-, 10-, and 30-year bonds achieves a portfolio that is neutral with respect to the 2-, 5-, 10-, and 30-year spot rates.

Constructing Greek-Neutral Portfolios of European Stock Options

The option sensitivity measures familiar to most option traders are often referred to as the *greeks*: *delta*, *gamma*, *vega*, *lambda*, *rho*, and *theta*. Delta is the price sensitivity of an option with respect to changes in the price of the underlying asset. It represents a first-order sensitivity measure analogous to duration in fixed income markets. Gamma is the sensitivity of an option's delta to changes in the price of the underlying asset, and represents a second-order price sensitivity analogous to convexity in fixed income markets. Vega is the price sensitivity of an option with respect to changes in the volatility of the underlying asset. See "Pricing and Analyzing

Equity Derivatives" on page 2-40 or the "Glossary" on page Glossary-1 for other definitions.

The greeks of a particular option are a function of the model used to price the option. However, given enough different options to work with, a trader can construct a portfolio with any desired values for its greeks. For example, to insulate the value of an option portfolio from small changes in the price of the underlying asset, one trader might construct an option portfolio whose delta is zero. Such a portfolio is then said to be "delta neutral." Another trader may want to protect an option portfolio from larger changes in the price of the underlying asset, and so might construct a portfolio whose delta and gamma are both zero. Such a portfolio is both delta and gamma neutral. A third trader may want to construct a portfolio insulated from small changes in the volatility of the underlying asset in addition to delta and gamma neutrality. Such a portfolio is then delta, gamma, and vega neutral.

Using the Black-Scholes model for European options, this example creates an equity option portfolio that is simultaneously delta, gamma, and vega neutral. The value of a particular greek of an option portfolio is a weighted average of the corresponding greek of each individual option. The weights are the quantity of each option in the portfolio. Hedging an option portfolio thus involves solving a system of linear equations, an easy process in MATLAB. This example M-file is `ftspex4.m`.

Step 1. Create an input data matrix to summarize the relevant information. Each row of the matrix contains the standard inputs to Financial Toolbox Black-Scholes suite of functions: column 1 contains the current price of the underlying stock; column 2 the strike price of each option; column 3 the time to-expiry of each option in years; column 4 the annualized stock price volatility; and column 5 the annualized dividend rate of the underlying asset. Note that rows 1 and 3 are data related to call options, while rows 2 and 4 are data related to put options.

```
DataMatrix = [100.000  100  0.2  0.3   0        % Call
              119.100  125  0.2  0.2   0.025    % Put
               87.200   85  0.1  0.23  0        % Call
              301.125  315  0.5  0.25  0.0333]  % Put
```

Also, assume the annualized risk-free rate is 10% and is constant for all maturities of interest.

```
RiskFreeRate = 0.10;
```

For clarity, assign each column of `DataMatrix` to a column vector whose name reflects the type of financial data in the column.

```
StockPrice   = DataMatrix(:,1);
StrikePrice  = DataMatrix(:,2);
ExpiryTime   = DataMatrix(:,3);
Volatility   = DataMatrix(:,4);
DividendRate = DataMatrix(:,5);
```

Step 2. Based on the Black-Scholes model, compute the prices, and the delta, gamma, and vega sensitivity greeks of each of the four options. Note that the functions `blsprice` and `blsdelta` have two outputs, while `blsgamma` and `blsvega` have only one. The price and delta of a call option differ from the price and delta of an otherwise equivalent put option, in contrast to the gamma and vega sensitivities, which are valid for both calls and puts.

```
[CallPrices, PutPrices] = blsprice(StockPrice, StrikePrice,...
RiskFreeRate, ExpiryTime, Volatility, DividendRate);

[CallDeltas, PutDeltas] = blsdelta(StockPrice,...
StrikePrice, RiskFreeRate, ExpiryTime, Volatility,...
DividendRate);

Gammas = blsgamma(StockPrice, StrikePrice, RiskFreeRate,...
                  ExpiryTime, Volatility , DividendRate)';

Vegas  = blsvega(StockPrice, StrikePrice, RiskFreeRate,...
                 ExpiryTime, Volatility , DividendRate)';
```

Extract the prices and deltas of interest to account for the distinction between call and puts.

```
Prices = [CallPrices(1) PutPrices(2) CallPrices(3)...
PutPrices(4)];

Deltas = [CallDeltas(1) PutDeltas(2) CallDeltas(3)...
PutDeltas(4)];
```

Step 3. Now, assuming an arbitrary portfolio value of $17,000, set up and solve the linear system of equations such that the overall option portfolio is simultaneously delta, gamma, and vega-neutral. The solution computes the value of a particular greek of a portfolio of options as a weighted average of the corresponding greek of each individual option in the portfolio. The system of equations is solved using the back slash (\) operator discussed in "Solving Simultaneous Linear Equations" on page 1-14.

```
A = [Deltas; Gammas; Vegas; Prices];
b = [0; 0; 0; 17000];
OptionQuantities = A\b; % Quantity (number) of each option.
```

Step 4. Finally, compute the market value, delta, gamma, and vega of the overall portfolio as a weighted average of the corresponding parameters of the component options. The weighted average is computed as an inner product of two vectors.

```
PortfolioValue =  Prices * OptionQuantities;
PortfolioDelta =  Deltas * OptionQuantities;
PortfolioGamma =  Gammas * OptionQuantities;
PortfolioVega  =  Vegas  * OptionQuantities;
```

The example `ftspex4.m` performs these computations and displays the output on the screen.

```
Option  Price    Delta    Gamma    Vega     Quantity
   1   6.3441   0.5856   0.0290  17.4293   22332.6131
   2   6.6035  -0.6255   0.0353  20.0347    6864.0731
   3   4.2993   0.7003   0.0548   9.5837  -15654.8657
   4  22.7694  -0.4830   0.0074  83.5225   -4510.5153

Portfolio Value: $17000.00
Portfolio Delta:      0.00
Portfolio Gamma:     -0.00
Portfolio Vega :      0.00
```

You can verify that the portfolio value is $17,000 and that the option portfolio is indeed delta, gamma, and vega neutral, as desired. Hedges based on these measures are effective only for small changes in the underlying variables.

Term Structure Analysis and Interest Rate Swap Pricing

This example illustrates some of the term-structure analysis functions found in Financial Toolbox software. Specifically, it illustrates how to derive implied zero (*spot*) and forward curves from the observed market prices of coupon-bearing bonds. The zero and forward curves implied from the market data are then used to price an interest rate swap agreement.

In an interest rate swap, two parties agree to a periodic exchange of cash flows. One of the cash flows is based on a fixed interest rate held constant throughout the life of the swap. The other cash flow stream is tied to some variable index rate. Pricing a swap at inception amounts to finding the fixed rate of the swap agreement. This fixed rate, appropriately scaled by the notional principal of the swap agreement, determines the periodic sequence of fixed cash flows.

In general, interest rate swaps are priced from the forward curve such that the variable cash flows implied from the series of forward rates and the periodic sequence of fixed-rate cash flows have the same current value. Thus, interest rate swap pricing and term structure analysis are intimately related.

Step 1. Specify values for the settlement date, maturity dates, coupon rates, and market prices for 10 U.S. Treasury Bonds. This data allows you to price a five-year swap with net cash flow payments exchanged every six months. For simplicity, accept default values for the end-of-month payment rule (rule in effect) and day-count basis (actual/actual). To avoid issues of accrued interest, assume that all Treasury Bonds pay semiannual coupons and that settlement occurs on a coupon payment date.

```
Settle   = datenum('15-Jan-1999');

BondData = {'15-Jul-1999'  0.06000   99.93
            '15-Jan-2000'  0.06125   99.72
            '15-Jul-2000'  0.06375   99.70
            '15-Jan-2001'  0.06500   99.40
            '15-Jul-2001'  0.06875   99.73
            '15-Jan-2002'  0.07000   99.42
            '15-Jul-2002'  0.07250   99.32
            '15-Jan-2003'  0.07375   98.45
            '15-Jul-2003'  0.07500   97.71
```

```
                '15-Jan-2004'  0.08000   98.15};
```

`BondData` is an instance of a MATLAB *cell array*, indicated by the curly braces ({}).

Next assign the date stored in the cell array to `Maturity`, `CouponRate`, and `Prices` vectors for further processing.

```
Maturity   = datenum(strvcat(BondData{:,1}));
CouponRate = [BondData{:,2}]';
Prices     = [BondData{:,3}]';
Period     = 2; % semiannual coupons
```

Step 2. Now that the data has been specified, use the term structure function `zbtprice` to bootstrap the zero curve implied from the prices of the coupon-bearing bonds. This implied zero curve represents the series of zero-coupon Treasury rates consistent with the prices of the coupon-bearing bonds such that arbitrage opportunities will not exist.

```
ZeroRates = zbtprice([Maturity CouponRate], Prices, Settle);
```

The zero curve, stored in `ZeroRates`, is quoted on a semiannual bond basis (the periodic, six-month, interest rate is doubled to annualize). The first element of `ZeroRates` is the annualized rate over the next six months, the second element is the annualized rate over the next 12 months, and so on.

Step 3. From the implied zero curve, find the corresponding series of implied forward rates using the term structure function `zero2fwd`.

```
ForwardRates = zero2fwd(ZeroRates, Maturity, Settle);
```

The forward curve, stored in `ForwardRates`, is also quoted on a semiannual bond basis. The first element of `ForwardRates` is the annualized rate applied to the interval between settlement and six months after settlement, the second element is the annualized rate applied to the interval from six months to 12 months after settlement, and so on. This implied forward curve is also consistent with the observed market prices such that arbitrage activities will be unprofitable. Since the first forward rate is also a zero rate, the first element of `ZeroRates` and `ForwardRates` are the same.

Step 4. Now that you have derived the zero curve, convert it to a sequence of discount factors with the term structure function `zero2disc`.

```
DiscountFactors = zero2disc(ZeroRates, Maturity, Settle);
```

Step 5. From the discount factors, compute the present value of the variable cash flows derived from the implied forward rates. For plain interest rate swaps, the notional principle remains constant for each payment date and cancels out of each side of the present value equation. The next line assumes unit notional principle.

```
PresentValue = sum((ForwardRates/Period) .* DiscountFactors);
```

Step 6. Compute the swap's price (the fixed rate) by equating the present value of the fixed cash flows with the present value of the cash flows derived from the implied forward rates. Again, since the notional principle cancels out of each side of the equation, it is simply assumed to be 1.

```
SwapFixedRate = Period * PresentValue / sum(DiscountFactors);
```

The example `ftspex5.m` performs these computations and displays the output on the screen.

```
Zero Rates  Forward Rates
  0.0614        0.0614
  0.0642        0.0670
  0.0660        0.0695
  0.0684        0.0758
  0.0702        0.0774
  0.0726        0.0846
  0.0754        0.0925
  0.0795        0.1077
  0.0827        0.1089
  0.0868        0.1239

Swap Price (Fixed Rate) = 0.0845
```

All rates are in decimal format. The swap price, 8.45%, would likely be the mid-point between a market-maker's bid/ask quotes.

Producing Graphics with the Toolbox

In this section...

"Introduction" on page 6-21

"Plotting an Efficient Frontier" on page 6-21

"Plotting Sensitivities of an Option" on page 6-24

"Plotting Sensitivities of a Portfolio of Options" on page 6-26

Introduction

Financial Toolbox and MATLAB graphics functions work together to produce presentation quality graphics, as these examples show. The examples ship with the toolbox as M-files. Try them by entering the commands directly or by executing the M-files. For help using MATLAB plotting functions, see "Creating Line Plots" in the MATLAB documentation.

Plotting an Efficient Frontier

This example plots the efficient frontier of a hypothetical portfolio of three assets. It illustrates how to specify the expected returns, standard deviations, and correlations of a portfolio of assets, how to convert standard deviations and correlations into a covariance matrix, and how to compute and plot the efficient frontier from the returns and covariance matrix. The example also illustrates how to randomly generate a set of portfolio weights, and how to add the random portfolios to an existing plot for comparison with the efficient frontier. The example M-file is `ftgex1.m`.

First, specify the expected returns, standard deviations, and correlation matrix for a hypothetical portfolio of three assets.

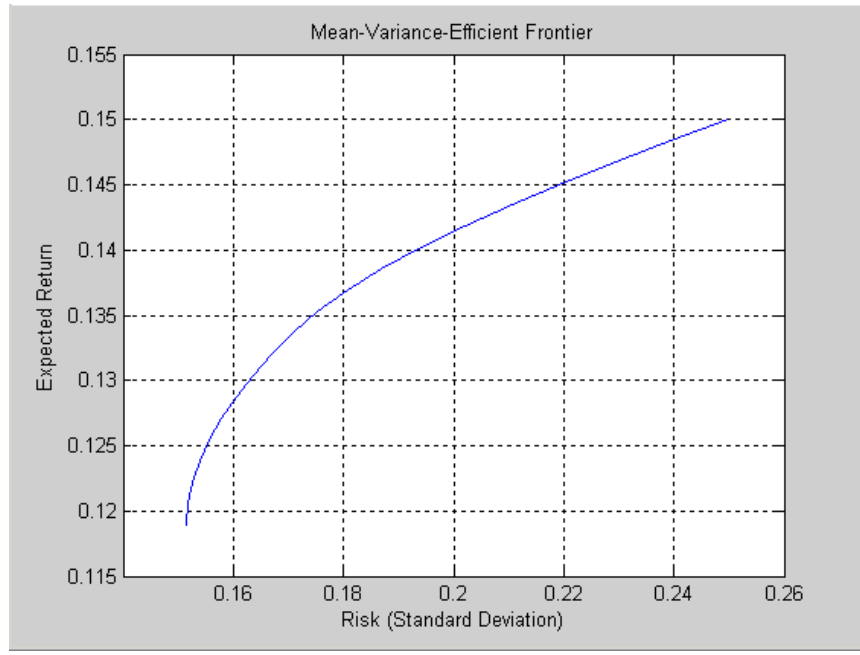
```
Returns      = [0.1 0.15 0.12];
STDs         = [0.2 0.25 0.18];

Correlations = [ 1  0.3  0.4
                 0.3  1   0.3
                 0.4 0.3   1 ];
```

Convert the standard deviations and correlation matrix into a variance-covariance matrix with the Financial Toolbox function `corr2cov`.

```
Covariances = corr2cov(STDs, Correlations);
```

Evaluate and plot the efficient frontier at 20 points along the frontier, using the function `portopt` and the expected returns and corresponding covariance matrix. Although rather elaborate constraints can be placed on the assets in a portfolio, for simplicity accept the default constraints and scale the total value of the portfolio to 1 and constrain the weights to be positive (no short-selling).

```
portopt(Returns, Covariances, 20)
```



Now that the efficient frontier is displayed, randomly generate the asset weights for 1000 portfolios starting from the MATLAB initial state.

```
rand('state', 0)
Weights = rand(1000, 3);
```

The previous line of code generates three columns of uniformly distributed random weights, but does not guarantee they sum to 1. The following code segment normalizes the weights of each portfolio so that the total of the three weights represent a valid portfolio.

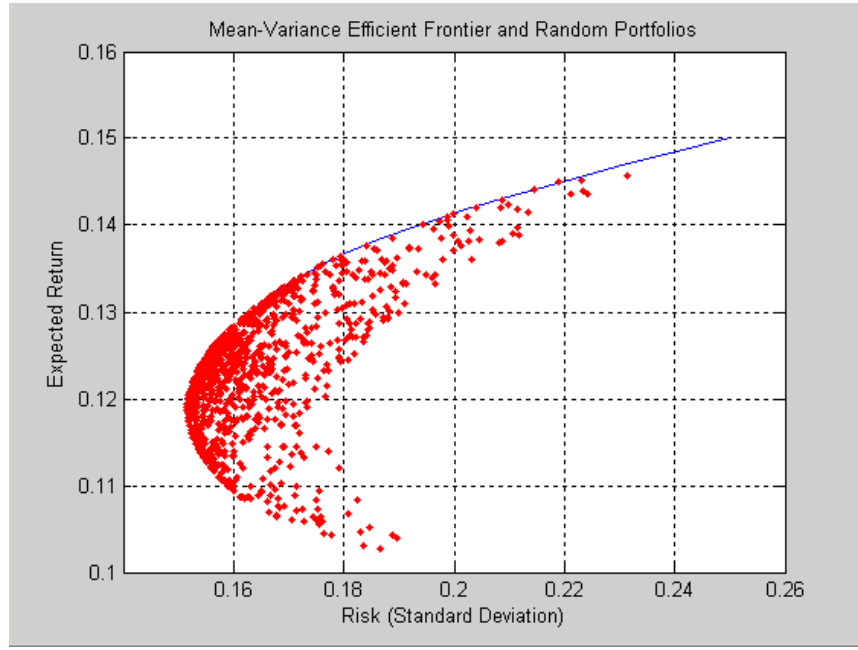
```
Total = sum(Weights, 2);     % Add the weights
Total = Total(:,ones(3,1));  % Make size-compatible matrix
Weights = Weights./Total;    % Normalize so sum = 1
```

Given the 1000 random portfolios just created, compute the expected return and risk of each portfolio associated with the weights.

```
[PortRisk, PortReturn] = portstats(Returns, Covariances, ...
                         Weights);
```

Finally, hold the current graph, and plot the returns and risks of each portfolio on top of the existing efficient frontier for comparison. After plotting, annotate the graph with a title and return the graph to default holding status (any subsequent plots will erase the existing data). The efficient frontier appears in blue, while the 1000 random portfolios appear as a set of red dots on or below the frontier.

```
hold on
plot (PortRisk, PortReturn, '.r')
title('Mean-Variance Efficient Frontier and Random Portfolios')
hold off
```



Plotting Sensitivities of an Option

This example creates a three-dimensional plot showing how gamma changes relative to price for a Black-Scholes option. Recall that gamma is the second derivative of the option price relative to the underlying security price. The plot shows a three-dimensional surface whose *z*-value is the gamma of an option as price (*x*-axis) and time (*y*-axis) vary. It adds yet a fourth dimension by showing option delta (the first derivative of option price to security price) as the color of the surface. This example M-file is `ftgex2.m`.

First set the price range of the options, and set the time range to one year divided into half-months and expressed as fractions of a year.

```
Range = 10:70;
Span = length(Range);
j = 1:0.5:12;
Newj = j(ones(Span,1),:)'/12;
```

For each time period create a vector of prices from 10 to 70 and create a matrix of all ones.

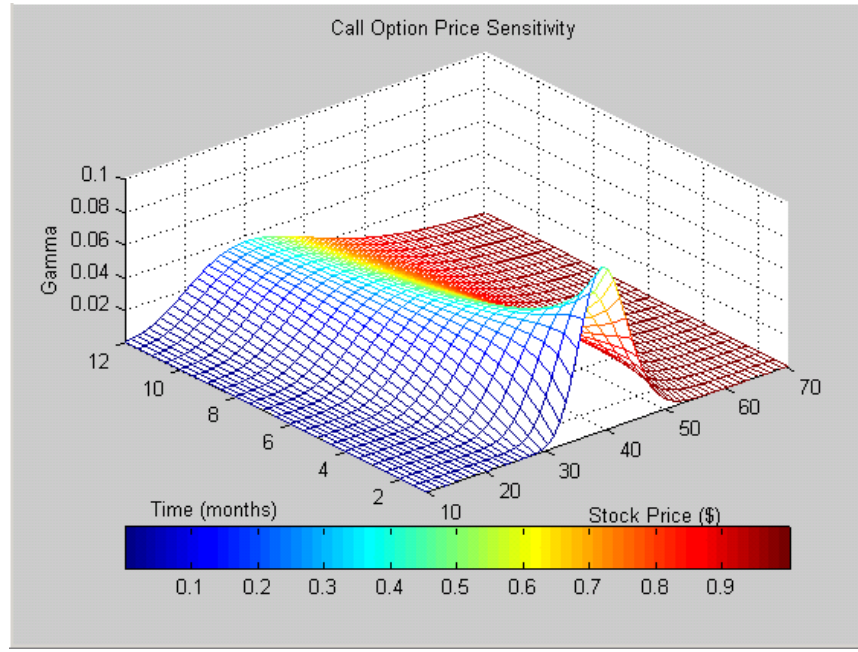
```
JSpan = ones(length(j),1);
NewRange = Range(JSpan,:);
Pad = ones(size(Newj));
```

Calculate the toolbox gamma and delta sensitivity functions (greeks). (Recall that gamma is the second derivative of the option price with respect to the stock price, and delta is the first derivative of the option price with respect to the stock price.) The exercise price is $40, the risk-free interest rate is 10%, and volatility is 0.35 for all prices and periods.

```
ZVal = blsgamma(NewRange, 40*Pad, 0.1*Pad, Newj, 0.35*Pad);
Color = blsdelta(NewRange, 40*Pad, 0.1*Pad, Newj, 0.35*Pad);
```

Display the greeks as a function of price and time. Gamma is the *z*-axis; delta is the color.

```
mesh(Range, j, ZVal, Color);
xlabel('Stock Price ($)');
ylabel('Time (months)');
zlabel('Gamma');
title('Call Option Price Sensitivity');
axis([10 70  1 12  -inf inf]);
view(-40, 50);
colorbar('horiz');
```



Plotting Sensitivities of a Portfolio of Options

This example plots gamma as a function of price and time for a portfolio of 10 Black-Scholes options. The plot shows a three-dimensional surface. For each point on the surface, the height (*z*-value) represents the sum of the gammas for each option in the portfolio weighted by the amount of each option. The *x*-axis represents changing price, and the *y*-axis represents time. The plot adds a fourth dimension by showing delta as surface color. This has applications in hedging.

This example M-file is `ftgex3.m`.

First set up the portfolio with arbitrary data. Current prices range from $20 to $90 for each option. Set corresponding exercise prices for each option.

```
Range = 20:90;
PLen = length(Range);
ExPrice = [75 70 50 55 75 50 40 75 60 35];
```

Set all risk-free interest rates to 10%, and set times to maturity in days. Set all volatilities to 0.35. Set the number of options of each instrument, and allocate space for matrices.

```
Rate = 0.1*ones(10,1);
Time = [36  36  36  27  18  18  18  9  9  9];
Sigma = 0.35*ones(10,1);
NumOpt = 1000*[4  8  3  5  5.5  2  4.8  3  4.8  2.5];
ZVal = zeros(36, PLen);
Color = zeros(36, PLen);
```

For each instrument, create a matrix (of size `Time` by `PLen`) of prices for each period.

```
for i = 1:10
    Pad = ones(Time(i),PLen);
    NewR = Range(ones(Time(i),1),:);
```

Create a vector of time periods `1` to `Time`; and a matrix of times, one column for each price.

```
    T = (1:Time(i))';
    NewT = T(:,ones(PLen,1));
```

Call the toolbox gamma and delta sensitivity functions to compute gamma and delta.

```
    ZVal(36-Time(i)+1:36,:) = ZVal(36-Time(i)+1:36,:) ...
        + NumOpt(i) * blsgamma(NewR, ExPrice(i)*Pad, ...
        Rate(i)*Pad, NewT/36, Sigma(i)*Pad);

    Color(36-Time(i)+1:36,:) = Color(36-Time(i)+1:36,:) ...
        + NumOpt(i) * blsdelta(NewR, ExPrice(i)*Pad, ...
        Rate(i)*Pad, NewT/36, Sigma(i)*Pad);
end
```

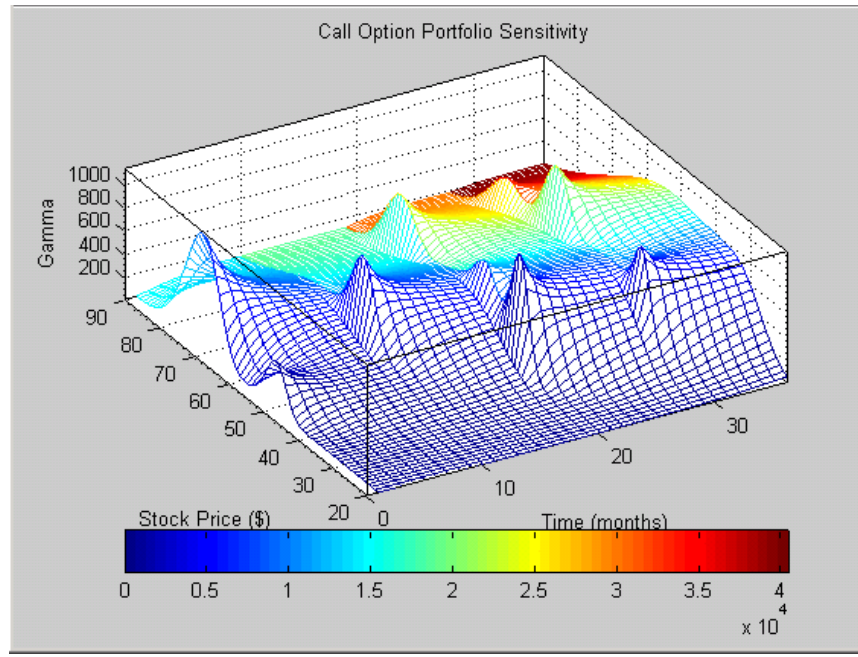
Draw the surface as a mesh, set the viewpoint, and reverse the *x*-axis because of the viewpoint. The axes range from 20 to 90, 0 to 36, and $-\infty$ to ∞.

```
mesh(Range, 1:36, ZVal, Color);
view(60,60);
```

```
set(gca, 'xdir','reverse', 'tag', 'mesh_axes_3');
axis([20 90  0 36  -inf inf]);
```

Add a title and axis labels and draw a box around the plot. Annotate the colors with a bar and label the colorbar.

```
title('Call Option Portfolio Sensitivity');
xlabel('Stock Price ($)');
ylabel('Time (months)');
zlabel('Gamma');
set(gca, 'box', 'on');
colorbar('horiz');
```



7

Financial Time Series Analysis

- "Analyzing Financial Time Series" on page 7-2
- "Creating Financial Time Series Objects" on page 7-3
- "Visualizing Financial Time Series Objects" on page 7-18

Analyzing Financial Time Series

Financial Toolbox software provides a collection of tools for the analysis of time series data in the financial markets. The toolbox contains a financial time series object constructor and several methods that operate on and analyze the object. Financial engineers working with time series data, such as equity prices or daily interest fluctuations, can use these tools for more intuitive data management than by using regular vectors or matrices.

This chapter discusses how to create a financial time series object in one of two ways:

- "Using the Constructor" on page 7-3
- "Transforming a Text File" on page 7-14

The chapter also discusses `chartfts`, a graphical tool for visualizing financial time series objects. You can find this discussion in "Visualizing Financial Time Series Objects" on page 7-18.

Creating Financial Time Series Objects

In this section...

"Introduction" on page 7-3

"Using the Constructor" on page 7-3

"Transforming a Text File" on page 7-14

Introduction

Financial Toolbox software provides two ways to create a financial time series object:

- At the command line using the object constructor `fints`
- From a text data file through the function `ascii2fts`

The structure of the object minimally consists of a description field, a frequency indicator field, the date vector field, and at least one data series vector. The names for the fields are fixed for the first three fields: `desc`, `freq`, and `dates`. You can specify names of your choice for any data series vectors. If you do not specify names, the object uses the default names `series1`, `series2`, `series3`, and so on.

If time-of-day information is incorporated in the date vector, the object contains an additional field named `times`.

Using the Constructor

The object constructor function `fints` has five different syntaxes. These forms exist to simplify object construction. The syntaxes vary according to the types of input arguments presented to the constructor. The syntaxes are

- Single Matrix Input
  - See "Time-of-Day Information Excluded" on page 7-4.
  - See "Time-of-Day Information Included" on page 7-7.
- Separate Vector Input

- See “Time-of-Day Information Excluded” on page 7-8.
- See “Time-of-Day Information Included” on page 7-9.

- See “Data Name Input” on page 7-10.
- See “Frequency Indicator Input” on page 7-12.
- See “Description Field Input” on page 7-14.

Single Matrix Input

The date information provided with this syntax must be in serial date number format. The date number may or may not include time-of-day information.

Note If you are unfamiliar with the concepts of date strings and serial date numbers, consult “Handling and Converting Dates” on page 2-4.

Time-of-Day Information Excluded.

```
fts = fints(dates_and_data)
```

In this simplest form of syntax, the input must be at least a two-column matrix. The first column contains the dates in serial date format; the second column is the data series. The input matrix can have more than two columns, each additional column representing a different data series or set of observations.

If the input is a two-column matrix, the output object contains four fields: `desc`, `freq`, `dates`, and `series1`. The description field, `desc`, defaults to blanks `''`, and the frequency indicator field, `freq`, defaults to `0`. The dates field, `dates`, contains the serial dates from the first column of the input matrix, while the data series field, `series1`, has the data from the second column of the input matrix.

The first example makes two financial time series objects. The first one has only one data series, while the other has more than one. A random vector provides the values for the data series. The range of dates is arbitrarily chosen using the `today` function:

```
date_series = (today:today+100)';
```

```
data_series = exp(randn(1, 101))';
dates_and_data = [date_series data_series];
fts1 = fints(dates_and_data);
```

Examine the contents of the object `fts1` create. The actual date series you observe will vary according to the day when you run the example (the value of `today`). Also, your values in `series1` will differ from those shown, depending upon the sequence of random numbers generated:

```
fts1 =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (101)'    'series1:  (101)'
    '12-Jul-1999'      [         0.3124]
    '13-Jul-1999'      [         3.2665]
    '14-Jul-1999'      [         0.9847]
    '15-Jul-1999'      [         1.7095]
    '16-Jul-1999'      [         0.4885]
    '17-Jul-1999'      [         0.5192]
    '18-Jul-1999'      [         1.3694]
    '19-Jul-1999'      [         1.1127]
    '20-Jul-1999'      [         6.3485]
    '21-Jul-1999'      [         0.7595]
    '22-Jul-1999'      [         9.1390]
    '23-Jul-1999'      [         4.5201]
    '24-Jul-1999'      [         0.1430]
    '25-Jul-1999'      [         0.1863]
    '26-Jul-1999'      [         0.5635]
    '27-Jul-1999'      [         0.8304]
    '28-Jul-1999'      [         1.0090]...
```

The output is truncated for brevity. There are actually 101 data points in the object.

Note that the `desc` field displays as `(none)` instead of `''`, and that the contents of the object display as cell array elements. Although the object displays as such, it should be thought of as a MATLAB structure containing the default field names for a single data series object: `desc`, `freq`, `dates`, and `series1`.

Now create an object with more than one data series in it:

```
date_series = (today:today+100)';
data_series1 = exp(randn(1, 101))';
data_series2 = exp(randn(1, 101))';
dates_and_data = [date_series data_series1 data_series2];
fts2 = fints(dates_and_data);
```

Now look at the object created (again in abbreviated form):

```
fts2 =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (101)'    'series1:  (101)'    'series2:  (101)'
    '12-Jul-1999'      [         0.5816]    [         1.2816]
    '13-Jul-1999'      [         5.1253]    [         0.9262]
    '14-Jul-1999'      [         2.2824]    [         5.6869]
    '15-Jul-1999'      [         1.2596]    [         5.0631]
    '16-Jul-1999'      [         1.9574]    [         1.8709]
    '17-Jul-1999'      [         0.6017]    [         1.0962]
    '18-Jul-1999'      [         2.3546]    [         0.4459]
    '19-Jul-1999'      [         1.3080]    [         0.6304]
    '20-Jul-1999'      [         1.8682]    [         0.2451]
    '21-Jul-1999'      [         0.3509]    [         0.6876]
    '22-Jul-1999'      [         4.6444]    [         0.6244]
    '23-Jul-1999'      [         1.5441]    [         5.7621]
    '24-Jul-1999'      [         0.1470]    [         2.1238]
    '25-Jul-1999'      [         1.5999]    [         1.0671]
    '26-Jul-1999'      [         3.5764]    [         0.7462]
    '27-Jul-1999'      [         1.8937]    [         1.0863]
    '28-Jul-1999'      [         3.9780]    [         2.1516]...
```

The second data series name defaults to `series2`, as expected.

Before you can perform any operations on the object, you must set the frequency indicator field `freq` to the valid frequency of the data series contained in the object. You can leave the description field `desc` blank.

To set the frequency indicator field to a daily frequency, enter

`fts2.freq = 1`, or

`fts2.freq = 'daily'`

See the `fints` function description in Chapter 13, "Function Reference" or Chapter 14, "Functions — Alphabetical List".

Time-of-Day Information Included. The serial date number used with this form of the `fints` function can incorporate time-of-day information. When time-of-day information is present, the output of the function contains a field `times` that indicates the time of day.

If you recode the previous example to include time-of-day information, you can see the additional column present in the output object:

```
time_series = (now:now+100)';
data_series = exp(randn(1, 101))';
times_and_data = [time_series data_series];
fts1 = fints(times_and_data);

fts1 =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (101)'    'times:  (101)'    'series1:  (101)'
    '29-Nov-2001'      '14:57'            [         0.5816]
    '30-Nov-2001'      '14:57'            [         5.1253]
    '01-Dec-2001'      '14:57'            [         2.2824]
    '02-Dec-2001'      '14:57'            [         1.2596]...
```

Separate Vector Input

The date information provided with this syntax can be in serial date number or date string format. The date information may or may not include time-of-day information.

Time-of-Day Information Excluded.

```
fts = fints(dates, data)
```

In this second syntax the dates and data series are entered as separate vectors to `fints`, the financial time series object constructor function. The `dates` vector must be a column vector, while the data series `data` can be a column vector (if there is only one data series) or a column-oriented matrix (for multiple data series). A column-oriented matrix, in this context, indicates that each column is a set of observations. Different columns are different sets of data series.

Here is an example:

```
dates = (today:today+100)';
data_series1 = exp(randn(1, 101))';
data_series2 = exp(randn(1, 101))';
data = [data_series1 data_series2];
fts = fints(dates, data)
fts =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (101)'    'series1:  (101)'    'series2:  (101)'
    '12-Jul-1999'      [         0.5816]    [         1.2816]
    '13-Jul-1999'      [         5.1253]    [         0.9262]
    '14-Jul-1999'      [         2.2824]    [         5.6869]
    '15-Jul-1999'      [         1.2596]    [         5.0631]
    '16-Jul-1999'      [         1.9574]    [         1.8709]
    '17-Jul-1999'      [         0.6017]    [         1.0962]
    '18-Jul-1999'      [         2.3546]    [         0.4459]
    '19-Jul-1999'      [         1.3080]    [         0.6304]
    '20-Jul-1999'      [         1.8682]    [         0.2451]
    '21-Jul-1999'      [         0.3509]    [         0.6876]
    '22-Jul-1999'      [         4.6444]    [         0.6244]
    '23-Jul-1999'      [         1.5441]    [         5.7621]
    '24-Jul-1999'      [         0.1470]    [         2.1238]
    '25-Jul-1999'      [         1.5999]    [         1.0671]
    '26-Jul-1999'      [         3.5764]    [         0.7462]
```

```
    '27-Jul-1999'      [          1.8937]    [          1.0863]
    '28-Jul-1999'      [          3.9780]    [          2.1516]...
```

The result is exactly the same as the first syntax. The only difference between the first and second syntax is the way the inputs are entered into the constructor function.

Time-of-Day Information Included. With this form of the function you can enter the time-of-day information either as a serial date number or as a date string. If more than one serial date and time are present, the entry must be in the form of a column-oriented matrix. If more than one string date and time are present, the entry must be a column-oriented cell array of dates and times.

With date string input the dates and times can initially be separate column-oriented date and time series, but you must concatenate them into a single column-oriented cell array before entering them as the first input to `fints`.

For date string input the allowable formats are

- `'ddmmmyy hh:mm'` or `'ddmmmyyyy hh:mm'`
- `'mm/dd/yy hh:mm'` or `'mm/dd/yyyy hh:mm'`
- `'dd-mmm-yy hh:mm'` or `'dd-mmm-yyyy hh:mm'`
- `'mmm.dd,yy hh:mm'` or `'mmm.dd,yyyy hh:mm'`

The next example shows time-of-day information input as serial date numbers in a column-oriented matrix:

```
f = fints([now;now+1],(1:2)')

f =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (2)'    'times:  (2)'    'series1:  (2)'
    '29-Nov-2001'    '15:22'          [            1]
    '30-Nov-2001'    '15:22'          [            2]
```

If the time-of-day information is in date string format, you must provide it to `fints` as a column-oriented cell array:

```
f = fints({'01-Jan-2001 12:00';'02-Jan-2001 12:00'},(1:2)')

f =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (2)'    'times:  (2)'    'series1:  (2)'
    '01-Jan-2001'    '12:00'          [            1]
    '02-Jan-2001'    '12:00'          [            2]
```

If the dates and times are in date string format and contained in separate matrices, you must concatenate them before using the date and time information as input to `fints`:

```
dates = ['01-Jan-2001'; '02-Jan-2001'; '03-Jan-2001'];
times = ['12:00';'12:00';'12:00'];
dates_time = cellstr([dates,repmat(' ',size(dates,1),1),times]);
f = fints(dates_time,(1:3)')

f =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (3)'    'times:  (3)'    'series1:  (3)'
    '01-Jan-2001'    '12:00'          [            1]
    '02-Jan-2001'    '12:00'          [            2]
    '03-Jan-2001'    '12:00'          [            3]
```

Data Name Input

```
fts = fints(dates, data, datanames)
```

The third syntax lets you specify the names for the data series with the argument `datanames`. The `datanames` argument can be a MATLAB string

for a single data series. For multiple data series names, it must be a cell array of strings.

Look at two examples, one with a single data series and a second with two. The first example sets the data series name to the specified name `First`:

```
dates = (today:today+100)';
data = exp(randn(1, 101))';
fts1 = fints(dates, data, 'First')

fts1 =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (101)'    'First:  (101)'
    '12-Jul-1999'      [       0.4615]
    '13-Jul-1999'      [       1.1640]
    '14-Jul-1999'      [       0.7140]
    '15-Jul-1999'      [       2.6400]
    '16-Jul-1999'      [       0.8983]
    '17-Jul-1999'      [       2.7552]
    '18-Jul-1999'      [       0.6217]
    '19-Jul-1999'      [       1.0714]
    '20-Jul-1999'      [       1.4897]
    '21-Jul-1999'      [       3.0536]
    '22-Jul-1999'      [       1.8598]
    '23-Jul-1999'      [       0.7500]
    '24-Jul-1999'      [       0.2537]
    '25-Jul-1999'      [       0.5037]
    '26-Jul-1999'      [       1.3933]
    '27-Jul-1999'      [       0.3687]...
```

The second example provides two data series named `First` and `Second`:

```
dates = (today:today+100)';
data_series1 = exp(randn(1, 101))';
data_series2 = exp(randn(1, 101))';
data = [data_series1 data_series2];
fts2 = fints(dates, data, {'First', 'Second'})
```

```
fts2 =
    desc:  (none)
    freq:  Unknown (0)

    'dates:  (101)'    'First:  (101)'    'Second:  (101)'
    '12-Jul-1999'      [       1.2305]    [        0.7396]
    '13-Jul-1999'      [       1.2473]    [        2.6038]
    '14-Jul-1999'      [       0.3657]    [        0.5866]
    '15-Jul-1999'      [       0.6357]    [        0.4061]
    '16-Jul-1999'      [       4.0530]    [        0.4096]
    '17-Jul-1999'      [       0.6300]    [        1.3214]
    '18-Jul-1999'      [       1.0333]    [        0.4744]
    '19-Jul-1999'      [       2.2228]    [        4.9702]
    '20-Jul-1999'      [       2.4518]    [        1.7758]
    '21-Jul-1999'      [       1.1479]    [        1.3780]
    '22-Jul-1999'      [       0.1981]    [        0.8595]
    '23-Jul-1999'      [       0.1927]    [        1.3713]
    '24-Jul-1999'      [       1.5353]    [        3.8332]
    '25-Jul-1999'      [       0.4784]    [        0.1067]
    '26-Jul-1999'      [       1.7593]    [        3.6434]
    '27-Jul-1999'      [       0.2505]    [        0.6849]
    '28-Jul-1999'      [       1.5845]    [        1.0025]...
```

Note Data series names must be valid MATLAB variable names. The only allowed nonalphanumeric character is the underscore (_) character.

Because `freq` for `fts2` has not been explicitly indicated, the frequency indicator for `fts2` is set to `Unknown`. Set the frequency indicator field `freq` before you attempt any operations on the object. You will not be able to use the object until the frequency indicator field is set to a valid indicator.

Frequency Indicator Input

```
fts = fints(dates, data, datanames, freq)
```

With the fourth syntax you can set the frequency indicator field when you create the financial time series object. The frequency indicator field `freq` is set as the fourth input argument. You will not be able to use the financial time series object until `freq` is set to a valid indicator. Valid frequency indicators are

```
UNKNOWN, Unknown, unknown, U, u,0
DAILY, Daily, daily, D, d,1
WEEKLY, Weekly, weekly, W, w,2
MONTHLY, Monthly, monthly, M, m,3
QUARTERLY, Quarterly, quarterly, Q, q,4
SEMIANNUAL, Semiannual, semiannual, S, s,5
ANNUAL, Annual, annual, A, a,6
```

The previous example contained sets of daily data. The `freq` field displayed as `Unknown (0)` because the frequency indicator was not explicitly set. The command

```
fts = fints(dates, data, {'First', 'Second'}, 1);
```

sets the `freq` indicator to `Daily(1)` when creating the financial time series object:

```
fts =

    desc:  (none)
    freq:  Daily (1)

    'dates:  (101)'    'First:  (101)'    'Second:  (101)'
    '12-Jul-1999'      [       1.2305]    [        0.7396]
    '13-Jul-1999'      [       1.2473]    [        2.6038]
    '14-Jul-1999'      [       0.3657]    [        0.5866]
    '15-Jul-1999'      [       0.6357]    [        0.4061]
    '16-Jul-1999'      [       4.0530]    [        0.4096]
    '17-Jul-1999'      [       0.6300]    [        1.3214]
    '18-Jul-1999'      [       1.0333]    [        0.4744]...
```

When you create the object using this syntax, you can use the other valid frequency indicators for a particular frequency. For a daily data set you can

use DAILY, Daily, daily, D, or d. Similarly, with the other frequencies, you can use the valid string indicators or their numeric counterparts.

Description Field Input

```
fts = fints(dates, data, datanames, freq, desc)
```

With the fifth syntax, you can explicitly set the description field as the fifth input argument. The description can be anything you want. It is not used in any operations performed on the object.

This example sets the desc field to 'Test TS'.

```
dates = (today:today+100)';
data_series1 = exp(randn(1, 101))';
data_series2 = exp(randn(1, 101))';
data = [data_series1 data_series2];
fts = fints(dates, data, {'First', 'Second'}, 1, 'Test TS')

fts =
    desc:  Test TS
    freq:  Daily (1)

    'dates:  (101)'    'First:  (101)'    'Second:  (101)'
    '12-Jul-1999'      [       0.5428]    [        1.2491]
    '13-Jul-1999'      [       0.6649]    [        6.4969]
    '14-Jul-1999'      [       0.2428]    [        1.1163]
    '15-Jul-1999'      [       1.2550]    [        0.6628]
    '16-Jul-1999'      [       1.2312]    [        1.6674]
    '17-Jul-1999'      [       0.4869]    [        0.3015]
    '18-Jul-1999'      [       2.1335]    [        0.9081]...
```

Now the description field is filled with the specified string 'Test TS' when the constructor is called.

Transforming a Text File

The function ascii2fts creates a financial time series object from a text (ASCII) data file provided that the data file conforms to a general format. The general format of the text data file is as follows:

- Can contain header text lines.
- Can contain column header information. The column header information must immediately precede the data series columns unless the `skiprows` argument (see below) is specified.
- Leftmost column must be the date column.
- Dates must be in a valid date string format.
  - `'ddmmmyy'` or `'ddmmmyyyy'`
  - `'mm/dd/yy'` or `'mm/dd/yyyy'`
  - `'dd-mmm-yy'` or `'dd-mmm-yyyy'`
  - `'mmm.dd,yy'` or `'mmm.dd,yyyy'`
- Each column must be separated either by spaces or a tab.

Several example text data files are included with the toolbox. These files are in the `ftsdata` subdirectory within the directory *`matlabroot`*`/toolbox/finance`.

The syntax of the function

```
fts = ascii2fts(filename, descrow, colheadrow, skiprows);
```

takes in the data file name (`filename`), the row number where the text for the description field is (`descrow`), the row number of the column header information (`colheadrow`), and the row numbers of rows to be skipped (`skiprows`). For example, rows need to be skipped when there are intervening rows between the column head row and the start of the time series data.

Look at the beginning of the ASCII file `disney.dat` in the `ftsdata` subdirectory:

```
Walt Disney Company (DIS)
Daily prices (3/29/96 to 3/29/99)
DATE     OPEN     HIGH     LOW     CLOSE     VOLUME
3/29/99  33.0625  33.188   32.75   33.063    6320500
3/26/99  33.3125  33.375   32.75   32.938    5552800
3/25/99  33.5     33.625   32.875  33.375    7936000
3/24/99  33.0625  33.25    32.625  33.188    6025400...
```

The command line

```
disfts = ascii2fts('disney.dat', 1, 3, 2)
```

uses `disney.dat` to create time series object `disfts`. This example

- Reads the text data file `disney.dat`
- Uses the first line in the file as the content of the description field
- Skips the second line
- Parses the third line in the file for column header (or data series names)
- Parses the rest of the file for the date vector and the data series values

The resulting financial time series object looks like this.

```
disfts =

 desc:  Walt Disney Company (DIS)
 freq:  Unknown (0)

 'dates:  (782)'    'OPEN:  (782)'    'HIGH:  (782)'    'LOW:  (782)'
'29-Mar-1996'     [    21.1938]    [    21.6250]   [   21.2920]
'01-Apr-1996'     [    21.1120]    [    21.6250]   [   21.4170]
'02-Apr-1996'     [    21.3165]    [    21.8750]   [   21.6670]
'03-Apr-1996'     [    21.4802]    [    21.8750]   [   21.7500]
'04-Apr-1996'     [    21.4393]    [    21.8750]   [   21.5000]
'05-Apr-1996'     [        NaN]    [        NaN]   [       NaN]
'09-Apr-1996'     [    21.1529]    [    21.5420]   [   21.2080]
'10-Apr-1996'     [    20.7387]    [    21.1670]   [   20.2500]
'11-Apr-1996'     [    20.0829]    [    20.5000]   [   20.0420]
'12-Apr-1996'     [    19.9189]    [    20.5830]   [   20.0830]
'15-Apr-1996'     [    20.2878]    [    20.7920]   [   20.3750]
'16-Apr-1996'     [    20.3698]    [    20.9170]   [   20.1670]
'17-Apr-1996'     [    20.4927]    [    20.9170]   [   20.7080]
'18-Apr-1996'     [    20.4927]    [    21.0420]   [   20.7920]
```

There are 782 data points in this object. Only the first few lines are shown here. Also, this object has two other data series, the `CLOSE` and `VOLUME` data

series, that are not shown here. Note that in creating the financial time series object, `ascii2fts` sorts the data into ascending chronological order.

The frequency indicator field, `freq`, is set to `0` for `Unknown` frequency. You can manually reset it to the appropriate frequency using structure syntax `disfts.freq = 1` for `Daily` frequency.

With a slightly different syntax, the function `ascii2fts` can create a financial time series object when time-of-day data is present in the ASCII file. The new syntax has the form

```
fts = ascii2fts(filename, timedata, descrow, colheadrow,
skiprows);
```

Set `timedata` to `'T'` when time-of-day data is present and to `'NT'` when there is no time data. For an example using this function with time-of-day data, see the reference page for `ascii2fts`.

Visualizing Financial Time Series Objects

In this section...

"Introduction" on page 7-18

"Using chartfts" on page 7-18

"Zoom Tool" on page 7-21

"Combine Axes Tool" on page 7-24

Introduction

Financial Toolbox software contains the function `chartfts`, which provides a visual representation of a financial time series object. `chartfts` is an interactive charting and graphing utility for financial time series objects. With this function, you can observe time series values on the entire range of dates covered by the time series.

Note Interactive charting is also available from the **Graphs** menu of the graphical user interface. See "Interactive Chart" on page 10-17 for additional information.

Using chartfts

`chartfts` requires a single input argument, `tsobj`, where `tsobj` is the name of the financial time series object you want to explore. Most equity financial time series objects contain four price series, such as opening, closing, highest, and lowest prices, plus an additional series containing the volume traded. However, `chartfts` is not limited to a time series of equity prices and volume traded. It can be used to display any time series data you may have.

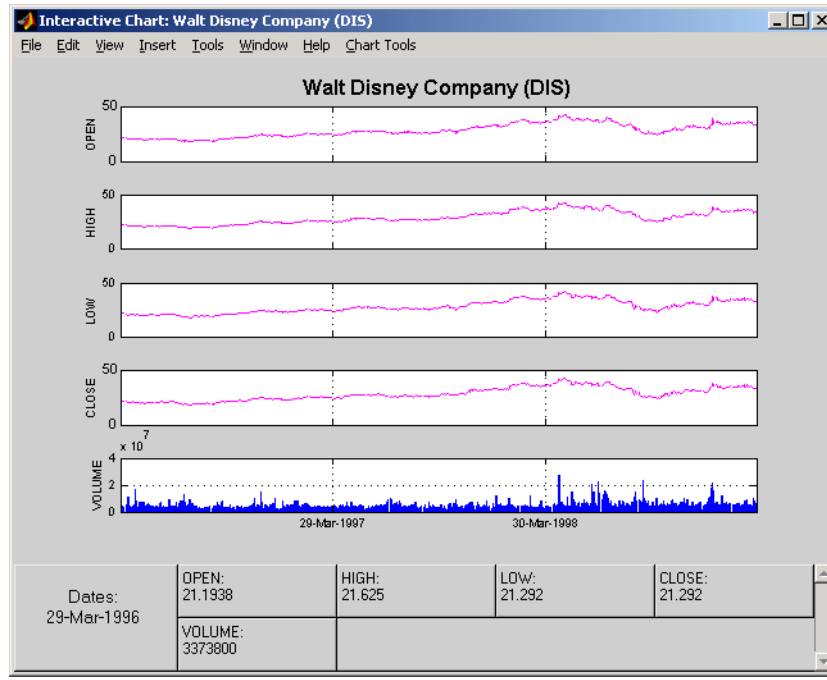
To illustrate the use of `chartfts`, use the equity price and volume traded data for the Walt Disney Corporation (NYSE: DIS) provided in the file `disney.mat`:

```
load disney.mat

whos
```

```
Name              Size          Bytes  Class

dis             782x5           39290  fints object
dis_CLOSE       782x1            6256  double array
dis_HIGH        782x1            6256  double array
dis_LOW         782x1            6256  double array
dis_OPEN        782x1            6256  double array
dis_VOLUME      782x1            6256  double array
dis_nv          782x4           32930  fints object
q_dis            13x4            2196  fints object
```

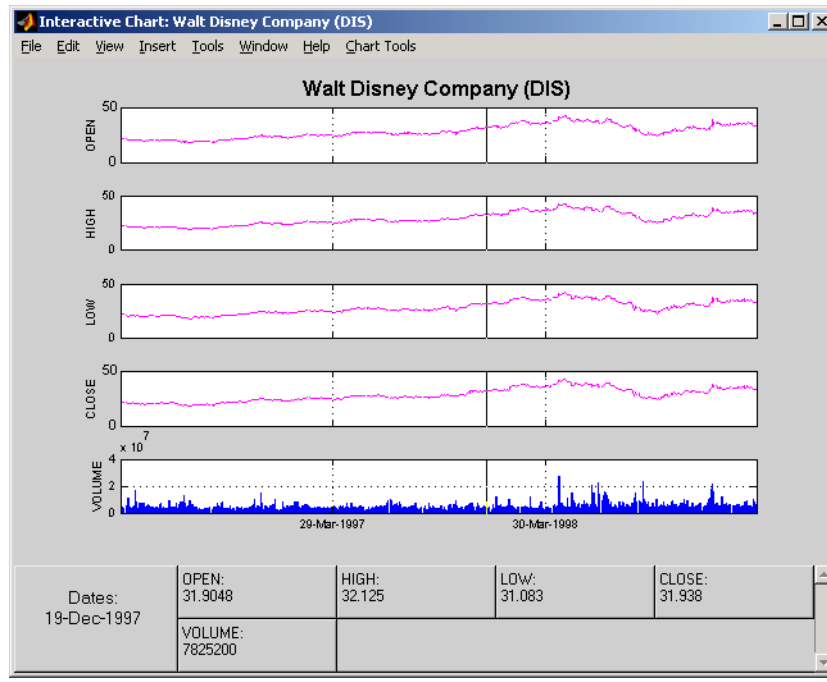
For charting purposes look only at the objects `dis` (daily equity data including volume traded) and `dis_nv` (daily data without volume traded). Both objects contain the series `OPEN`, `HIGH`, `LOW`, and `CLOSE`, but only `dis` contains the additional `VOLUME` series.

Use `chartfts(dis)` to observe the values.

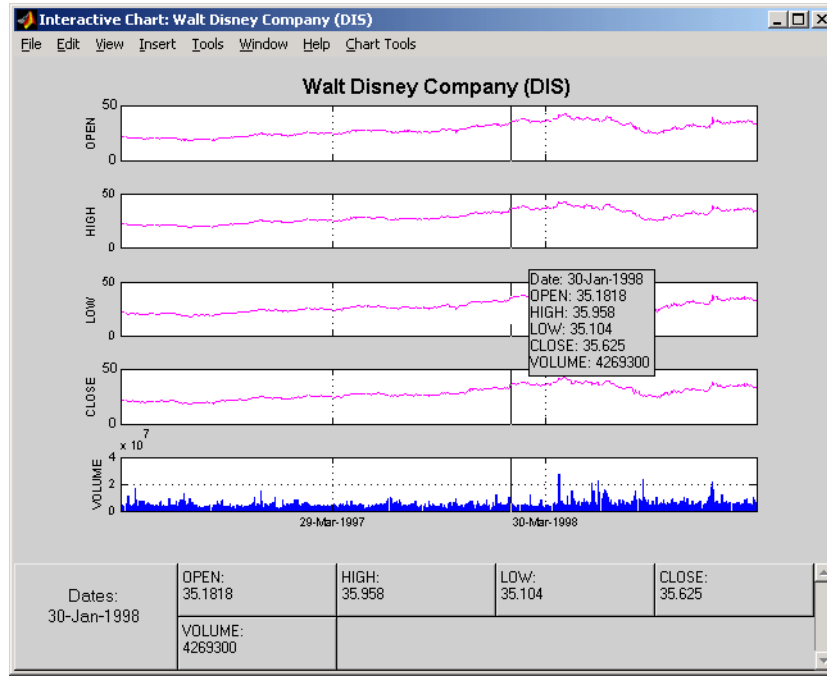


The chart contains five plots, each representing one of the series in the time series object. Boxes indicate the value of each individual plot. The date box is always on the left. The number of data boxes on the right depends upon the number of data series in the time series object, five in this case. The order in which these boxes are arranged (left to right) matches the plots from top to bottom. With more than eight data series in the object, the scroll bar on the right is activated so that additional data from the other series can be brought into view.

Slide the mouse cursor over the chart. A vertical bar appears across all plots. This bar selects the set of data shown in the boxes below. Move this bar horizontally and the data changes accordingly.

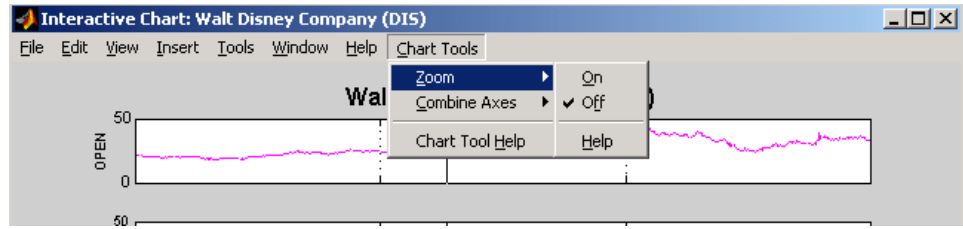


Click the plot. A small information box displays the data at the point where you click the mouse button.



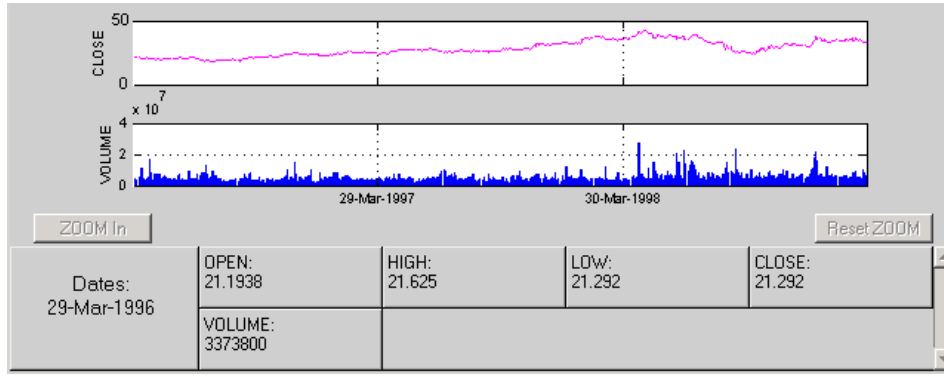
Zoom Tool

The zoom feature of `chartfts` enables a more detailed look at the data during a selected time frame. The Zoom tool is found under the **Chart Tools** menu.

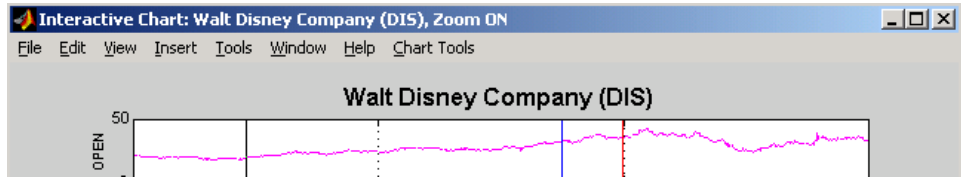


Note Due to the specialized nature of this feature, do not use the MATLAB `zoom` command or **Zoom In** and **Zoom Out** from the **Tools** menu.

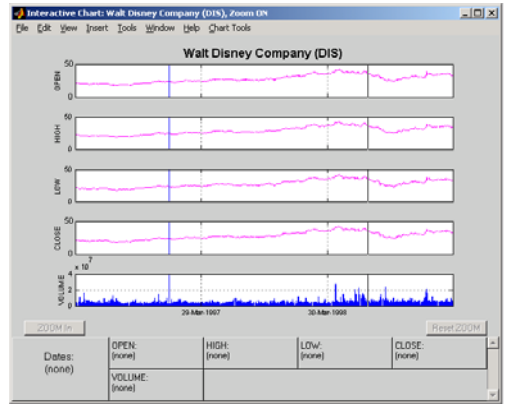
When the feature is turned on, you will see two inactive buttons (**ZOOM In** and **Reset ZOOM**) above the boxes. The buttons become active later after certain actions have been performed.

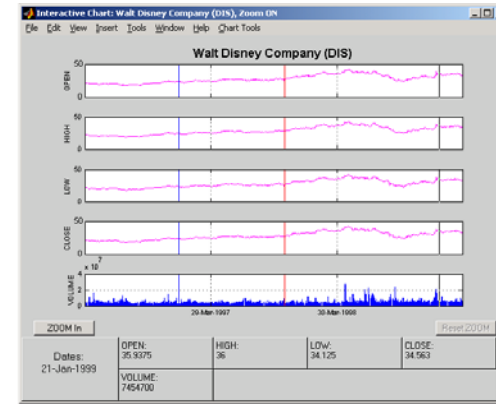


The window title bar displays the status of the chart tool that you are using. With the Zoom tool turned on, you see **Zoom ON** in the title bar in addition to the name of the time series you are working with. When the tool is off, no status is displayed.

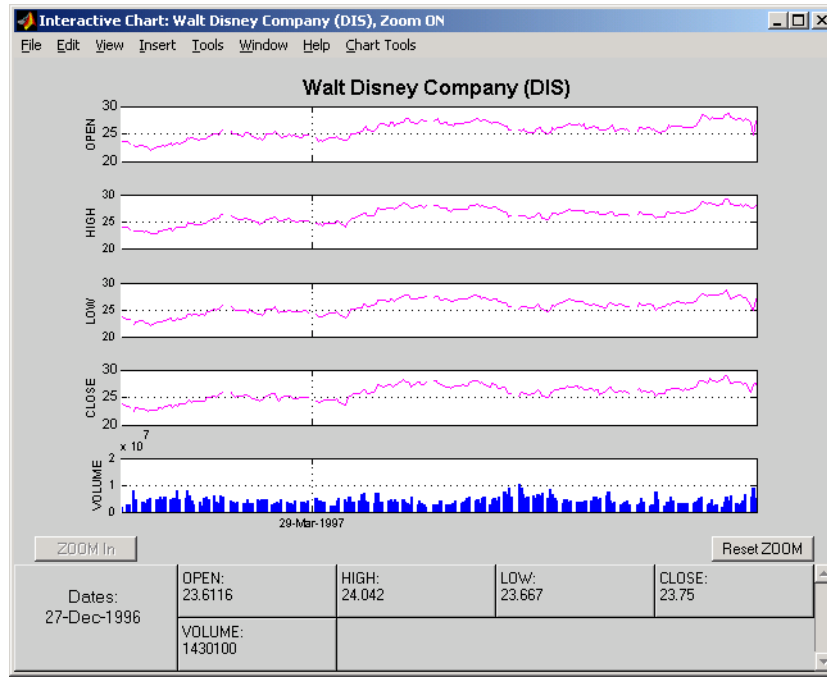


To zoom into the chart, you need to define the starting and ending dates. Define the starting date by moving the cursor over the chart until the desired date appears at the bottom-left box and click the mouse button. A blue vertical line indicates the starting date you have selected. Next, again move the cursor over the chart until the desired ending date appears in the box and click the mouse once again. This time, a red vertical line appears and the **ZOOM In** button is activated.





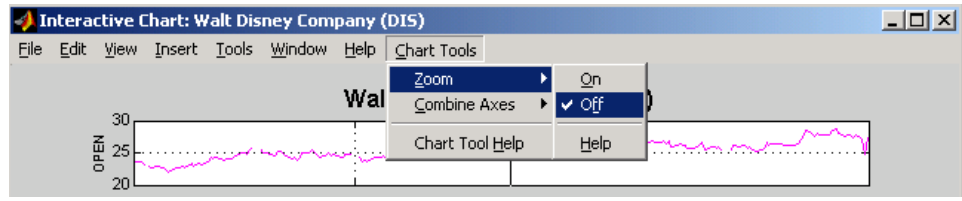
To zoom into the chart, click the **ZOOM In** button.



The chart is zoomed in. Note that the **Reset ZOOM** button now becomes active while the **ZOOM In** button becomes inactive again. To return the chart

to its original state (not zoomed), click the **Reset ZOOM** button. To zoom into the chart even further, repeat the steps above for zooming into the chart.

Turn the Zoom tool off by going back to the **Chart Tools** menu and choosing **Zoom Off**.



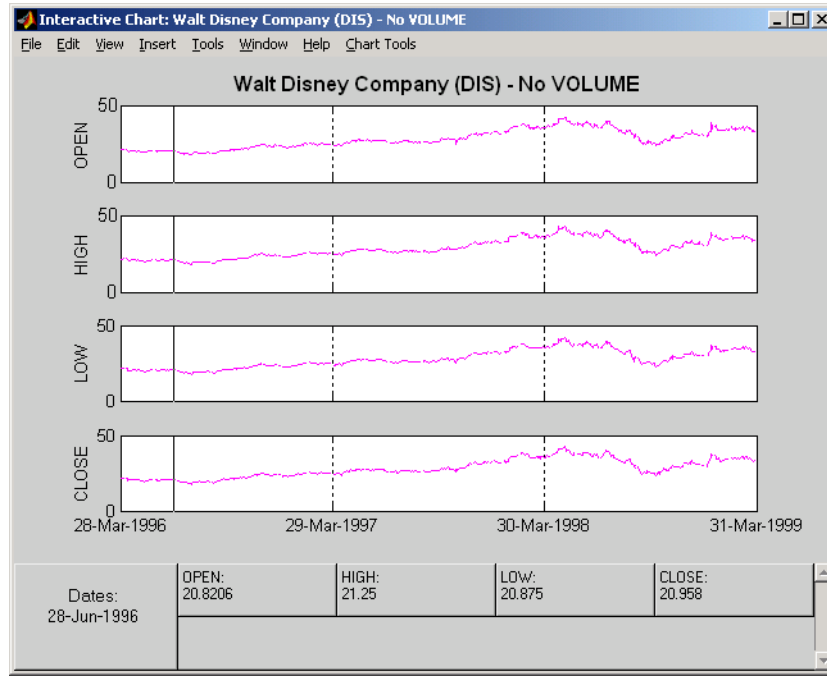
With the tool turned off, the chart stays at the last state that it was in. If you turn it off when the chart is zoomed in, the chart stays zoomed in. If you reset the zoom before turning it off, the chart becomes the original (not zoomed).

Combine Axes Tool

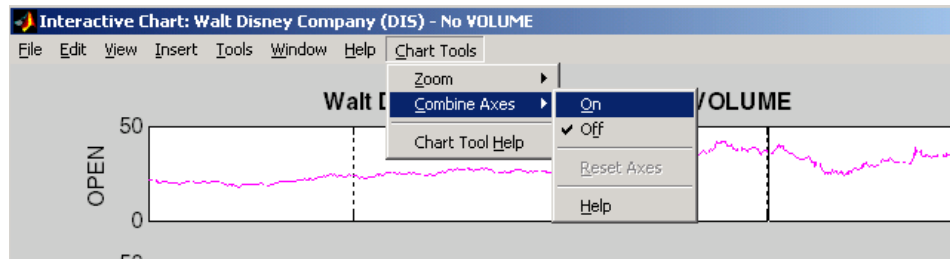
The Combine Axes tool allows you to combine all axes or specific axes into one. With axes combined, you can visually spot any trends that can occur among the data series in a financial time series object.

To illustrate this tool, use `dis_nv`, the financial time series object that does not contain volume traded data:

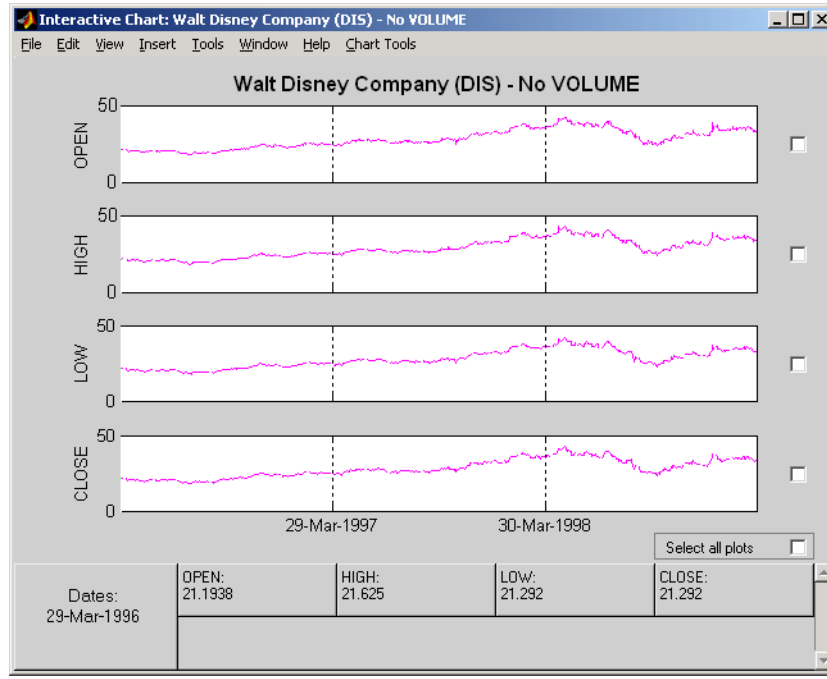
```
chartfts(dis_nv)
```



To combine axes, choose the **Chart Tools** menu, followed by **Combine Axes** and **On**.

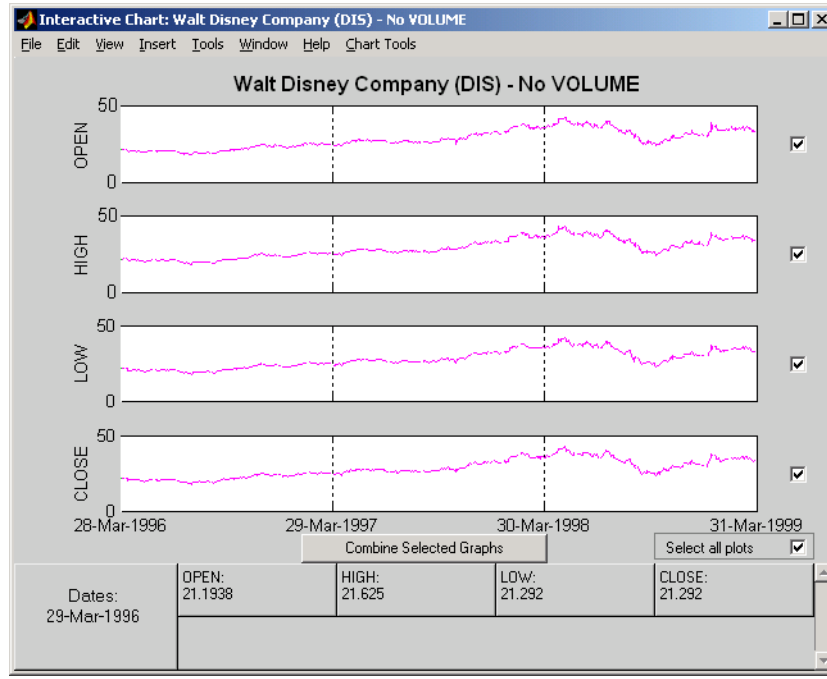


When the Combine Axes tool is on, check boxes appear beside each individual plot. An additional check box enables the combination of all plots.

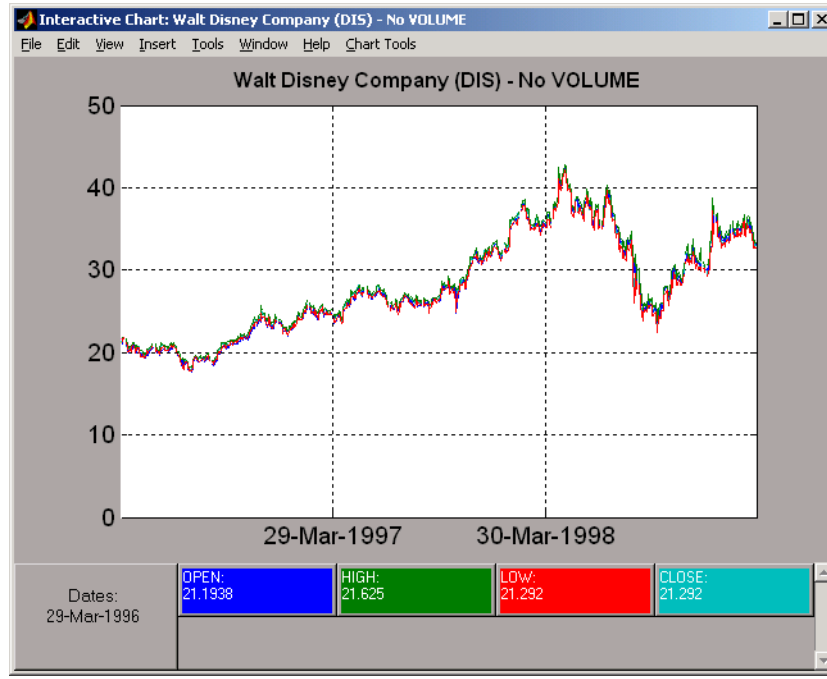


Combining All Axes

To combine all plots, select the **Select all plots** check box.



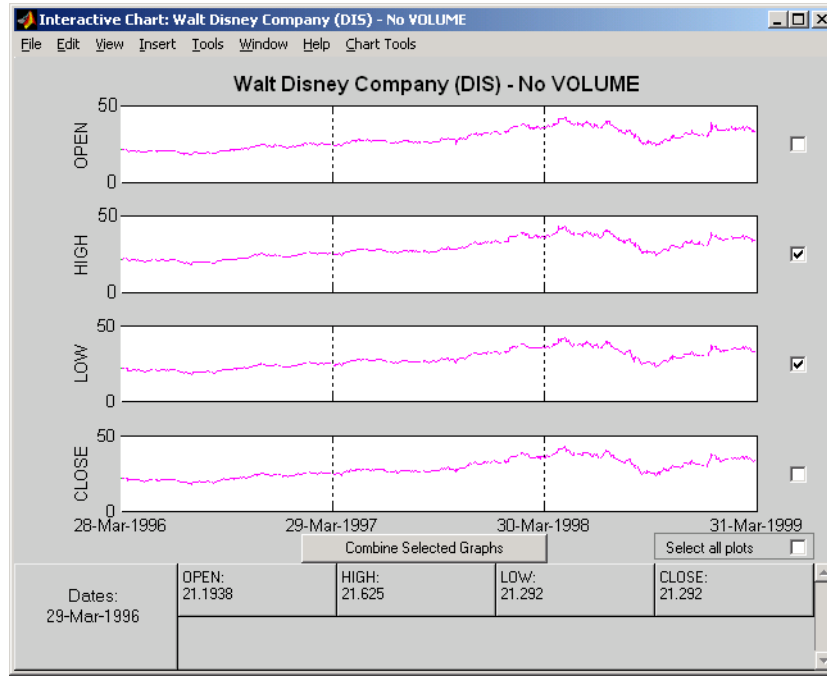
Now click the **Combine Selected Graphs** button to combine the chosen plots. In this case, all plots are combined.



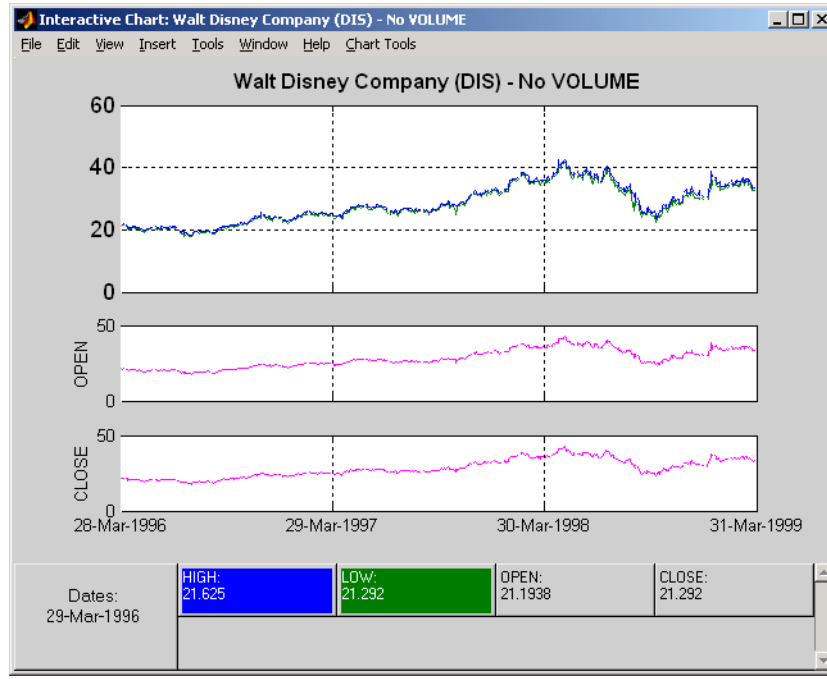
The combined plots have a single plot axis with all data series traced. The background of each data box has changed to the color corresponding to the color of the trace that represents the data series. After the axes are combined, the tool is turned off.

Combining Selected Axes

You can choose any combination of the available axes to combine. For example, combine the `HIGH` and `LOW` price series of the Disney time series. Click the check boxes next to the corresponding plots. The **Combine Selected Graphs** button appears and is active.



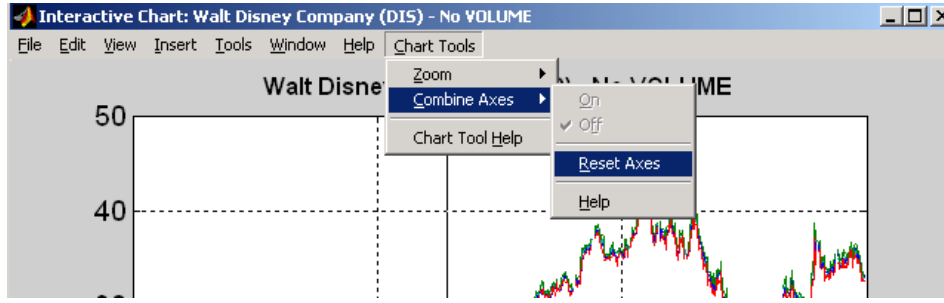
Click the **Combine Selected Graphs** button. The chart with the combined plots looks like the next figure.



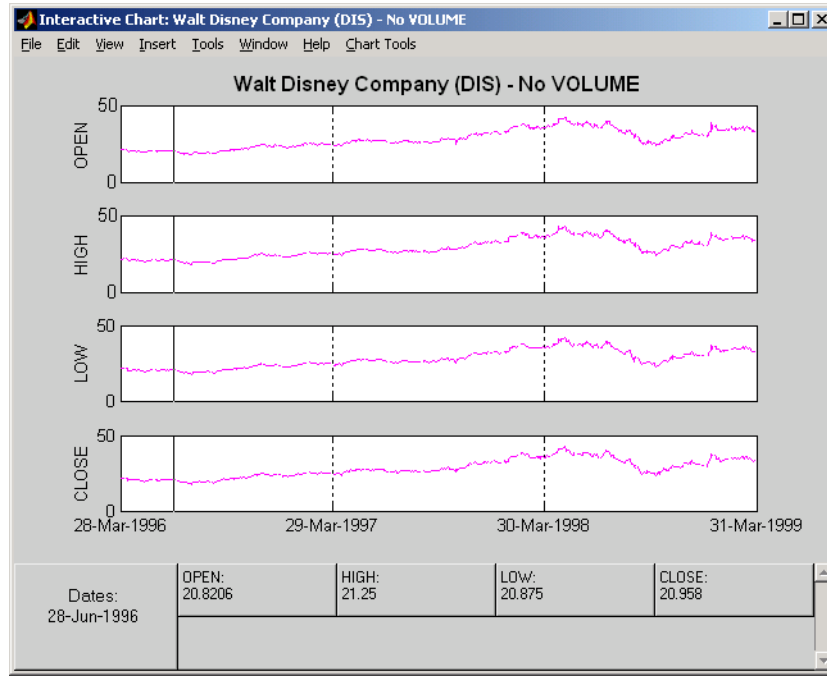
The plot with the combined axes is located at the top of the chart while the remaining plots follow it. The data boxes have also been changed. The boxes that correspond to the combined axes are relocated to the beginning, and the background colors are set to the color of the respective traces. The data boxes for the remaining axes retain their original formats.

Resetting Axes

If you have altered the chart by combining axes, you must reset the axes before you can visualize additional combinations. Reset the axes with the **Reset Axes** menu item under **Chart Tools > Combine Axes**. Note that now the **On** and **Off** features are turned off.



With axes reset, the interactive chart appears in its original format, and you can proceed with additional axes combinations.



8

Using Financial Time Series

- "Introduction" on page 8-2
- "Working with Financial Time Series Objects" on page 8-3
- "Demonstration Program" on page 8-25

Introduction

This chapter discusses how to manipulate and analyze financial time series data. The major topics discussed include

- "Financial Time Series Object Structure" on page 8-3
- "Data Extraction" on page 8-4
- "Object-to-Matrix Conversion" on page 8-6
- "Indexing a Financial Time Series Object" on page 8-8
- "Operations" on page 8-15
- "Data Transformation and Frequency Conversion" on page 8-19

Much of this information is summarized in the "Demonstration Program" on page 8-25.

Working with Financial Time Series Objects

In this section...

"Introduction" on page 8-3
"Financial Time Series Object Structure" on page 8-3
"Data Extraction" on page 8-4
"Object-to-Matrix Conversion" on page 8-6
"Indexing a Financial Time Series Object" on page 8-8
"Operations" on page 8-15
"Data Transformation and Frequency Conversion" on page 8-19

Introduction

A financial time series object is designed to be used as if it were a MATLAB structure. (See the MATLAB documentation for a description of MATLAB structures or how to use MATLAB in general.)

This part of the tutorial assumes that you know how to use MATLAB and are familiar with MATLAB structures. The terminology is similar to that of a MATLAB structure. The financial time series object term *component* is interchangeable with the MATLAB structure term *field*.

Financial Time Series Object Structure

A financial time series object always contains three component names: `desc` (description field), `freq` (frequency indicator field), and `dates` (date vector). If you build the object using the constructor `fints`, the default value for the description field is a blank string (`''`). If you build the object from a text data file using `ascii2fts`, the default is the name of the text data file. The default for the frequency indicator field is `0` (`Unknown` frequency). Objects created from operations can default the setting to `0`. For example, if you decide to pick out values selectively from an object, the frequency of the new object might not be the same as that of the object from which it came.

The date vector `dates` does not have a default set of values. When you create an object, you have to supply the date vector. You can change the date vector afterward but, at object creation time, you must provide a set of dates.

The final component of a financial time series object is one or more data series vectors. If you do not supply a name for the data series, the default name is `series1`. If you have multiple data series in an object and do not supply the names, the default is the name series followed by a number, for example, `series1`, `series2`, and `series3`.

Data Extraction

Here is an exercise on how to extract data from a financial time series object. As mentioned before, you can think of the object as a MATLAB structure. Highlight each line in the exercise in the MATLAB Help browser, press the right mouse button, and select **Evaluate Selection** to execute it.

To begin, create a financial time series object called `myfts`:

```
dates = (datenum('05/11/99'):datenum('05/11/99')+100)';
data_series1 = exp(randn(1, 101))';
data_series2 = exp(randn(1, 101))';
data = [data_series1 data_series2];
myfts = fints(dates, data);
```

The `myfts` object looks like this:

```
myfts =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (101)'    'series1:  (101)'    'series2:  (101)'
    '11-May-1999'      [         2.8108]    [         0.9323]
    '12-May-1999'      [         0.2454]    [         0.5608]
    '13-May-1999'      [         0.3568]    [         1.5989]
    '14-May-1999'      [         0.5255]    [         3.6682]
    '15-May-1999'      [         1.1862]    [         5.1284]
    '16-May-1999'      [         3.8376]    [         0.4952]
    '17-May-1999'      [         6.9329]    [         2.2417]
```

```
    '18-May-1999'      [          2.0987]    [          0.3579]
    '19-May-1999'      [          2.2524]    [          3.6492]
    '20-May-1999'      [          0.8669]    [          1.0150]
    '21-May-1999'      [          0.9050]    [          1.2445]
    '22-May-1999'      [          0.4493]    [          5.5466]
    '23-May-1999'      [          1.6376]    [          0.1251]
    '24-May-1999'      [          3.4472]    [          1.1195]
    '25-May-1999'      [          3.6545]    [          0.3374]...
```

There are more dates in the object; only the first few lines are shown here.

Note The actual data in your `series1` and `series2` will differ from the above because of the use of random numbers.

Now create another object with only the values for `series2`:

```
srs2 = myfts.series2

srs2 =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (101)'    'series2:  (101)'
    '11-May-1999'      [          0.9323]
    '12-May-1999'      [          0.5608]
    '13-May-1999'      [          1.5989]
    '14-May-1999'      [          3.6682]
    '15-May-1999'      [          5.1284]
    '16-May-1999'      [          0.4952]
    '17-May-1999'      [          2.2417]
    '18-May-1999'      [          0.3579]
    '19-May-1999'      [          3.6492]
    '20-May-1999'      [          1.0150]
    '21-May-1999'      [          1.2445]
    '22-May-1999'      [          5.5466]
    '23-May-1999'      [          0.1251]
    '24-May-1999'      [          1.1195]
```

```
    '25-May-1999'      [          0.3374]...
```

The new object `srs2` contains all the dates in `myfts`, but the only data series is `series2`. The name of the data series retains its name from the original object, `myfts`.

Note The output from referencing a data series field or indexing a financial time series object is always another financial time series object. The exceptions are referencing the description, frequency indicator, and dates fields, and indexing into the dates field.

Object-to-Matrix Conversion

The function `fts2mat` extracts the dates and/or the data series values from an object and places them into a vector or a matrix. The default behavior extracts just the values into a vector or a matrix. Look at the next example:

```
srs2_vec = fts2mat(myfts.series2)

srs2_vec =

    0.9323
    0.5608
    1.5989
    3.6682
    5.1284
    0.4952
    2.2417
    0.3579
    3.6492
    1.0150
    1.2445
    5.5466
    0.1251
    1.1195
    0.3374...
```

If you want to include the dates in the output matrix, provide a second input argument and set it to 1. This results in a matrix whose first column is a vector of serial date numbers:

```
format long g

srs2_mtx = fts2mat(myfts.series2, 1)

srs2_mtx =

            730251      0.932251754559576
            730252      0.560845677519876
            730253      1.59888712183914
            730254      3.6681500883527
            730255      5.12842215360269
            730256      0.49519254119977
            730257      2.24174134286213
            730258      0.357918065917634
            730259      3.64915665824198
            730260      1.01504236943148
            730261      1.24446420606078
            730262      5.54661849025711
            730263      0.12507959735904
            730264      1.11953883096805
            730265      0.337398214166607
```

The vector `srs2_vec` contains just `series2` values. The matrix `srs2_mtx` contains dates in the first column and the values of the `series2` data series in the second. Dates in the first column are in serial date format. Serial date format is a representation of the date string format (for example, serial date = 1 is equivalent to 01-Jan-0000). (The serial date vector can include time-of-day information.)

The `long g` display format displays the numbers without exponentiation. (To revert to the default display format, use `format short`. (See the `format` command in the MATLAB documentation for a description of MATLAB display formats.) Remember that both the vector and the matrix have 101 rows of data as in the original object `myfts` but are shown truncated here.

Indexing a Financial Time Series Object

You can also index into the object as with any other MATLAB variable or structure. A financial time series object lets you use a date string, a cell array of date strings, a date string range, or normal integer indexing. *You cannot, however, index into the object using serial dates.* If you have serial dates, you must first use the MATLAB `datestr` command to convert them into date strings.

When indexing by date string, note that

- Each date string must contain the day, month, and year. Valid formats are
  - `'ddmmmyy hh:mm'` or `'ddmmmyyyy hh:mm'`
  - `'mm/dd/yy hh:mm'` or `'mm/dd/yyyy hh:mm'`
  - `'dd-mmm-yy hh:mm'` or `'dd-mmm-yyyy hh:mm'`
  - `'mmm.dd,yy hh:mm'` or `'mmm.dd,yyyy hh:mm'`
- All data falls at the end of the indicated time period, that is, weekly data falls on Fridays, monthly data falls on the end of each month, and so on, whenever the data has gone through a frequency conversion.

Indexing with Date Strings

With date string indexing you get the values in a financial time series object for a specific date using a date string as the index into the object. Similarly, if you want values for multiple dates in the object, you can put those date strings into a cell array and use the cell array as the index to the object. Here are some examples.

This example extracts all values for May 11, 1999 from `myfts`:

```
format short
myfts('05/11/99')

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (1)'    'series1:  (1)'    'series2:  (1)'
```

```
    '11-May-1999'    [       2.8108]    [       0.9323]
```

The next example extracts only `series2` values for May 11, 1999 from `myfts`:

```
myfts.series2('05/11/99')

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (1)'    'series2:  (1)'
    '11-May-1999'    [       0.9323]
```

The third example extracts all values for three different dates:

```
myfts({'05/11/99', '05/21/99', '05/31/99'})

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (3)'    'series1:  (3)'    'series2:  (3)'
    '11-May-1999'    [       2.8108]    [       0.9323]
    '21-May-1999'    [       0.9050]    [       1.2445]
    '31-May-1999'    [       1.4266]    [       0.6470]
```

The next example extracts only `series2` values for the same three dates:

```
myfts.series2({'05/11/99', '05/21/99', '05/31/99'})

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (3)'    'series2:  (3)'
    '11-May-1999'    [       0.9323]
    '21-May-1999'    [       1.2445]
```

```
    '31-May-1999'    [       0.6470]
```

Indexing with Date String Range

A financial time series is unique because it allows you to index into the object using a date string range. A date string range consists of two date strings separated by two colons (`::`). In MATLAB this separator is called the double-colon operator. An example of a MATLAB date string range is `'05/11/99::05/31/99'`. The operator gives you all data points available between those dates, including the start and end dates.

Here are some date string range examples:

```
myfts ('05/11/99::05/15/99')

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (5)'    'series1:  (5)'    'series2:  (5)'
    '11-May-1999'    [       2.8108]    [       0.9323]
    '12-May-1999'    [       0.2454]    [       0.5608]
    '13-May-1999'    [       0.3568]    [       1.5989]
    '14-May-1999'    [       0.5255]    [       3.6682]
    '15-May-1999'    [       1.1862]    [       5.1284]

myfts.series2('05/11/99::05/15/99')

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (5)'    'series2:  (5)'
    '11-May-1999'    [       0.9323]
    '12-May-1999'    [       0.5608]
    '13-May-1999'    [       1.5989]
    '14-May-1999'    [       3.6682]
    '15-May-1999'    [       5.1284]
```

As with any other MATLAB variable or structure, you can assign the output to another object variable:

```
nfts = myfts.series2('05/11/99::05/20/99');
```

`nfts` is the same as `ans` in the second example.

If one of the dates does not exist in the object, an error message indicates that one or both date indexes are out of the range of the available dates in the object. You can either display the contents of the object or use the command `ftsbound` to determine the first and last dates in the object.

Indexing with Integers

Integer indexing is the normal form of indexing in MATLAB. Indexing starts at 1 (not 0); index = 1 corresponds to the first element, index = 2 to the second element, index = 3 to the third element, and so on. Here are some examples with and without data series reference.

Get the first item in `series2`:

```
myfts.series2(1)

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (1)'    'series2:  (1)'
    '11-May-1999'    [       0.9323]
```

Get the first, third, and fifth items in `series2`:

```
myfts.series2([1, 3, 5])

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (3)'    'series2:  (3)'
```

```
    '11-May-1999'    [       0.9323]
    '13-May-1999'    [       1.5989]
    '15-May-1999'    [       5.1284]
```

Get items 16 through 20 in `series2`:

```
myfts.series2(16:20)

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (5)'    'series2:  (5)'
    '26-May-1999'    [       0.2105]
    '27-May-1999'    [       1.8916]
    '28-May-1999'    [       0.6673]
    '29-May-1999'    [       0.6681]
    '30-May-1999'    [       1.0877]
```

Get items 16 through 20 in the financial time series object `myfts`:

```
myfts(16:20)

ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (5)'    'series1:  (5)'    'series2:  (5)'
    '26-May-1999'    [       0.7571]    [       0.2105]
    '27-May-1999'    [       1.2425]    [       1.8916]
    '28-May-1999'    [       1.8790]    [       0.6673]
    '29-May-1999'    [       0.5778]    [       0.6681]
    '30-May-1999'    [       1.2581]    [       1.0877]
```

Get the last item in `myfts`:

```
myfts(end)
```

```
ans =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (1)'    'series1:  (1)'    'series2:  (1)'
    '19-Aug-1999'    [       1.4692]    [       3.4238]
```

This example uses the MATLAB special variable `end`, which points to the last element of the object when used as an index. The example returns an object whose contents are the values in the object `myfts` on the last date entry.

Indexing When Time-of-Day Data Is Present

Both integer and date string indexing are permitted when time-of-day information is present in the financial time series object. You can index into the object with both date and time specifications, but not with time of day alone. To show how indexing works with time-of-day data present, create a financial time series object called `timeday` containing a time specification:

```
dates = ['01-Jan-2001';'01-Jan-2001'; '02-Jan-2001'; ...
         '02-Jan-2001'; '03-Jan-2001';'03-Jan-2001'];
times = ['11:00';'12:00';'11:00';'12:00';'11:00';'12:00'];
dates_times = cellstr([dates, repmat(' ',size(dates,1),1),...
                       times]);
timeday = fints(dates_times,(1:6)',{'Data1'},1,'My first FINTS')

timeday =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [          4]
    '03-Jan-2001'    '11:00'          [          5]
    '     "     '    '12:00'          [          6]
```

Use integer indexing to extract the second and third data items from `timeday`:

```
timeday(2:3)

ans =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (2)'    'times:  (2)'    'Data1:  (2)'
    '01-Jan-2001'    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
```

For date string indexing, enclose the date and time string in one pair of quotation marks. If there is one date with multiple times, indexing with only the date returns the data for all the times for that specific date. For example, the command `timeday('01-Jan-2001')` returns the data for all times on January 1, 2001:

```
ans =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (2)'    'times:  (2)'    'Data1:  (2)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
```

You can also indicate a specific date and time:

```
timeday('01-Jan-2001 12:00')

ans =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (1)'    'times:  (1)'    'Data1:  (1)'
    '01-Jan-2001'    '12:00'          [          2]
```

Use the double-colon operator `::` to specify a range of dates and times:

```
timeday('01-Jan-2001 12:00::03-Jan-2001 11:00')

ans =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (4)'    'times:  (4)'    'Data1:  (4)'
    '01-Jan-2001'    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [          4]
    '03-Jan-2001'    '11:00'          [          5]
```

Treat `timeday` as a MATLAB structure if you want to obtain the contents of a specific field. For example, to find the times of day included in this object, enter

```
datestr(timeday.times)

ans =

11:00 AM
12:00 PM
11:00 AM
12:00 PM
11:00 AM
12:00 PM
```

Operations

Several MATLAB functions have been overloaded to work with financial time series objects. The overloaded functions include basic arithmetic functions such as addition, subtraction, multiplication, and division and other functions such as arithmetic average, filter, and difference. Also, specific methods have been designed to work with the financial time series object. For a list of functions grouped by type, refer to Chapter 13, “Function Reference” or enter

```
help ftseries
```

at the MATLAB command prompt.

Basic Arithmetic

Financial time series objects permit you to do addition, subtraction, multiplication, and division, either on the entire object or on specific object fields. This is a feature that MATLAB structures do not allow. You cannot do arithmetic operations on entire MATLAB structures, only on specific fields of a structure.

You can perform arithmetic operations on two financial time series objects as long as they are compatible. (All contents are the same except for the description and the values associated with the data series.)

Note *Compatible* time series are not the same as *equal* time series. Two time series objects are equal when everything but the description fields is the same.

Here are some examples of arithmetic operations on financial time series objects.

Load a MAT-file that contains some sample financial time series objects:

```
load dji30short
```

One of the objects in `dji30short` is called `myfts1`:

```
myfts1 =

desc:  DJI30MAR94.dat
freq:  Daily (1)

'dates: (20)'  'Open: (20)' 'High: (20)' 'Low: (20)' 'Close: (20)'
'04-Mar-1994'  [ 3830.90]   [ 3868.04]  [ 3800.50]   [ 3832.30]
'07-Mar-1994'  [ 3851.72]   [ 3882.40]  [ 3824.71]   [ 3856.22]
'08-Mar-1994'  [ 3858.48]   [ 3881.55]  [ 3822.45]   [ 3851.72]
'09-Mar-1994'  [ 3853.97]   [ 3874.52]  [ 3817.95]   [ 3853.41]
'10-Mar-1994'  [ 3852.57]   [ 3865.51]  [ 3801.63]   [ 3830.62]...
```

Create another financial time series object that is identical to `myfts1`:

```
newfts = fints(myfts1.dates, fts2mat(myfts1)/100,...
{'Open','High','Low', 'Close'}, 1, 'New FTS')

newfts =

desc:  New FTS
freq:  Daily (1)

'dates: (20)' 'Open: (20)' 'High: (20)' 'Low: (20)' 'Close:(20)'
'04-Mar-1994'  [ 38.31]     [ 38.68]     [ 38.01]    [ 38.32]
'07-Mar-1994'  [ 38.52]     [ 38.82]     [ 38.25]    [ 38.56]
'08-Mar-1994'  [ 38.58]     [ 38.82]     [ 38.22]    [ 38.52]
'09-Mar-1994'  [ 38.54]     [ 38.75]     [ 38.18]    [ 38.53]
'10-Mar-1994'  [ 38.53]     [ 38.66]     [ 38.02]    [ 38.31]...
```

Perform an addition operation on both time series objects:

```
addup = myfts1 + newfts

addup =

desc:  DJI30MAR94.dat
freq:  Daily (1)

'dates: (20)'  'Open: (20)' 'High: (20)' 'Low: (20)' 'Close: (20)'
'04-Mar-1994'  [ 3869.21]   [ 3906.72]   [ 3838.51]  [ 3870.62]
'07-Mar-1994'  [ 3890.24]   [ 3921.22]   [ 3862.96]  [ 3894.78]
'08-Mar-1994'  [ 3897.06]   [ 3920.37]   [ 3860.67]  [ 3890.24]
'09-Mar-1994'  [ 3892.51]   [ 3913.27]   [ 3856.13]  [ 3891.94]
'10-Mar-1994'  [ 3891.10]   [ 3904.17]   [ 3839.65]  [ 3868.93]...
```

Now, perform a subtraction operation on both time series objects:

```
subout = myfts1 - newfts

subout =

desc:  DJI30MAR94.dat
freq:  Daily (1)
```

```
'dates: (20)'  'Open: (20)' 'High: (20)' 'Low: (20)' 'Close: (20)'
'04-Mar-1994'  [ 3792.59]   [ 3829.36]   [ 3762.49]  [ 3793.98]
'07-Mar-1994'  [ 3813.20]   [ 3843.58]   [ 3786.46]  [ 3817.66]
'08-Mar-1994'  [ 3819.90]   [ 3842.73]   [ 3784.23]  [ 3813.20]
'09-Mar-1994'  [ 3815.43]   [ 3835.77]   [ 3779.77]  [ 3814.88]
'10-Mar-1994'  [ 3814.04]   [ 3826.85]   [ 3763.61]  [ 3792.31]...
```

Operations with Objects and Matrices

You can also perform operations involving a financial time series object and a matrix or scalar:

```
addscalar = myfts1 + 10000

addscalar =

desc:  DJI30MAR94.dat
freq:  Daily (1)

'dates: (20)'  'Open: (20)' 'High: (20)' 'Low: (20)' 'Close: (20)'
'04-Mar-1994'  [ 13830.90]  [ 13868.04]  [ 13800.50] [ 13832.30]
'07-Mar-1994'  [ 13851.72]  [ 13882.40]  [ 13824.71] [ 13856.22]
'08-Mar-1994'  [ 13858.48]  [ 13881.55]  [ 13822.45] [ 13851.72]
'09-Mar-1994'  [ 13853.97]  [ 13874.52]  [ 13817.95] [ 13853.41]
'10-Mar-1994'  [ 13852.57]  [ 13865.51]  [ 13801.63] [ 13862.70]...
```

For operations with both an object and a matrix, the size of the matrix must match the size of the object. For example, a matrix to be subtracted from `myfts1` must be `20`-by-`4`, since `myfts1` has 20 dates and four data series:

```
submtx = myfts1 - randn(20, 4)

submtx =

desc:  DJI30MAR94.dat
freq:  Daily (1)

'dates: (20)'  'Open: (20)' 'High: (20)' 'Low: (20)' 'Close: (20)'
'04-Mar-1994'  [ 3831.33]   [ 3867.75]   [ 3802.10]  [ 3832.63]
'07-Mar-1994'  [ 3853.39]   [ 3883.74]   [ 3824.45]  [ 3857.06]
```

```
'08-Mar-1994'  [ 3858.35]   [ 3880.84]   [ 3823.51]  [ 3851.22]
'09-Mar-1994'  [ 3853.68]   [ 3872.90]   [ 3816.53]  [ 3851.92]
'10-Mar-1994'  [ 3853.72]   [ 3866.20]   [ 3802.44]  [ 3831.17]...
```

Arithmetic Operations with Differing Data Series Names

Arithmetic operations on two objects that have the same size but contain different data series names require the function `fts2mat`. This function extracts the values in an object and puts them into a matrix or vector, whichever is appropriate.

To see an example, create another financial time series object the same size as `myfts1` but with different values and data series names:

```
newfts2 = fints(myfts1.dates, fts2mat(myfts1/10000),...
{'Rat1','Rat2', 'Rat3','Rat4'}, 1, 'New FTS')
```

If you attempt to add (or subtract, and so on) this new object to `myfts1`, an error indicates that the objects are not identical. Although they contain the same dates, number of dates, number of data series, and frequency, the two time series objects do not have the same data series names. Use `fts2mat` to bypass this problem:

```
addother = myfts1 + fts2mat(newfts2);
```

This operation adds the matrix that contains the contents of the data series in the object `newfts2` to `myfts1`. You should carefully consider the effects on your data before deciding to combine financial time series objects in this manner.

Other Arithmetic Operations

In addition to the basic arithmetic operations, several other mathematical functions operate directly on financial time series objects. These functions include exponential (`exp`), natural logarithm (`log`), common logarithm (`log10`), and many more. See Chapter 13, “Function Reference” for more details.

Data Transformation and Frequency Conversion

The data transformation and the frequency conversion functions convert a data series into a different format.

Data Transformation Functions

Function	Purpose
`boxcox`	Box-Cox transformation
`diff`	Differencing
`fillts`	Fill missing values
`filter`	Filter
`lagts`	Lag time series object
`leadts`	Lead time series object
`peravg`	Periodic average
`smoothts`	Smooth data
`tsmovavg`	Moving average

Frequency Conversion Functions

Function	New Frequency
`convertto`	As specified
`resamplets`	As specified
`toannual`	Annual
`todaily`	Daily
`tomonthly`	Monthly
`toquarterly`	Quarterly
`tosemi`	Semiannually
`toweekly`	Weekly

As an example look at `boxcox`, the Box-Cox transformation function. This function transforms the data series contained in a financial time series object into another set of data series with relatively normal distributions.

First create a financial time series object from the supplied `whirlpool.dat` data file.

```
whrl = ascii2fts('whirlpool.dat', 1, 2, []);
```

Fill any missing values denoted with `NaN`s in `whrl` with values calculated using the linear method:

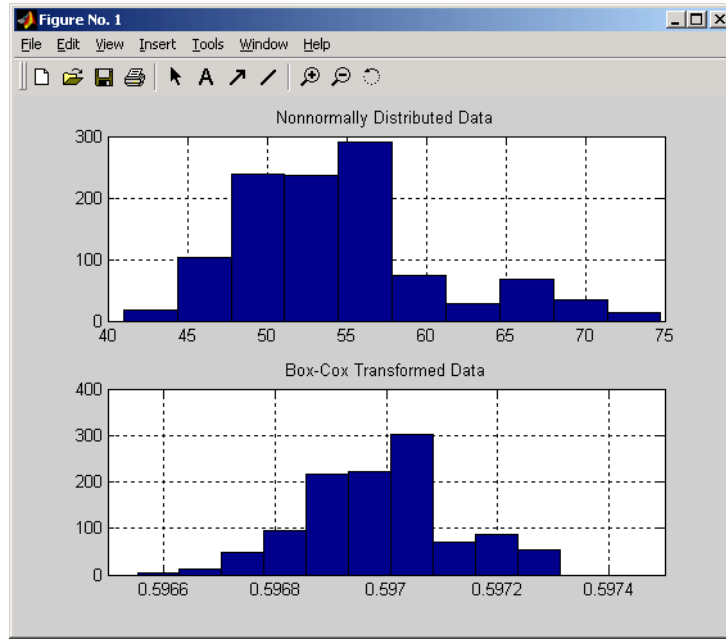
```
f_whrl = fillts(whrl);
```

Transform the nonnormally distributed filled data series `f_whrl` into a normally distributed one using Box-Cox transformation:

```
bc_whrl = boxcox(f_whrl);
```

Compare the result of the `Close` data series with a normal (Gaussian) probability distribution function and the nonnormally distributed `f_whrl`:

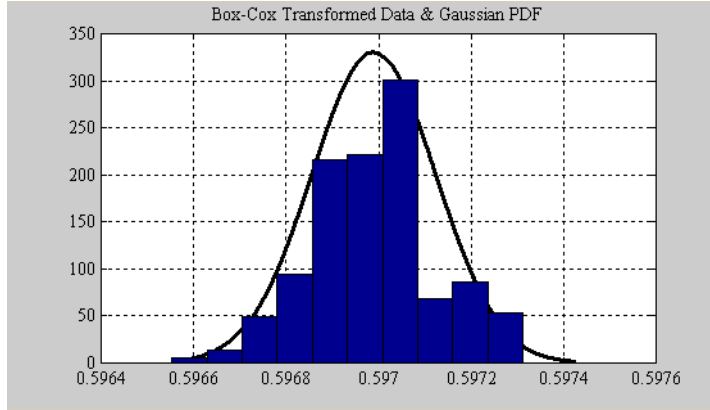
```
subplot(2, 1, 1);
hist(f_whrl.Close);
grid; title('Nonnormally Distributed Data');
subplot(2, 1, 2);
hist(bc_whrl.Close);
grid; title('Box-Cox Transformed Data');
```



Box-Cox Transformation

The bar chart on the top represents the probability distribution function of the filled data series, `f_whrl`, which is the original data series `whrl` with the missing values interpolated using the linear method. The distribution is skewed toward the left (not normally distributed). The bar chart on the bottom is less skewed to the left. If you plot a Gaussian probability distribution function (PDF) with similar mean and standard deviation, the distribution of the transformed data is very close to normal (Gaussian).

When you examine the contents of the resulting object `bc_whrl`, you find an identical object to the original object `whrl` but the contents are the transformed data series. If you have the Statistics Toolbox™ software, you can generate a Gaussian PDF with mean and standard deviation equal to those of the transformed data series and plot it as an overlay to the second bar chart. In the next figure, you can see that it is an approximately normal distribution.



Overlay of Gaussian PDF

The next example uses the `smoothts` function to smooth a time series.

To begin, transform `ibm9599.dat`, a supplied data file, into a financial time series object:

```
ibm = ascii2fts('ibm9599.dat', 1, 3, 2);
```

Fill the missing data for holidays with data interpolated using the `fillts` function and the `Spline` fill method:

```
f_ibm = fillts(ibm, 'Spline');
```

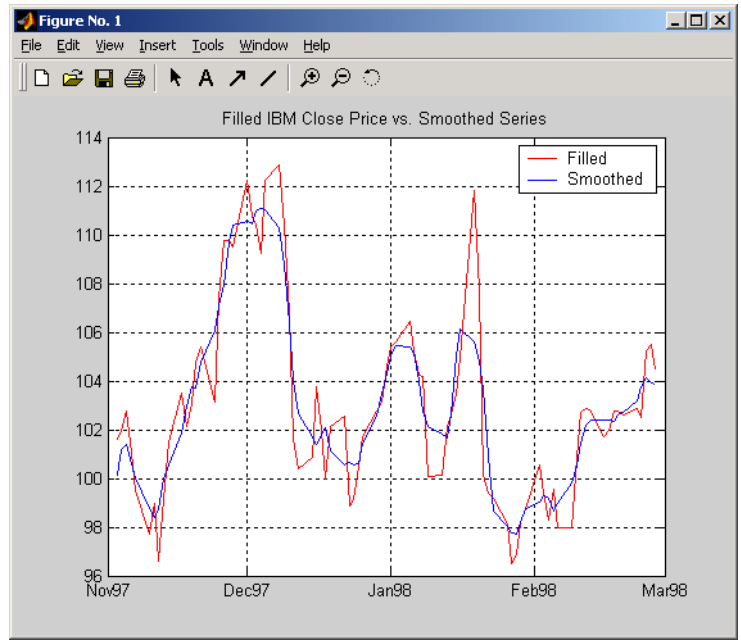
Smooth the filled data series using the default Box (rectangular window) method:

```
sm_ibm = smoothts(f_ibm);
```

Now, plot the original and smoothed closing price series for IBM stock:

```
plot(f_ibm.CLOSE('11/01/97::02/28/98'), 'r')
datetick('x', 'mmmyy')
hold on
plot(sm_ibm.CLOSE('11/01/97::02/28/98'), 'b')
hold off
datetick('x', 'mmmyy')
legend('Filled', 'Smoothed')
```

```
title('Filled IBM Close Price vs. Smoothed Series')
```



Smoothed Data Series

These examples give you an idea of what you can do with a financial time series object. This toolbox provides some MATLAB functions that have been overloaded to work directly with the these objects. The overloaded functions are those most commonly needed to work with time series data.

Demonstration Program

In this section...

"Overview" on page 8-25
"Loading the Data" on page 8-26
"Create Financial Time Series Objects" on page 8-26
"Create Closing Prices Adjustment Series" on page 8-27
"Adjust Closing Prices and Make Them Spot Prices" on page 8-28
"Create Return Series" on page 8-28
"Regress Return Series Against Metric Data" on page 8-28
"Plot the Results" on page 8-29
"Calculate the Dividend Rate" on page 8-30

Overview

This example demonstrates a practical use of financial time series objects, predicting the return of a stock from a given set of data. The data is a series of closing stock prices, a series of dividend payments from the stock, and an explanatory series (in this case a market index). Additionally, the example calculates the dividend rate from the stock data provided.

Note You can find a script M-file for this demonstration program in the directory `matlabroot/toolbox/finance/ftsdemos` on your MATLAB path. The script is named `predict_ret.m`.

To perform these computations:

1. Load the data.
2. Create financial time series objects from the loaded data.
3. Create the series from dividend payment for adjusting the closing prices.
4. Adjust the closing prices and make them the spot prices.

5. Create the return series.
6. Regress the return series against the metric data (for example, a market index) using the MATLAB \ operator.
7. Plot the results.
8. Calculate the dividend rate.

Loading the Data

The data for this demonstration is found in the MAT-file `predict_ret_data.mat`:

```
load predict_ret_data.mat
```

The MAT-file contains six vectors:

- Dates corresponding to the closing stock prices, `sdates`
- Closing stock prices, `sdata`
- Dividend dates, `divdates`
- Dividend paid, `divdata`
- Dates corresponding to the metric data, `expdates`
- Metric data, `expdata`

Use the `whos` command to see the variables in your MATLAB workspace.

Create Financial Time Series Objects

It is useful to work with financial time series objects rather than with the vectors now in the workspace. By using objects, you can easily keep track of the dates. Also, you can easily manipulate the data series based on dates because the object keeps track of the administration of time series for you.

Use the object constructor `fints` to construct three financial time series objects.

```
t0 = fints(sdates, sdata, {'Close'}, 'd', 'Inc');
d0 = fints(divdates, divdata, {'Dividends'}, 'u', 'Inc');
```

```
x0 = fints(expdates, expdata, {'Metric'}, 'w', 'Index');
```

The variables t0, d0, and x0 are financial time series objects containing the stock closing prices, dividend payments, and the explanatory data, respectively. To see the contents of an object, type its name at the MATLAB command prompt and press **Enter**. For example:

```
d0
d0 =
    'desc:'          'Inc'
    'freq:'          'Unknown (0)'
                ''                      ''
    'dates:  (4)'    'Dividends:  (4)'
    '04/15/99'       '0.2000'
    '06/30/99'       '0.3500'
    '10/02/99'       '0.2000'
    '12/30/99'       '0.1500'
```

Create Closing Prices Adjustment Series

The price of a stock is affected by the dividend payment. On the day before the dividend payment date, the stock price reflects the amount of dividend to be paid the next day. On the dividend payment date, the stock price is decreased by the amount of dividend paid. Create a time series that reflects this adjustment factor:

```
dadj1       = d0;
dadj1.dates = dadj1.dates-1;
```

Now create the series that adjust the prices at the day of dividend payment; this is an adjustment of 0. You also need to add the previous dividend payment date since the stock price data reflect the period subsequent to that day; the previous dividend date was December 31, 1998:

```
dadj2             = d0;
dadj2.Dividends   = 0;
dadj2             = fillts(dadj2,'linear','12/31/98');
dadj2('12/31/98') = 0;
```

Combining the two objects above gives the data needed to adjust the prices. However, since the stock price data is daily data and the effect of the dividend

is linearly divided during the period, use the `fillts` function to make a daily time series from the adjustment data. Use the dates from the stock price data to make the dates of the adjustment the same:

```
dadj3 = [dadj1; dadj2];
dadj3 = fillts(dadj3, 'linear', t0.dates);
```

Adjust Closing Prices and Make Them Spot Prices

The stock price recorded already reflects the dividend effect. To obtain the "correct" price, subtract the dividend amount from the closing prices. Put the result inside the same object `t0` with the data series name `Spot`.

To make sure that adjustments correspond, index into the adjustment series using the dates from the stock price series `t0`. Use the `datestr` command because `t0.dates` returns the dates in serial date format. Also, since the data series name in the adjustment series `dadj3` does not match the one in `t0`, use the function `fts2mat`:

```
t0.Spot = t0.Close - fts2mat(dadj3(datestr(t0.dates)));
```

Create Return Series

Now calculate the return series from the stock price data. A stock return is calculated by dividing the difference between the current closing price and the previous closing price by the previous closing price.

```
tret = (t0.Spot - lagts(t0.Spot, 1)) ./ lagts(t0.Spot, 1);
tret = chfield(tret, 'Spot', 'Return');
```

Ignore any warnings you receive during this sequence. Since the operation on the first line above preserves the data series name `Spot`, it has to be changed with the `chfield` command to reflect the contents correctly.

Regress Return Series Against Metric Data

The explanatory (metric) data set is a weekly data set while the stock price data is a daily data set. The frequency needs to be the same. Use `todaily` to convert the weekly series into a daily series. The constant needs to be included here to get the constant factor from the regression:

```
x1 = todaily(x0);
```

```
x1.Const = 1;
```

Get all the dates common to the return series calculated above and the explanatory (metric) data. Then combine the contents of the two series that have dates in common into a new time series:

```
dcommon = intersect(tret.dates, x1.dates);
regts0  = [tret(datestr(dcommon)), x1(datestr(dcommon))];
```

Remove the contents of the new time series that are not finite:

```
finite_regts0 = find(all(isfinite( fts2mat(regts0)), 2));
regts1        = regts0( finite_regts0 );
```

Now, place the data to be regressed into a matrix using the function `fts2mat`. The first column of the matrix corresponds to the values of the first data series in the object, the second column to the second data series, and so on. In this case, the first column is regressed against the second and third column:

```
DataMatrix = fts2mat(regts1);
XCoeff     = DataMatrix(:, 2:3) \ DataMatrix(:, 1);
```

Using the regression coefficients, calculate the predicted return from the stock price data. Put the result into the return time series `tret` as the data series `PredReturn`:

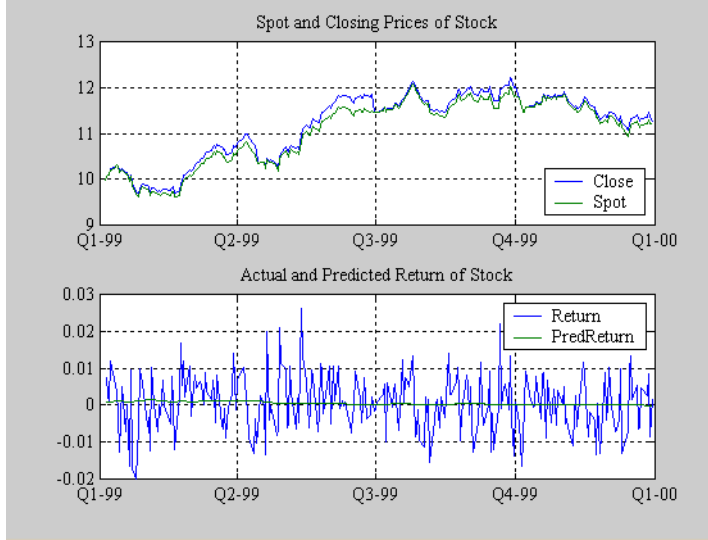
```
RetPred = DataMatrix(:,2:3) * XCoeff;
tret.PredReturn(datestr(regts1.dates)) = RetPred;
```

Plot the Results

Plot the results in a single figure window. The top plot in the window has the actual closing stock prices and the dividend-adjusted stock prices (spot prices). The bottom plot shows the actual return of the stock and the predicted stock return through regression:

```
subplot(2, 1, 1);
plot(t0);
title('Spot and Closing Prices of Stock');
subplot(2, 1, 2);
plot(tret);
```

```
title('Actual and Predicted Return of Stock');
```



Closing Prices and Returns

Calculate the Dividend Rate

The last part of the task is to calculate the dividend rate from the stock price data. Calculate the dividend rate by dividing the dividend payments by the corresponding closing stock prices.

First check to see if you have the stock price data on all the dividend dates:

```
datestr(d0.dates, 2)
ans =

04/15/99
06/30/99
10/02/99
12/30/99
t0(datestr(d0.dates))
ans =

    'desc:'          'Inc'                        ''
```

```
    'freq:'          'Daily (1)'                ''
                ''                ''                ''
    'dates:  (3)'    'Close:  (3)'    'Spot:  (3)'
    '04/15/99'       '10.3369'        '10.3369'
    '06/30/99'       '11.4707'        '11.4707'
    '12/30/99'       '11.2244'        '11.2244'
```

Note that stock price data for October 2, 1999 does not exist. The `fillts` function can overcome this situation; `fillts` allows you to insert a date and interpolate a value for the date from the existing values in the series. There are a number of interpolation methods. See `fillts` in Chapter 13, "Function Reference" for details.

Use `fillts` to create a new time series containing the missing date from the original data series. Then set the frequency indicator to daily:

```
t1 = fillts(t0,'nearest',d0.dates);
t1.freq = 'd';
```

Calculate the dividend rate:

```
tdr = d0./fts2mat(t1.Close(datestr(d0.dates)))
tdr =

    'desc:'          'Inc'
    'freq:'          'Unknown (0)'
                ''                    ''
    'dates:  (4)'    'Dividends:  (4)'
    '04/15/99'       '0.0193'
    '06/30/99'       '0.0305'
    '10/02/99'       '0.0166'
    '12/30/99'       '0.0134'
```

9

Financial Time Series Tool (FTSTool)

- "What Is the Financial Time Series Tool?" on page 9-2
- "Getting Started with FTSTool" on page 9-4
- "Loading Data with FTSTool" on page 9-5
- "Using FTSTool for Supported Tasks" on page 9-10
- "Using FTSTool with Other Time Series GUIs" on page 9-18

What Is the Financial Time Series Tool?

The Financial Time Series Tool (`ftstool`) provides a graphical user interface to create and manage financial time series (`fints`) objects. `ftstool` interoperates with the Financial Time Series Graphical User Interface (`ftsgui`) and Interactive Chart (`chartfts`). In addition, you can use Datafeed Toolbox™ or Database Toolbox™ software to connect to external data sources.

A financial time series object minimally consists of:

- `Desc`, which is the description field.
- `Freq`, which is a frequency indicator field.
- `Dates`, which is a date vector field. If the date vector incorporates time-of-day information, the object contains an additional field named `times`.
- In addition, you can have at least one data series vector. You can specify names for any data series vectors. If you do not specify names, the object uses the default names `series1`, `series2`, `series3`, and so on.

In general, the workflow for using FTSTool is:

1. Acquire data.
2. Create a variable.
3. Convert the variable to `fints`.
4. Convert `fints` to a MATLAB double object.

To obtain the data for `ftstool`, you need to use a MATLAB double object or a financial time series (`fints`) object. You can use previously stored internal data on your computer or you can connect to external data sources using Datafeed Toolbox or Database Toolbox software.

Note You must obtain a license for these products from The MathWorks™ before you can use either of these toolboxes.

After creating a financial time series object, you can use `ftstool` to change the characteristics of the time series object, including merging with other financial time series objects, removing rows or columns, and changing the frequency. You can also use `ftstool` to generate various forms of plotted output and you can reconvert a `fints` object to a MATLAB double-precision matrix.

Getting Started with FTSTool

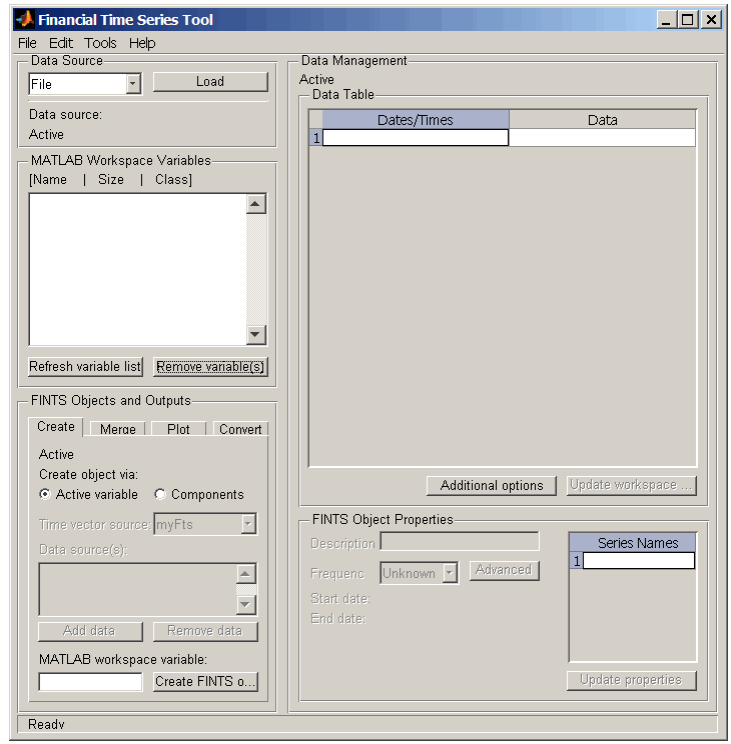
To start the Financial Time Series Tool:

1. At the MATLAB command prompt, enter

   ```
   ftstool
   ```

   The Financial Time Series Tool opens.

2. If you plan to load data from Database Toolbox or Datafeed Toolbox software, ensure you have a license. For more information on using these toolboxes, see the Database Toolbox User's Guide and Datafeed Toolbox User's Guide documentation.



Loading Data with FTSTool

In this section...

"Overview" on page 9-5

"Obtaining External Data" on page 9-5

"Obtaining Internal Data" on page 9-7

"Viewing the MATLAB Workspace" on page 9-8

Overview

The **Data source** pane in the Financial Time Series Tool window lets you do the following:

- Obtain live data from various external data servers using either Datafeed Toolbox or Database Toolbox software.
- Load data you previously obtained and stored in a file.
- View data contained within the MATLAB workspace.

Obtaining External Data

You can obtain external data using Datafeed Toolbox or Database Toolbox software. Datafeed Toolbox software lets you obtain data from several financial data servers, including:

- Bloomberg®
- FactSet®
- Federal Reserve Economic Data
- Haver Analytics financial data
- Interactive Data Pricing and Reference Data
- Kx Systems®, Inc. kdb+ database
- Reuters®
- Thomson® Datastream®
- Yahoo!®

Except for Federal Reserve Economic Data and Yahoo!, these data servers require that you obtain a license from the vendor before you can access their data.

Tip If you open Datafeed Toolbox or Database Toolbox software before starting FTSTool, FTSTool is unable to recognize the toolboxes. When working with FTSTool, select **File > Load** to open these toolboxes.

Obtaining External Data with Datafeed Toolbox Software

1. From the Financial Time Series Tool window, select **File** > **Load** > **Datafeed Toolbox** to open the toolbox.
2. Click the **Connection** tab in Datafeed Toolbox software to select the data source you want to load into FTSTool.
3. Click the **Data** tab in Datafeed Toolbox software to select the security and the associated data that you want to load into FTSTool.
4. After using Datafeed Toolbox software to define the connection, security, data, and **MATLAB variable** name, click **Get Data** and then, using FTSTool, click **Refresh variable list**. The **Data source** field in FTSTool displays the name of the security you selected from the **Data** tab in Datafeed Toolbox software. The FTSTool **Active variable** field indicates the name of the MATLAB workspace variable you chose for this security.
5. Click **Close** to exit Datafeed Toolbox software. FTSTool clears the **Data source** and **Active variable** fields.

Obtaining External Data with Database Toolbox Software

1. From the Financial Time Series Tool window, select **File** > **Load** > **Database Toolbox** to open the toolbox.

2. From the Visual Query Builder window, select the data you want to load into FTSTool.

3. After using Database Toolbox software to select data and name the **MATLAB workspace variable**, click **Execute** and then, using FTSTool, click **Refresh variable list**. The **Data source** field in FTSTool displays the name of the highlighted data source that you selected from the **Data** list box in the Visual Query Builder window. The FTSTool **Active variable** field indicates the name of the MATLAB workspace variable you chose for the security in the Visual Query Builder window.

4. From the Database Toolbox software, select **Query** > **Close Visual Query Builder**, FTSTool clears the **Data source** and **Active variable** fields.

Obtaining Internal Data

You can use FTSTool to load data from files previously stored on your computer. The types of data files you can load are as follows:

- MATLAB `.mat` files
- ASCII text files (`.dat` or `.txt` suffixes)
- Excel `.xls` files

To obtain internal data:

1. From the Financial Time Series Tool window, select **File** > **Load** > **File** to open the Load a MAT, ASCII, .XLS File dialog box.

2. Select the data you want to load into FTSTool.

   - If you load a MATLAB MAT-file, the variables in the file are placed into the MATLAB workspace. The **MATLAB Workspace Variables** list box shows the variables that have been added to the workspace. For example, if you load the file `disney.mat`, which is distributed with the toolbox, the **MATLAB Workspace Variables** list box displays the variables in that MAT-file.

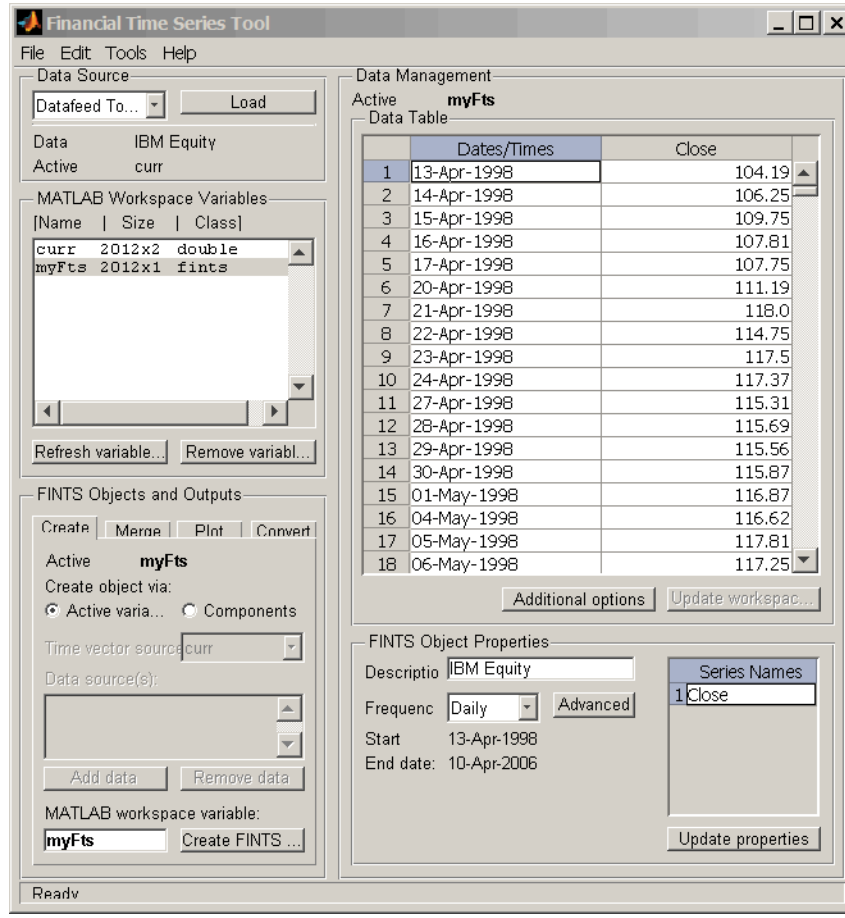
Note FTSTool automatically generates a line plot for each workspace variables unless you disable this feature by resetting the default action under **File** > **Preferences** > **Generate line plot on load**.

- If you load a `.dat` or an ASCII `.txt` file, the ASCII File Parameters dialog box opens. Use this dialog box to transform a text data file into a MATLAB financial time series `fints` object. (See the reference page for `ascii2fts` for further explanation of the fields in the ASCII File Parameters dialog box.
- If you load an Excel `.xls` file, the Excel File Parameters dialog box opens. Use this dialog box to transform Excel worksheet data into a MATLAB financial time series (`fints`) object.

3 From the Financial Time Series Tool window, select **File** > **Save** to save the data you gave loaded from an internal file.

Viewing the MATLAB Workspace

The **MATLAB Workspace Variables** list box displays all existing MATLAB workspace variables. Double-click any variable to display the data in the **Data Table**. You can only display financial time series (`fints`) objects, MATLAB doubles, and cell arrays of double data in the **Data Table**.



In addition, you can click **Refresh variable list** to refresh the **MATLAB Workspace Variables** list box. You need to refresh this list periodically because it is refreshed automatically only for operations performed with FTSTool, not for operations performed within MATLAB itself.

Click **Remove variable(s)** to remove variable from the **MATLAB Workspace Variables** list and from the MATLAB workspace.

Using FTSTool for Supported Tasks

In this section...

"Creating a Financial Time Series Object" on page 9-10

"Merging Financial Time Series Objects" on page 9-11

"Converting a Financial Time Series Object to a MATLAB Double-Precision Matrix" on page 9-12

"Plotting the Output in Several Formats" on page 9-12

"Viewing Data for a Financial Time Series Object in the Data Table" on page 9-13

"Modifying Data for a Financial Time Series Object in the Data Table" on page 9-14

"Viewing and Modifying the Properties for a FINTS Object" on page 9-16

Creating a Financial Time Series Object

Using the **Create** tab in the **FINTS Objects and Outputs** pane for FTSTool, you can create a financial time series (`fints`) object from one or more selected variables.

Note When you first start FTSTool, the **Create** tab appears on top, unless you reset the default using **File** > **Preferences** > **Show Create tab when ftstool starts**.

To create a financial time series (`fints`) object from one or more selected variables:

1. Load data into FTSTool from either an external data source using Datafeed Toolbox or Database Toolbox software or an internal data source using **File** > **Load** > **File**.

2. Select one or more variables from the **MATLAB Workspace Variables** list.

3 Click the **Create** tab and then click **Active variable**.

   When combining multiple variables, you can type a new variable name for the combined variables in the **MATLAB workspace variable** box. The new variable name is added to the **MATLAB Workspace Variables** list. (If you do not choose a name for the **MATLAB workspace variable**, FTSTool uses the default name `myFts`.)

4 Click **Create FINTS object** to display the result in the **Data Table**.

Merging Financial Time Series Objects

Using the **Create** tab in the **FINTS Objects and Outputs** pane for FTSTool, you can create a new financial time series object by merging (joining) multiple existing financial time series objects.

Note When you first start FTSTool, the **Create** tab appears on top, unless you reset the default using **File** > **Preferences**.

To create a financial time series (`fints`) object by merging multiple existing financial time series objects:

1 Load data into FTSTool from either an external data source using Datafeed Toolbox or Database Toolbox software or an internal data source using **File** > **Load** > **File**.

2 To merge multiple existing financial time series objects, click the **Create** tab, click **Components**, and then select a value for the **Time vector source** and one or more items from the **Data sources** list.

   Note You can merge at once multiple financial time series objects. For more information on merging `fints` objects, see `merge`.

   ---

3 Click **Create FINTS object** to display the result in the **Data Table**.

Converting a Financial Time Series Object to a MATLAB Double-Precision Matrix

Using the **Convert** tab in the **FINTS Objects and Outputs** pane for FTSTool, you can convert a financial time series (`fints`) object to a MATLAB double-precision matrix.

To create a financial time series object from one or more selected variables:

1. Load data into FTSTool from either an external data source using Datafeed Toolbox or Database Toolbox software or an internal data source using **File** > **Load** > **File**.
2. Select a variable from the **MATLAB Workspace Variables** list box.
3. Click the **Convert** tab and then determine whether to include or exclude dates in the conversion by clicking **Include dates** or **Exclude dates**.
4. Type a variable name in the **Output variable name** box. (If you do not choose a variable name, FTSTool uses the default name `myDbl`.)
5. Click **Convert FINTS to double matrix**. (This operation is equivalent to performing `fts2mat` on a financial time series object.)

Plotting the Output in Several Formats

Using the **Plot** tab in the **FINTS Objects and Outputs** pane for FTSTool, you can create several forms of plotted output by using a selection list. You can create four types of bar charts, candle plots, high-low plots, line plots, and interactive charts (the latter is created by using the interoperation of FTSTool with the function `chartfts`).

The set of plots supported by FTSTool are identical to the set provided by the **Graphs** menu of the Financial Time Series GUI. (See "Graphs Menu" on page 10-15.) You can find more detailed information for the supported plots by consulting the reference page for each individual type of plot.

To create a plotted output:

1. Load data into FTSTool from either an external data source using Datafeed Toolbox or Database Toolbox software or an internal data source using **File** > **Load** > **File**.
2. Select a variable from the **MATLAB Workspace Variables** list box or select data from the **Data Table**.
3. Click the **Plot** tab and indicate whether you are plotting based on a workspace variable or data from the **Data Table**.
4. From the **Type** drop-down list, select the type of plot.
5. Click **Plot**. The plot is displayed.

Note If the selected workspace variable that you are plotting is not a `fints` object, a `fints` object is created when you click **Plot**. The new `fints` object uses the name designated by the **MATLAB workspace variable** box on the **Create** tab.

Viewing Data for a Financial Time Series Object in the Data Table

Once a financial time series (`fints`) object is created, the FTSTool **Data Table** displays user-designated data, including financial time series objects, MATLAB double-precision variables, and cell arrays of doubles. (Cell arrays of doubles is often the resulting format when using Database Toolbox software.)

When displaying double variables (or a cell array of doubles) in the **Data Table**, the column headings for a double variable or cell array of doubles displayed in the **Data Table** are labeled **A**, **B**, **C**, and so on.

Overwriting Data in the Data Table Display

If you use the command line to overwrite data previously retrieved using Datafeed Toolbox or Database Toolbox software, two events could occur:

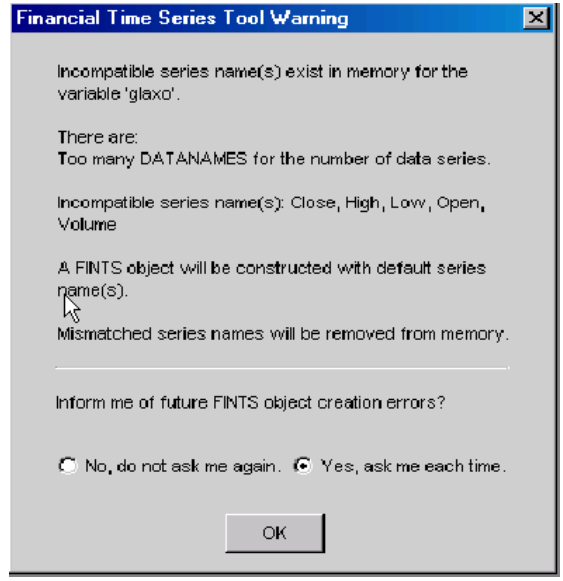
- If the new data contains the same number of columns as before, the headers remain unchanged when you attempt to create a financial time series (`fints`) object using the modified data.

- If the data contains a different number of columns, a warning dialog box appears.

For example, assume that you use Datafeed Toolbox software to obtain `Close`, `High`, `Low`, and `Volume` data for the equity GlaxoSmithkline. You store the data in the MATLAB workspace with the variable name `glaxo`. From the command line, if you redefine the variable `glaxo`, eliminating the second column (`Close`)

```
glaxo(:,2) = [ ]
```

and then return to FTSTool and attempt to create a financial time series object, a warning dialog box appears.



Modifying Data for a Financial Time Series Object in the Data Table

FTSTool lets you update your data displayed in the **Data Table** by adding or removing rows or columns.

Note Modifying data in the **Data Table** will not update the MATLAB workspace variable. To update the workspace variable after modifying the **Data Table**, click **Update workspace variable**.

Adding and Removing Rows

To add a row of data displayed in the **Data Table**:

1. Select a row from the **Data Table** display where you want to add a row. Click **Additional options** to open the Data Table Options dialog box.

2. Click **Add row**. The default is to add the row up. To add a row down, select **Insertion option** and then click **Add down**. In addition, you can select the **Insertion option** of **Date** to designate a specific date. (If a date is not specified, the added row will contain a date that is chronologically in order with respect to the initial row.)

   When you add rows, the **Data Table** display is immediately updated.

To remove a row of data from the **Data Table**:

1. Select one or more rows in the **Data Table** display that you want to remove. Click **Additional options** to open the Data Table Options dialog box.

2. Click **Remove row(s)**. The default is to remove the selected rows. In addition, to remove selected rows, select **Removal options** and then select other options for row removal from the **Remove rows** list box. You can specify a **Start** and **End** date or you can click the **Non-uniform range setting** option to designate a range.

   When you remove rows, the **Data Table** display is updated immediately.

Adding and Removing Columns

To add a column of data displayed in the **Data Table**:

1. Select a column from the **Data Table** display where you want to add a column. Click **Additional options** to open the Data Table Options dialog box.

2 Click **Add column**. The default is to add the column to the left of the selected column.

Note For time series objects, you cannot add a column to the left of the `Date/Times` column; there is no restriction for double data.

To add a column to the right, select **Insertion option** and then click **Add right**. In addition, you can use the **Insertion option** of **New Column Name** to designate a specific column name. (If a **New Column Name** is not specified, an added column will contain a column name of `series1`, `series2`, and so on.)

When you add columns, the **Data Table** display is updated immediately.

To remove a column of data displayed in the **Data Table**:

1 Select one or more columns in the **Data Table** display that you want to remove. Click **Additional options** to open the Data Table Options dialog box.

2 Click **Remove column(s)**. The default is to remove the selected rows. In addition, to remove selected columns, select **Removal options** and then select columns for removal from the **Remove columns** list box.

When you remove columns, the **Data Table** display is updated immediately.

Viewing and Modifying the Properties for a FINTS Object

The **FINTS Object Properties** pane in FTSTool lets you modify financial time series (`fints`) object properties. This area becomes active whenever the **Data Table** displays a financial time series object.

To modify the properties for a `fints` object:

1 After you create a `fints` object, double-click the object name in the **MATLAB Workspace Variables** list box to open the **Data Table** and display the `fints` object properties.

2 Click to modify the **Description**, **Frequency**, or **Series Names** fields.

The **Frequency** drop-down list supports the following conversion functions:

Function	New Frequency
`toannual`	Annual
`todaily`	Daily
`tomonthy`	Monthly
`toquarterly`	Quarterly
`tosemi`	Semiannually
`toweekly`	Weekly

3 Click **Update properties** to save the changes. This action also updates the associated workspace variable.

Using FTSTool with Other Time Series GUIs

FTSTool works with Datafeed Toolbox and Database Toolbox software to load data. In addition, FTSTool interoperates with `chartfts` to display an interactive plot and `ftsgui` to perform further time series data analysis.

The workflow for using FTSTool with `chartfts` is:

1. After loading data from either Datafeed Toolbox or Database Toolbox software or an internal file, select a variable from the **MATLAB Workspace Variables** list box.
2. Click the **Plot** tab, click **Type**, and then select **Interactive Chart**.
3. Click **Plot**. The interactive plot is displayed in `chartfts`. You can then use `chartfts` menu items for further display options.

   For more information on `chartfts`, select **Help** > **Graphics Help**.

The workflow for using FTSTool with the Financial Time Series GUI (`ftsgui`) is:

1. After loading data from either Datafeed Toolbox or Database Toolbox software or an internal file, select a variable from the **MATLAB Workspace Variables** list box.
2. Select **Tools** > **FTSGUI** to open the Financial Time Series GUI window.
3. Select a variable from the **MATLAB Workspace Variables** list box. Click the **Plot** tab and then select one of the following from the **Type** drop-down list: `Line Plot`, `High-Low Plot`, or `Candlestick Plot`.
4. Click **Plot**. The plot is displayed in a MATLAB graphic window. In addition, the Financial Time Series GUI window displays an entry for the plotted `fints` object. You can then use the menu items in the Financial Time Series GUI window to perform further analysis.

   For more information on `ftsgui`, select **Help** > **Help on Financial Time Series GUI**.

Note If the selected workspace variable that you are plotting is not a `fints` object, a `fints` object is created when you click **Plot**. The new `fints` object uses the name designated by the **MATLAB workspace variable** box on the **Create** tab.

10

Financial Time Series Graphical User Interface

- "Introduction" on page 10-2
- "Using the Financial Time Series GUI" on page 10-7

Introduction

Use the financial time series graphical user interface (GUI) to analyze your time series data and display the results graphically without resorting to the command line. The GUI lets you visualize the data and the results at the same time.

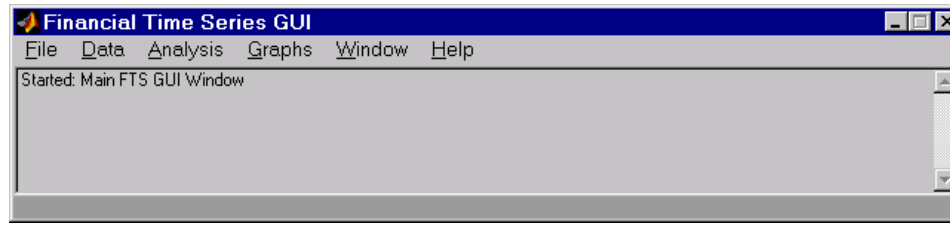
"Using the Financial Time Series GUI" on page 10-7 discusses how to use this GUI.

Main Window

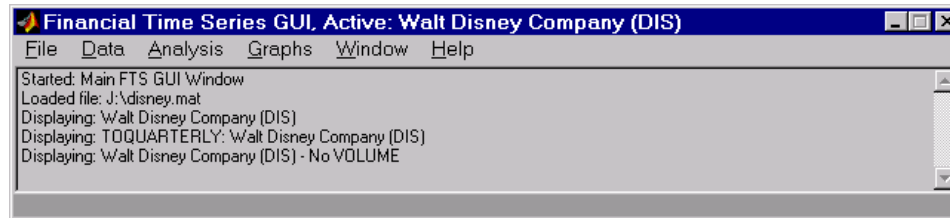
Start the financial time series GUI with the command

```
ftsgui
```

The Financial Time Series GUI window opens.

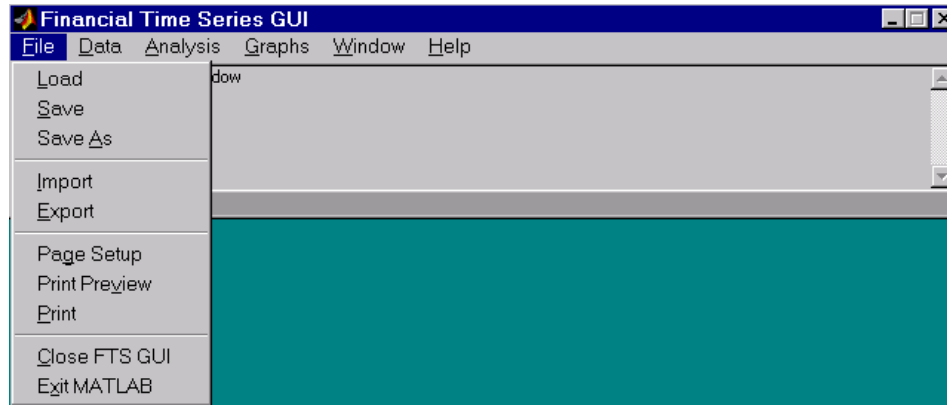


The title bar acts as an active time series object indicator (indicates the currently active financial time series object). For example, if you load the file `disney.mat` and want to use the time series data in the file `dis`, the title bar on the main GUI would read as shown.



The menu bar consists of six menu items: **File**, **Data**, **Analysis**, **Graphs**, **Window**, and **Help**. Under the menu bar is a status box that displays the steps you are doing.

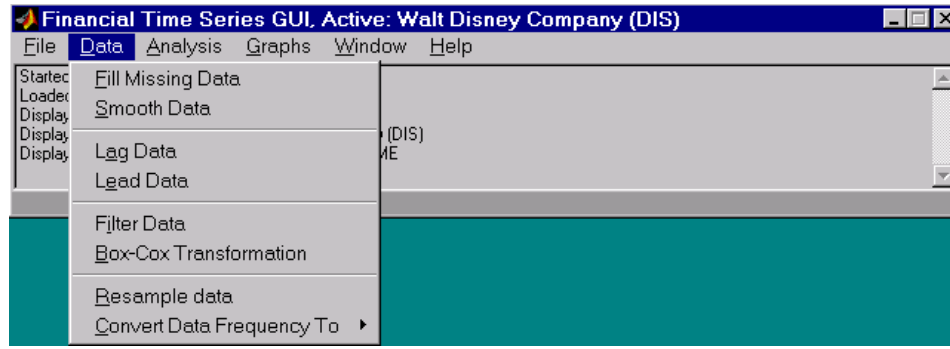
File Menu



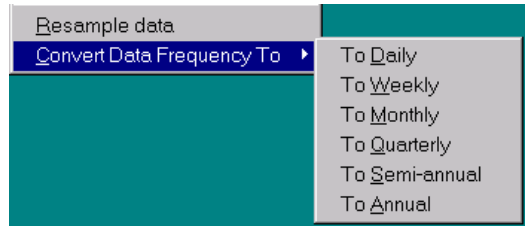
The **File** menu contains the commands for input and output. You can read and save (**Load**, **Save**, and **Save As**) MATLAB MAT-files, ASCII (text) data files, as well as import (**Import**) Excel XLS files. MATLAB software does not support the export of Excel XLS files at this time.

The **File** menu also contains the printing suite (**Page Setup**, **Print Preview**, and **Print**). Lastly, from this menu you can close the GUI itself (**Close FTS GUI**) and quit MATLAB (**Exit MATLAB**).

Data Menu

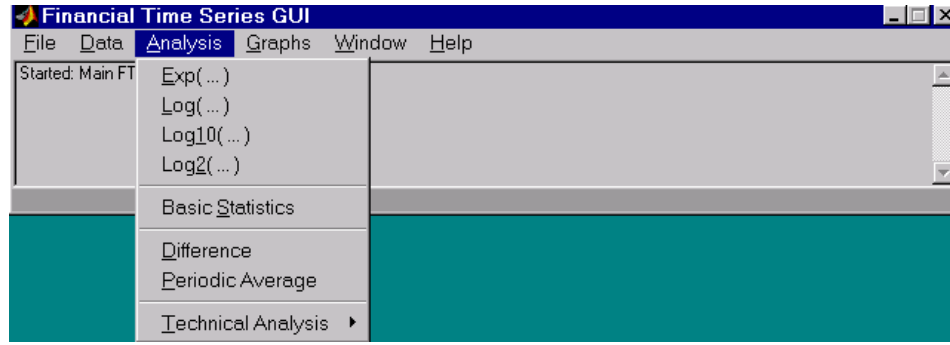


The **Data** menu provides a collection of data manipulation functions and data conversion functions.



To use any of the functions here, make sure that the correct financial time series object is displayed in the title bar of the main GUI window.

Analysis Menu

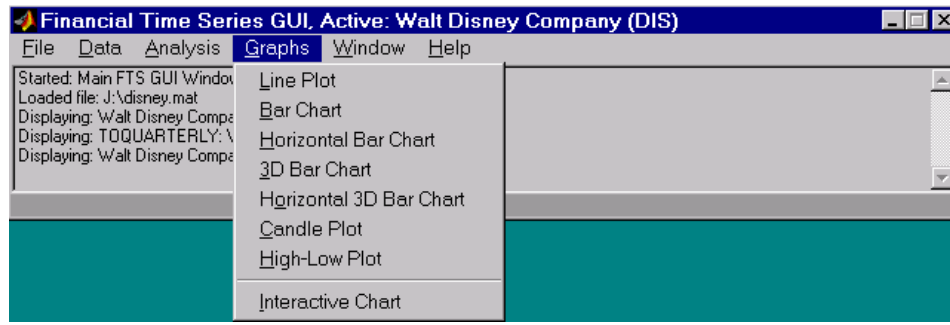


The **Analysis** menu provides

- A set of exponentiation and logarithmic functions.
- Statistical tools (**Basic Statistics**), which calculate and display the minimum, maximum, average (mean), standard deviation, and variance of the current (active) time series object; these basic statistics numbers are displayed in a dialog window.
- Data difference (**Difference**) and periodic average (**Periodic Average**) calculations. Data difference generates a vector of data that is the difference between the first data point and the second, the second and the third, and so on. The periodic average function calculates the average per defined length period, for example, averages of every five days.
- Technical analysis functions. See Chapter 12, "Technical Analysis" for a list of the provided technical analysis functions.

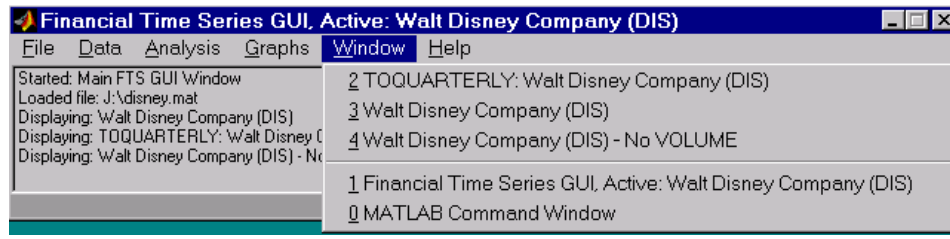
As with the **Data** menu, to use any of the **Analysis** menu functions, make sure that the correct financial time series object is displayed in the title bar of the main GUI window.

Graphs Menu



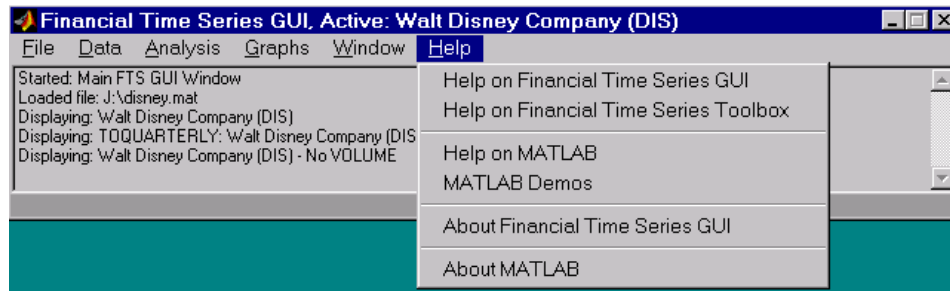
The **Graphs** menu contains functions that graphically display the current (active) financial time series object. You can also start up the interactive charting function (`chartfts`) from this menu.

Window Menu



The **Window** menu lists open windows under the current MATLAB session.

Help Menu



The **Help** menu provides a standard set of Help menu links.

Using the Financial Time Series GUI

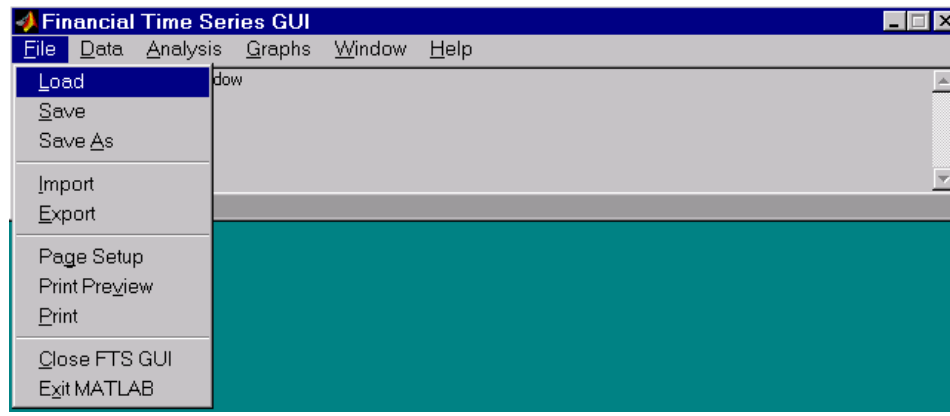
In this section...

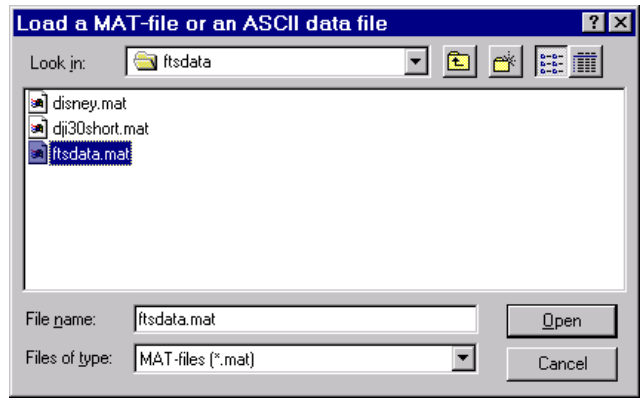
"Getting Started" on page 10-7
"Data Menu" on page 10-9
"Analysis Menu" on page 10-13
"Graphs Menu" on page 10-15
"Saving Time Series Data" on page 10-19

Getting Started

To use the Financial Time Series GUI, first start the financial time series GUI with the command `ftsgui`. Then load (or import) the time series data.

For example, if your data is in a MATLAB MAT-file, select **Load** from the **File** menu.



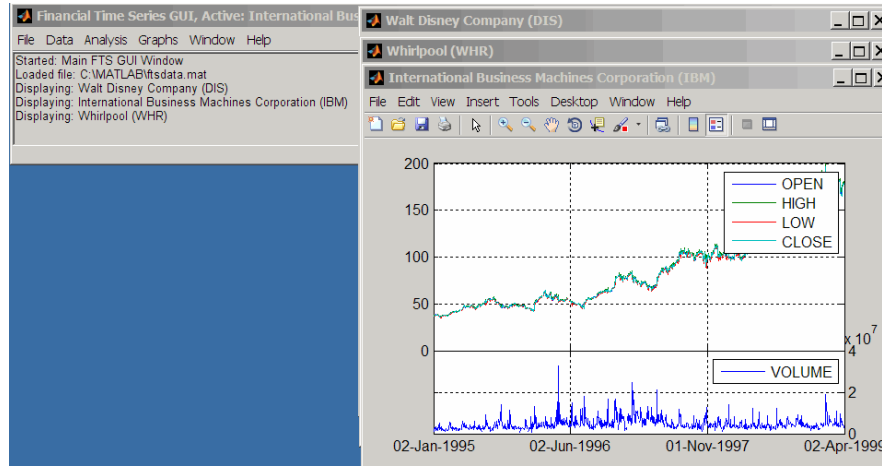


For illustration purposes, choose the file `ftsdata.mat` from the dialog presented.

If you don't see the MAT-file, look in the directory *`matlabroot`*`\toolbox\finance\findemos`, where *`matlabroot`* is the MATLAB root directory (the directory where MATLAB is installed).

Note Data loaded through the Financial Time Series GUI is not available in the MATLAB workspace. You can access this data only through the GUI itself, not with any MATLAB command-line functions.

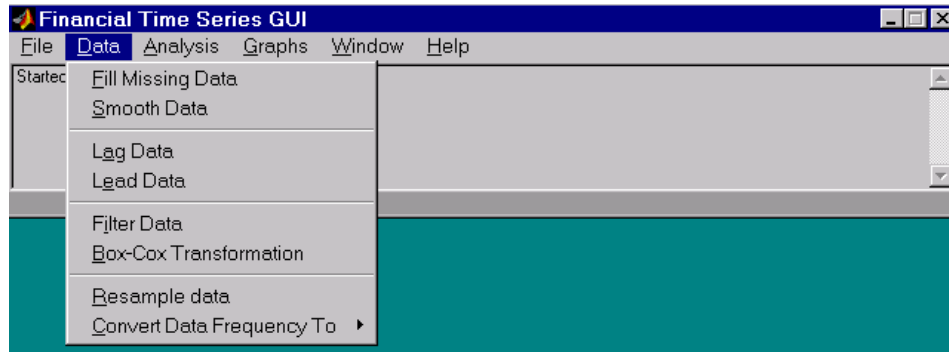
Each financial time series object inside the MAT-file is presented as a line plot in a separate window. The status window is updated accordingly.



Whirlpool (WHR) is the last plot displayed, as indicated on the title bar of the main window.

Data Menu

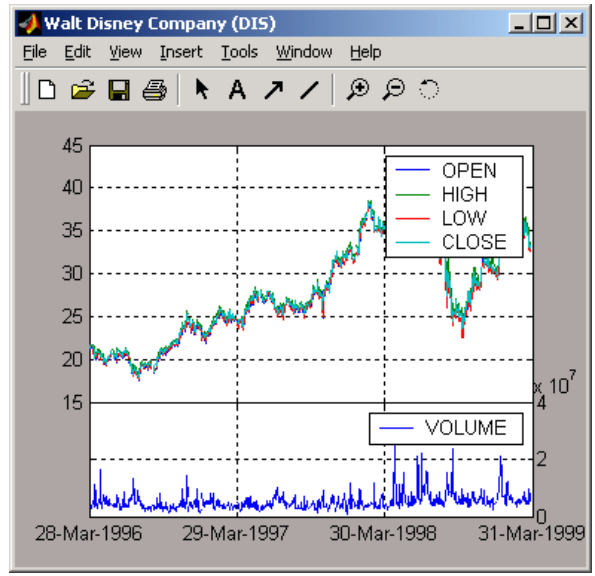
The **Data** menu provides functions that manipulate time series data.



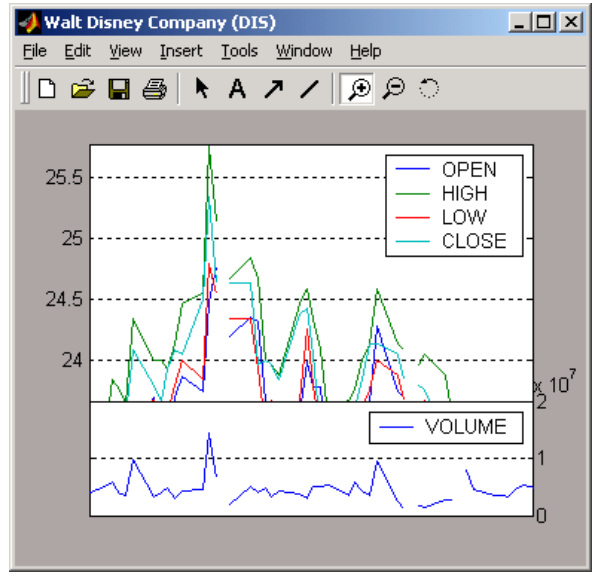
Here are some example tasks that illustrate the use of the functions on this menu.

Fill Missing Data

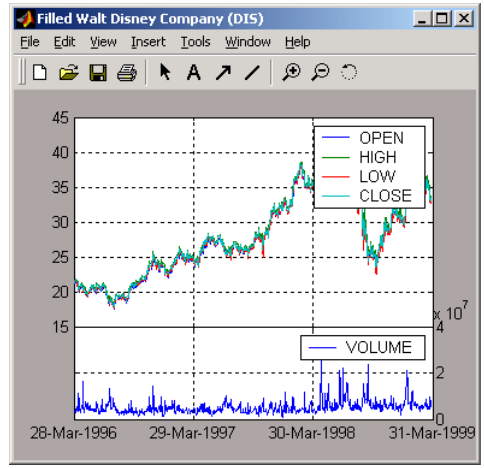
First, look at filling missing data. The **Fill Missing Data** item uses the toolbox function `fillts`. With the data loaded from the file `ftsdata`, you have three time series: IBM Corp. (IBM), Walt Disney Co. (DIS), and Whirlpool (WHR). Click on the window that shows the time series data for Walt Disney Co. (DIS).

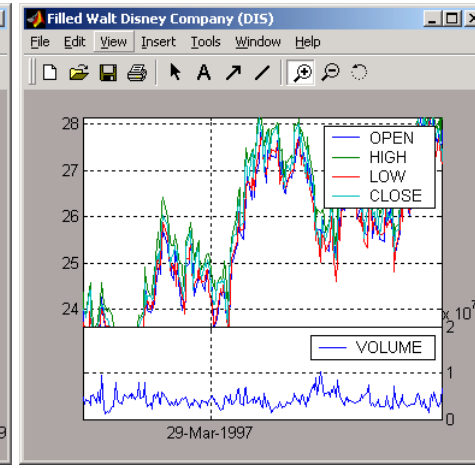


To view any missing data in this time series data set, zoom into the plot using the Zoom tool (the magnifying glass icon with the plus sign) from the toolbar and select a region.



The gaps represent the missing data in the series. To fill these gaps, select **Data > Fill Missing Data**. This selection automatically fills the gaps and generates a new plot that displays the filled time series data.

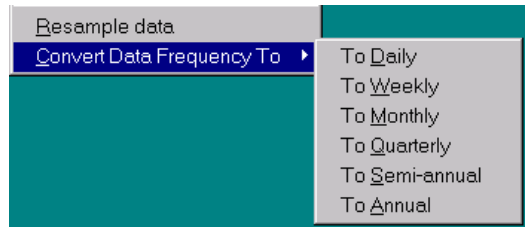




You cannot see the filled gaps when you display the entire data set. However, when you zoom into the plot, you see that the gaps have been eliminated. Note that the title bar has changed; the title has been prefixed with the word **Filled** to reflect the filled time series data.

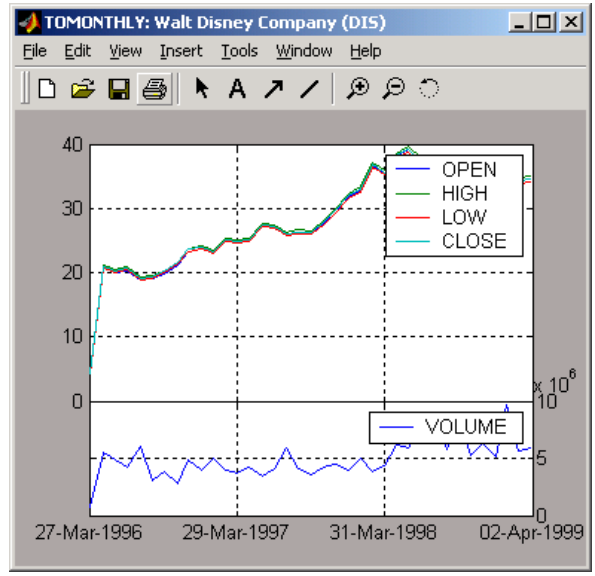
Frequency Conversion

The **Data** menu also provides access to frequency conversion functions.



This example changes the DIS time series data frequency from daily to monthly. Close the Filled Walt Disney Company (DIS) window, and click the Walt Disney Company (DIS) window to make it active (current) again. Then, from the **Data** menu, select **Convert Data Frequency To** and **To Monthly**.

A new figure window displays the result of this conversion.

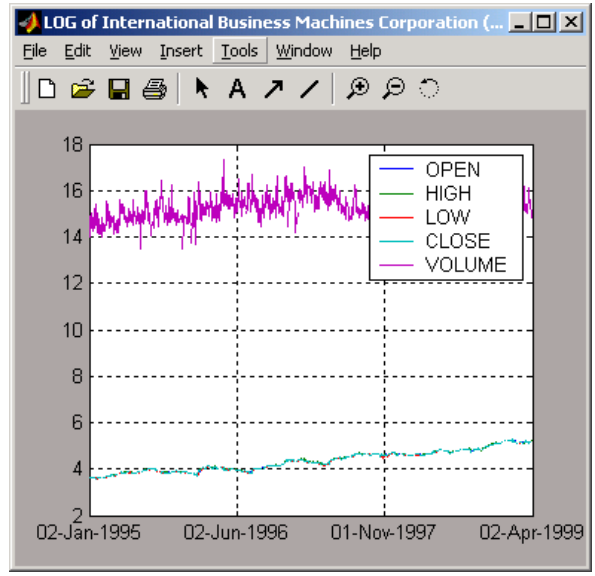


The title reflects that the data displayed had its frequency changed to monthly.

Analysis Menu

The **Analysis** menu provides functions that analyze time series data, including the technical analysis functions. (See Chapter 12, "Technical Analysis" for a complete list of the technical analysis functions and several usage examples.)

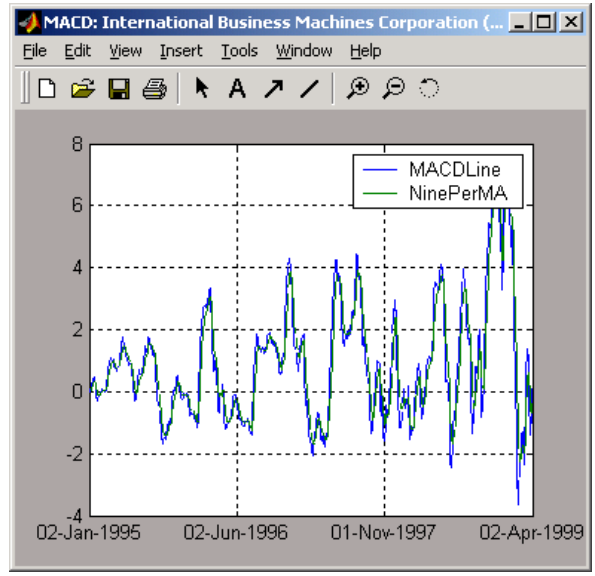
For example, you can use the **Analysis** menu to calculate the natural logarithm (`log`) of the data contained within the data set `ftsdata.mat`. This data file provides time series data for IBM (IBM), Walt Disney (DIS), and Whirlpool (WHR). Click the window displaying the data for IBM Corporation (IBM) to make it active (current). Then select the **Analysis** menu, followed by **Log(...)**. The result appears in its own window.



Close the above window and click again on the IBM data window to make it active (current).

Note Before proceeding with any time series analysis, make certain that the title bar confirms that the active data series is the correct one.

From the **Analysis** menu on the main window, select **Technical Analysis** and **MACD**. The result, again, is displayed in its own window.



Other analysis functions work similarly.

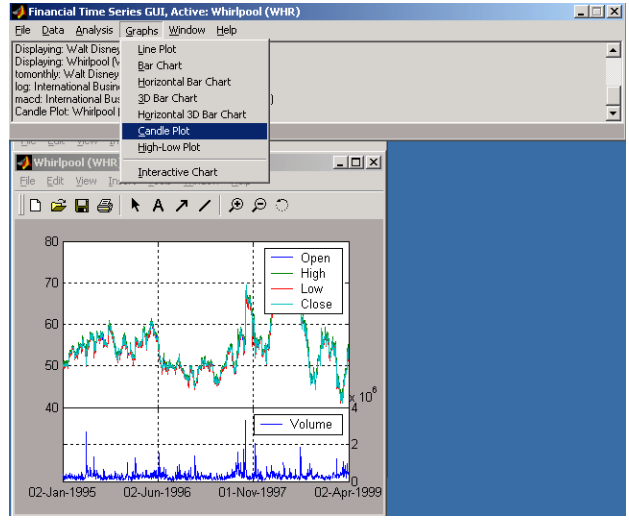
Graphs Menu

The **Graphs** menu displays time series data using the provided graphics functions. Included in the **Graphs** menu are several types of bar charts (`bar`, `barh` and `bar3`, `bar3h`), line plot (`plot`), candle plot (`candle`), and High-Low plot (`highlow`). The **Graphs** menu also provides access to the interactive charting function, `chartfts`.

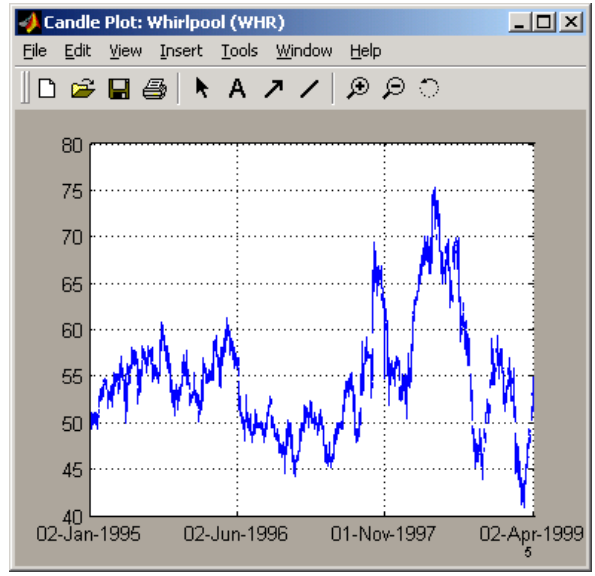
Candle Plot

For example, you can display the candle plot of a set of time series data and start up the interactive chart on the same data set.

Load the `ftsdata.mat` data set, and click the window that displays the Whirlpool (WHR) time series data to make it active (current). From the main window, select the **Graphs** menu and then **Candle Plot**.

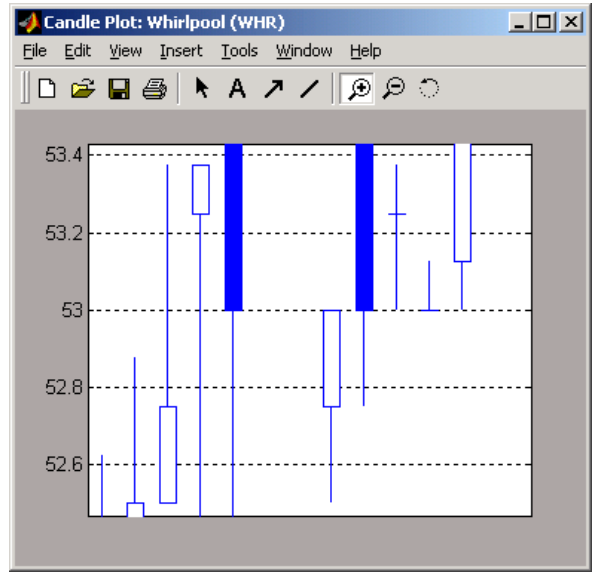


The result is shown below.



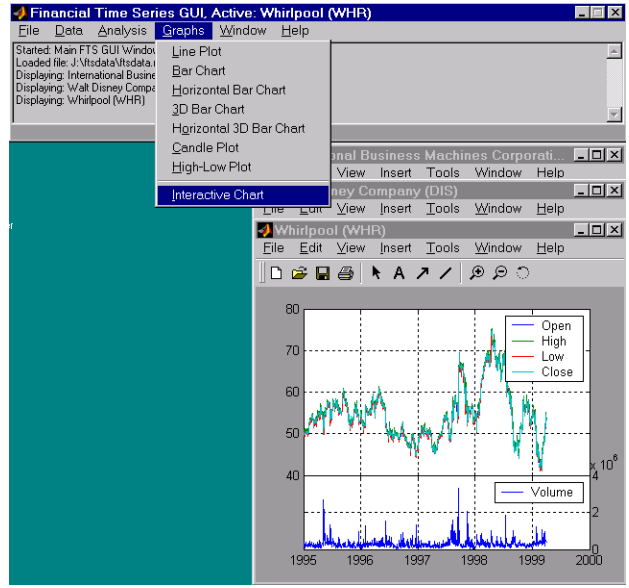
This does not look much like a candle plot because there are too many data points in the data set. All the candles are too compressed for effective

viewing. However, when you zoom into a region of this plot, the candles become apparent.

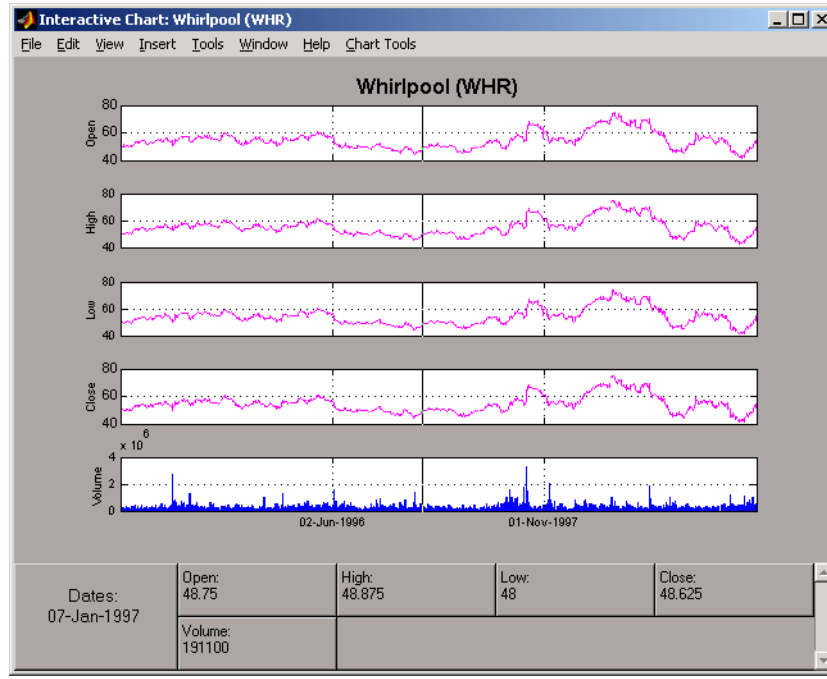


Interactive Chart

To create an interactive chart (`chartfts`) on the Whirlpool data, click the window that displays the Whirlpool (WHR) data to make it active (current). Then, go to the **Graphs** menu and select **Interactive Chart**.



The chart that results is shown below.



You can use this interactive chart as if you had invoked it with the `chartfts` command from the MATLAB command line. For a tutorial on the use of `chartfts`, see "Visualizing Financial Time Series Objects" on page 7-18.

Saving Time Series Data

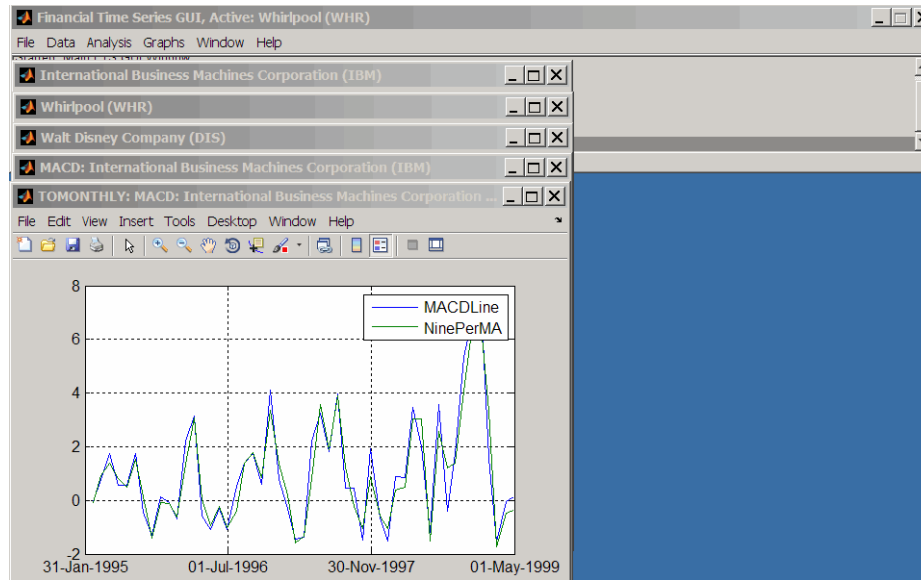
The **Save** and **Save As** items on the main window **File** menu let you save the time series data that results from your analyses and computations. These items save *all* time series data that has been loaded or processed during the current session, even if the window displaying the results of a computation has previously been dismissed.

Note The **Save** and **Save As** items on the **File** menu of the individual plot windows will not save the time series data, but will save the actual plot.

You can save your time series data in two ways:

- Into the latest MAT-file loaded (**Save**)
- Into a MAT-file chosen (or named) from the window (**Save As**)

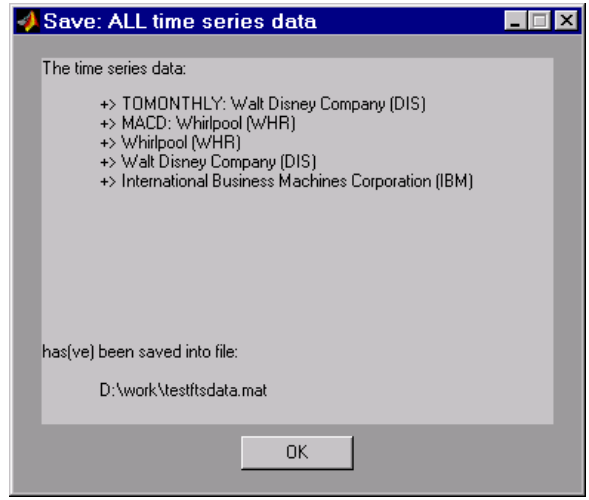
To illustrate this, start by loading the data file `testftsdata.mat` (located in *`matlabroot`*`/toolbox/finance/findemos`). Then, convert the Disney (DIS) data from daily (the original frequency) to monthly data. Next, run the MACD analysis on the Whirlpool (WHR) data. You now have a set of five open figure windows.



Saving into the Original File (Save)

To save the data back into the original file (`testftsdata.mat`), select **Save** from the **File** menu.

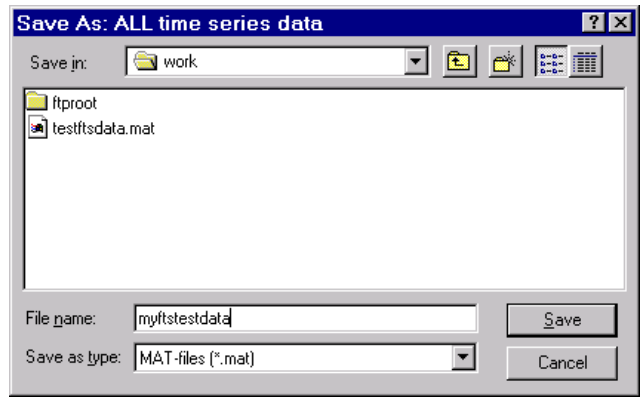
A confirmation window appears. It confirms that the data has been saved in the latest MAT-file loaded (`testftsdata.mat` in this example).



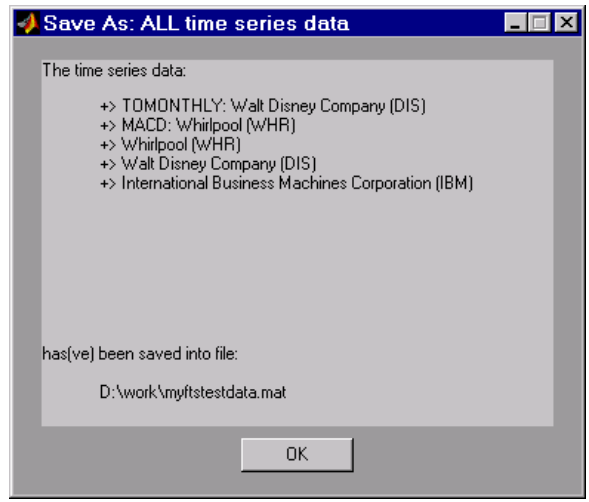
Saving into a New File (Save As)

To save the data in a different file, choose **Save As** from the **File** menu.

The dialog box that appears lets you choose an existing MAT-file from a list or type in the name of a new MAT-file you want to create.



After you click the **Save** button, another confirmation window appears.



This confirmation window indicates that the data has been saved in a new file named `myftstestdata.mat`.

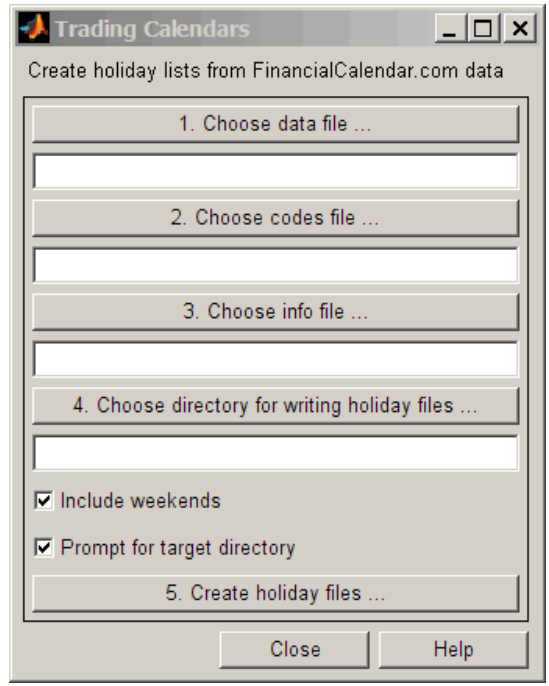
11

Trading Date Utilities

- “Trading Calendars Graphical User Interface” on page 11-2
- “UICalendar Graphical User Interface” on page 11-4

Trading Calendars Graphical User Interface

Use the `createholidays` function to open the Trading Calendars graphical user interface.



The `createholidays` function supports `http://www.FinancialCalendar.com` trading calendars. This function can be used from the command line or from the Trading Calendars graphical user interface. For more information on using the command line to programmatically generate the market specific `holidays.m` files without displaying the interface, see `createholidays`.

To use the Trading Calendars graphical user interface:

1. From the command line, type the following command to open the Trading Calendars graphical user interface.

```
createholidays
```

2. Click **Choose data file** to select the data file.
3. Click **Choose codes file** to select the codes file.
4. Click **Choose info file** to select the info file.
5. Click **Choose directory for writing holiday files** to select the output directory.
6. Select **Include weekends** to include weekends in the holiday list and click **Prompt for target directory** to be prompted for the file location for each `holidays.m` file that is created.
7. Click **Create holiday files** to convert `FinancialCalendar.com` financial center holiday data into market-specific `holidays.m` files.

   The market-specific `holidays.m` files can be used in place of the standard `holidays.m` that ships with Financial Toolbox software.

UICalendar Graphical User Interface

In this section...

"Using UICalendar in Standalone Mode" on page 11-4

"Using UICalendar with an Application" on page 11-5

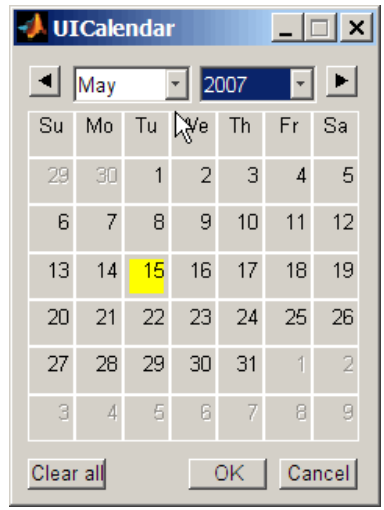
Using UICalendar in Standalone Mode

You can use the UICalendar graphical user interface in standalone mode to look up any date. To use the standalone mode:

1 Type the following command to open the UICalendar GUI:

```
uicalendar
```

The UICalendar interface is displayed:



2 Click the date and year controls to locate any date.

Using UICalendar with an Application

You can use the UICalendar graphical user interface with an application to look up any date. To use the UICalendar graphical interface with an application, use the following command:

```
uicalendar('PARAM1', VALUE1, 'PARAM2', VALUE2', ...)
```

For more information, see `uicalendar`.

Example of Using UICalendar with an Application

The UICalendar example creates a function that displays a graphical user interface that lets you select a date from the UICalendar graphical user interface and fill in a text field with that date.

1. Create a figure.

```
function uicalendarGUIExample
f = figure('Name', 'uicalendarGUIExample');
```

2. Add a text control field.

```
dateTextHandle = uicontrol(f, 'Style', 'Text', ...
'String', 'Date:', ...
'Horizontalalignment', 'left', ...
'Position', [100 200 50 20]);
```

3. Add a uicontrol editable text field to display the selected date.

```
dateEditBoxHandle = uicontrol(f, 'Style', 'Edit', ...
'Position', [140 200 100 20], ...
'BackgroundColor', 'w');
```

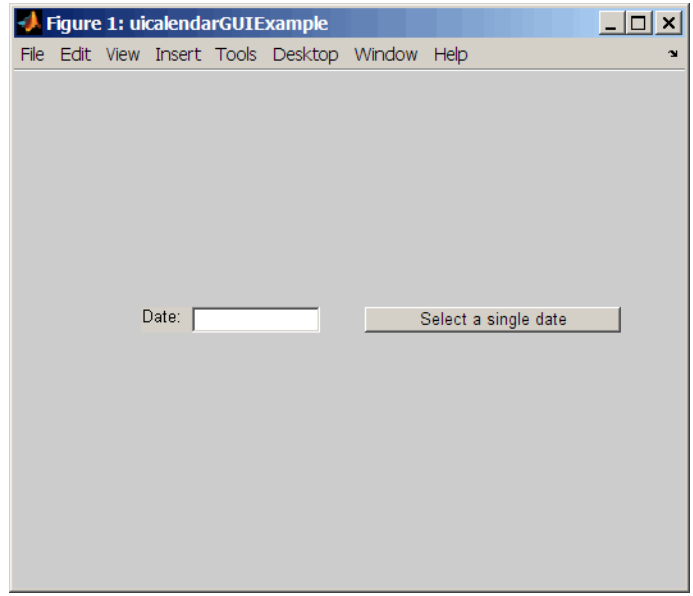
4. Create a push button that startups the UICalendar.

```
calendarButtonHandle = uicontrol(f, 'Style', 'PushButton', ...
'String', 'Select a single date', ...
'Position', [275 200 200 20], ...
'callback', @pushbutton_cb);
```

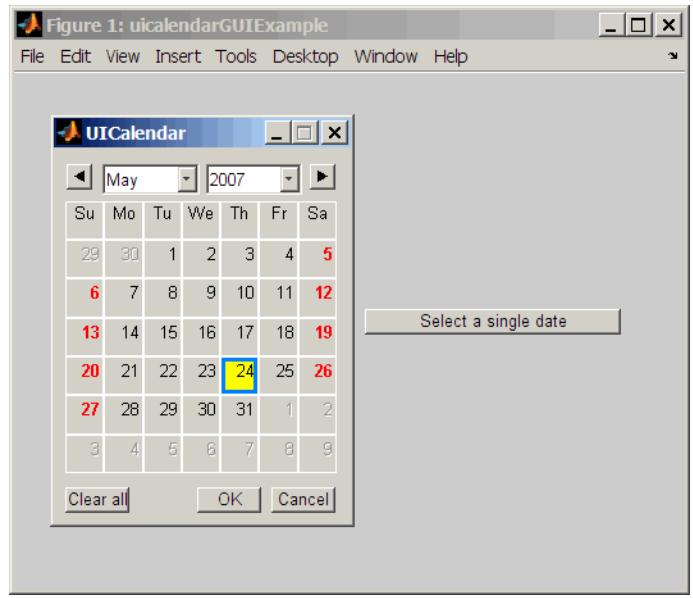
5. To startup UICalendar, create a nested function (callback function) for the push button.

```
function pushbutton_cb(hcbo, eventStruct)
% Create a UICALENDAR with the following properties:
% 1) Highlight weekend dates.
% 2) Only allow a single date to be selected at a time.
% 3) Send the selected date to the edit box uicontrol.
uicalendar('Weekend', [1 0 0 0 0 0 1], ...
'SelectionType', 1, ...
'DestinationUI', dateEditBoxHandle);
end
end
```

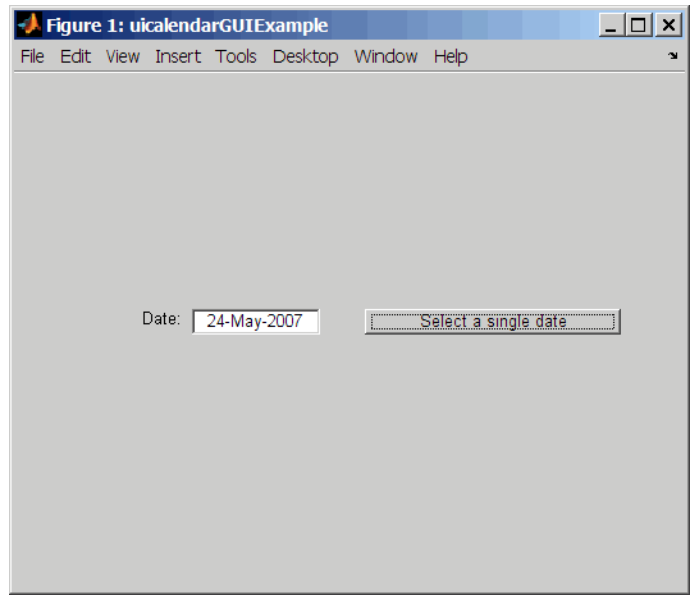
6 Run the function `uicalendarGUIExample` to display the application interface:



7 Click **Select a single date** to display the UICalendar graphical user interface:



8 Select a date and click **OK** to display the date in the text field:



12

Technical Analysis

- "Introduction" on page 12-2
- "Examples" on page 12-4

Introduction

Technical analysis (or charting) is used by some investment managers to help manage portfolios. Technical analysis relies heavily on the availability of historical data. Investment managers calculate different indicators from available data and plot them as charts. Observations of price, direction, and volume on the charts assist managers in making decisions on their investment portfolios.

The technical analysis functions in this toolbox are tools to help analyze your investments. The functions in themselves will not make any suggestions or perform any qualitative analysis of your investment.

Technical Analysis: Oscillators

Function	Type
`adosc`	Accumulation/distribution oscillator
`chaikosc`	Chaikin oscillator
`macd`	Moving Average Convergence/Divergence
`stochosc`	Stochastic oscillator
`tsaccel`	Acceleration
`tsmom`	Momentum

Technical Analysis: Stochastics

Function	Type
`chaikvolat`	Chaikin volatility
`fpctkd`	Fast stochastics
`spctkd`	Slow stochastics
`willpctr`	Williams %R

Technical Analysis: Indexes

Function	Type
`negvolidx`	Negative volume index
`posvolidx`	Positive volume index
`rsindex`	Relative strength index

Technical Analysis: Indicators

Function	Type
`adline`	Accumulation/distribution line
`bollinger`	Bollinger band
`hhigh`	Highest high
`llow`	Lowest low
`medprice`	Median price
`onbalvol`	On balance volume
`prcroc`	Price rate of change
`pvtrend`	Price-volume trend
`typprice`	Typical price
`volroc`	Volume rate of change
`wclose`	Weighted close
`willad`	Williams accumulation/distribution

Examples

In this section...

"Overview" on page 12-4
"Moving Average Convergence/Divergence (MACD)" on page 12-4
"Williams %R" on page 12-6
"Relative Strength Index (RSI)" on page 12-7
"On-Balance Volume (OBV)" on page 12-8

Overview

To illustrate some the technical analysis functions, this section uses the IBM stock price data contained in the supplied file `ibm9599.dat`. First create a financial time series object from the data using `ascii2fts`:

```
ibm = ascii2fts('ibm9599.dat', 1, 3, 2);
```

The time series data contains the open, close, high, and low prices, as well as the volume traded on each day. The time series dates start on January 3, 1995, and end on April 1, 1999, with some values missing for weekday holidays; weekend dates are not included.

Moving Average Convergence/Divergence (MACD)

Moving Average Convergence/Divergence (MACD) is an oscillator function used by technical analysts to spot overbought and oversold conditions. Look at the portion of the time series covering the 3-month period between October 1, 1995 and December 31, 1995. At the same time fill any missing values due to holidays within the time period specified:

```
part_ibm = fillts(ibm('10/01/95::12/31/95'));
```

Now calculate the MACD, which when plotted produces two lines; the first line is the MACD line itself and the second is the nine-period moving average line:

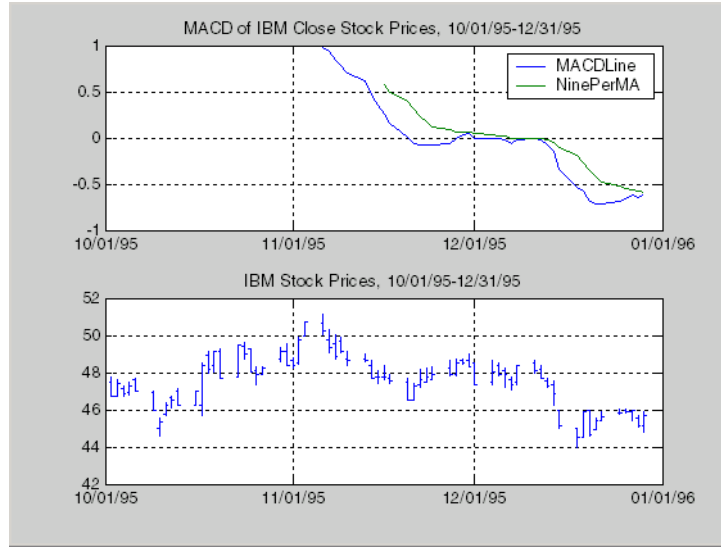
```
macd_ibm = macd(part_ibm);
```

Note When you call `macd` without giving it a second input argument to specify a particular data series name, it searches for a closing price series named `Close` (in all combinations of letter cases).

Plot the MACD lines and the High-Low plot of the IBM stock prices in two separate plots in one window.

```
subplot(2, 1, 1);
plot(macd_ibm);
title('MACD of IBM Close Stock Prices, 10/01/95-12/31/95');
datetick('x', 'mm/dd/yy');
subplot(2, 1, 2);
highlow(part_ibm);
title('IBM Stock Prices, 10/01/95-12/31/95');
datetick('x', 'mm/dd/yy')
```

The following figure shows the result.



Williams %R

Williams %R is an indicator that measures overbought and oversold levels. The function `willpctr` is from the stochastics category. All the technical analysis functions can accept a different name for a required data series. If, for example, a function needs the high, low, and closing price series but your time series object does not have the data series names exactly as `High`, `Low`, and `Close`, you can specify the correct names as follows.

```
wpr = willpctr(tsobj, 14, 'HighName', 'Hi', 'LowName', 'Lo',...
'CloseName', 'Closing')
```

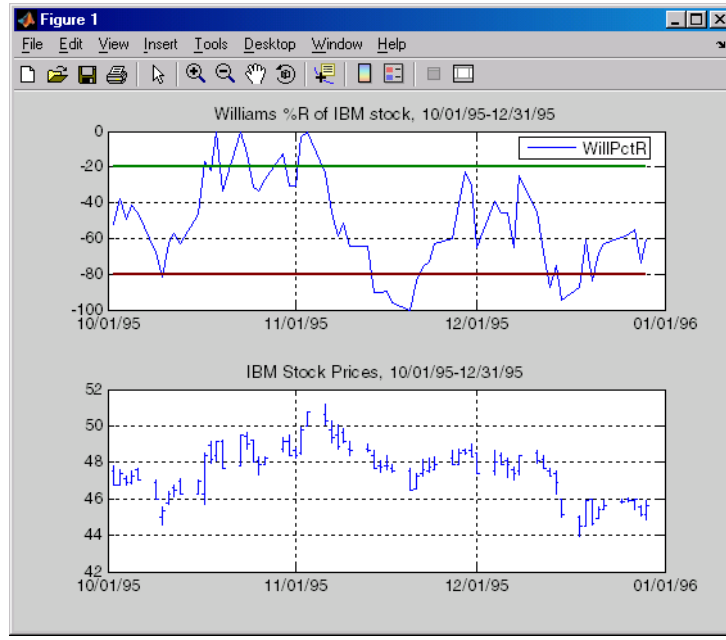
The function `willpctr` now assumes that your high price series is named `Hi`, low price series is named `Lo`, and closing price series is named `Closing`.

Since the time series object `part_ibm` has its data series names identical to the required names, name adjustments are not needed. The input argument to the function is only the name of the time series object itself.

Calculate and plot the Williams %R indicator for IBM stock along with the price range using these commands:

```
wpctr_ibm = willpctr(part_ibm);
subplot(2, 1, 1);
plot(wpctr_ibm);
title('Williams %R of IBM stock, 10/01/95-12/31/95');
datetick('x', 'mm/dd/yy');
hold on;
plot(wpctr_ibm.dates, -80*ones(1, length(wpctr_ibm)),...
'color', [0.5 0 0], 'linewidth', 2)
plot(wpctr_ibm.dates, -20*ones(1, length(wpctr_ibm)),...
'color', [0 0.5 0], 'linewidth', 2)
subplot(2, 1, 2);
highlow(part_ibm);
title('IBM Stock Prices, 10/01/95-12/31/95');
datetick('x', 'mm/dd/yy');
```

The next figure shows the results. The top plot has the Williams %R line plus two lines at -20% and -80%. The bottom plot is the High-Low plot of the IBM stock price for the corresponding time period.



Relative Strength Index (RSI)

The Relative Strength Index (RSI) is a momentum indicator that measures an equity's price relative to itself and its past performance. The function name is `rsindex`.

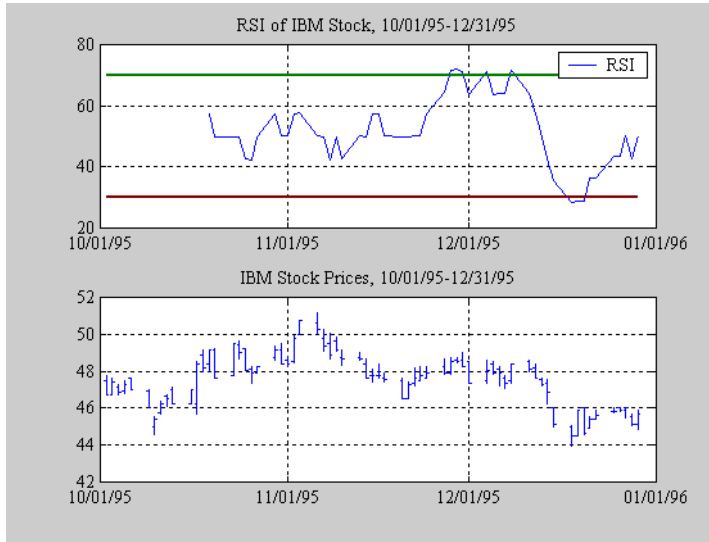
The `rsindex` function needs a series that contains the closing price of a stock. The default period length for the RSI calculation is 14 periods. This length can be changed by providing a second input argument to the function. Similar to the previous commands, if your closing price series is not named `Close`, you can provide the correct name.

Calculate and plot the RSI for IBM stock along with the price range using these commands:

```
rsi_ibm = rsindex(part_ibm);
subplot(2, 1, 1);
plot(rsi_ibm);
title('RSI of IBM stock, 10/01/95-12/31/95');
```

```
datetick('x', 'mm/dd/yy');
hold on;
plot(rsi_ibm.dates, 30*ones(1, length(wpctr_ibm)),...
'color', [0.5 0 0], 'linewidth', 2)
plot(rsi_ibm.dates, 70*ones(1, length(wpctr_ibm)),...
'color',[0 0.5 0], 'linewidth', 2)
subplot(2, 1, 2);
highlow(part_ibm);
title('IBM Stock Prices, 10/01/95-12/31/95');
datetick('x', 'mm/dd/yy');
```

The next figure shows the result.



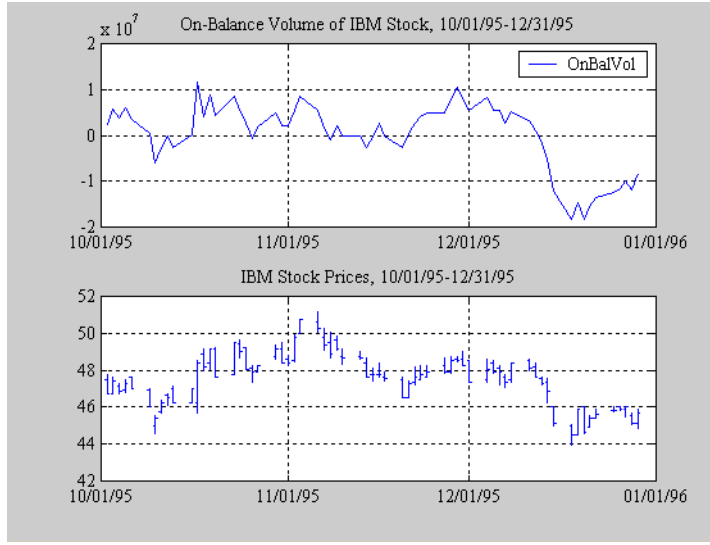
On-Balance Volume (OBV)

On-Balance Volume (OBV) relates volume to price change. The function `onbalvol` requires you to have the closing price (`Close`) series as well as the volume traded (`Volume`) series.

Calculate and plot the OBV for IBM stock along with the price range using these commands:

```
obv_ibm = onbalvol(part_ibm);
subplot(2, 1, 1);
plot(obv_ibm);
title('On-Balance Volume of IBM Stock, 10/01/95-12/31/95');
datetick('x', 'mm/dd/yy');
subplot(2, 1, 2);
highlow(part_ibm);
title('IBM Stock Prices, 10/01/95-12/31/95');
datetick('x', 'mm/dd/yy');
```

The next figure shows the result.



13

Function Reference

Dates (p. 13-2)	Work with dates
Currency and Price (p. 13-6)	Work with currency and price data
Financial Data Charts (p. 13-6)	Create charts
Cash Flows (p. 13-7)	Work with cash flows
Fixed-Income Securities (p. 13-9)	Work with fixed-income securities
Portfolios (p. 13-11)	Analyze and measure performance for portfolios
Financial Statistics (p. 13-14)	Perform statistical analysis of financial data
Derivatives (p. 13-16)	Price and analyze derivatives
GARCH Processes (p. 13-17)	Introduce GARCH analysis
Financial Time Series Object and File Construction (p. 13-18)	Functions for creating financial time series
Financial Time Series Arithmetic (p. 13-18)	Arithmetic in financial time series
Financial Time Series Math (p. 13-19)	Mathematical calculations in financial time series
Financial Time Series Descriptive Statistics (p. 13-19)	Statistics in financial time series
Financial Time Series Utility (p. 13-20)	Utility work with financial time series
Financial Time Series Data Transformation (p. 13-21)	Data transformations of financial time series

Financial Time Series Indicator (p. 13-22)	Work with indicators for financial time series
Financial Time Series GUI (p. 13-23)	Work with Financial Time Series GUI
Financial Time Series Tool (p. 13-23)	Work with Financial Time Series Tool

Dates

Current Time and Date (p. 13-2)	Work with current date and time
Date and Time Components (p. 13-2)	Compute dates and times
Date Conversion (p. 13-3)	Convert dates
Financial Dates (p. 13-4)	Compute financial dates
Coupon Bond Dates (p. 13-5)	Compute coupon bond dates

Current Time and Date

`now`	Current date and time
`today`	Current date

Date and Time Components

`datefind`	Indices of date numbers in matrix
`datevec`	Date components
`day`	Day of month
`eomdate`	Last date of month
`eomday`	Last day of month
`hour`	Hour of date or time

`lweekdate`	Date of last occurrence of weekday in month
`minute`	Minute of date or time
`month`	Month of date
`months`	Number of whole months between dates
`nweekdate`	Date of specific occurrence of weekday in month
`second`	Seconds of date or time
`weekday`	Day of week
`weeknum`	Week in a year
`year`	Year of date
`yeardays`	Number of days in year

Date Conversion

`date2time`	Time and frequency from dates
`datedisp`	Display date entries
`datenum`	Create date number
`datestr`	Create date string
`dec2thirtytwo`	Decimal to thirty-second quotation
`m2xdate`	MATLAB serial date number to Excel serial date number
`thirtytwo2dec`	Thirty-second quotation to decimal
`time2date`	Dates from time and frequency
`uicalendar`	Graphical calendar
`x2mdate`	Excel serial date number to MATLAB serial date number

Financial Dates

`busdate`	Next or previous business day
`busdays`	Business days in serial date format
`createholidays`	Create trading calendars
`datemnth`	Date of day in future or past month
`datewrkdy`	Date of future or past workday
`days360`	Days between dates based on 360-day year
`days360e`	Days between dates based on 360-day year (European)
`days360isda`	Days between dates based on 360-day year (International Swap Dealer Association (ISDA) compliant)
`days360psa`	Days between dates based on 360-day year (Public Securities Association (PSA) compliant)
`days365`	Days between dates based on 365-day year
`daysact`	Actual number of days between dates
`daysadd`	Date away from starting date for any day-count basis
`daysdif`	Days between dates for any day-count basis
`fbusdate`	First business date of month
`holidays`	Holidays and nontrading days
`isbusday`	True for dates that are business days
`lbusdate`	Last business date of month
`thirdwednesday`	Find third Wednesday of month

`wrkdydif`	Number of working days between dates
`yearfrac`	Fraction of year between dates

Coupon Bond Dates

`accrfrac`	Fraction of coupon period before settlement
`cfamounts`	Cash flow and time mapping for bond portfolio
`cfdates`	Cash flow dates for fixed-income security
`cfport`	Portfolio form of cash flow amounts
`cftimes`	Time factors corresponding to bond cash flow dates
`cpncount`	Coupon payments remaining until maturity
`cpndaten`	Next coupon date for fixed-income security
`cpndatenq`	Next quasi coupon date for fixed income security
`cpndatep`	Previous coupon date for fixed-income security
`cpndatepq`	Previous quasi coupon date for fixed income security
`cpndaysn`	Number of days to next coupon date
`cpndaysp`	Number of days since previous coupon date
`cpnpersz`	Number of days in coupon period

Currency and Price

`cur2frac`	Decimal currency values to fractional values
`cur2str`	Bank-formatted text
`dec2thirtytwo`	Decimal to thirty-second quotation
`frac2cur`	Fractional currency value to decimal value
`thirtytwo2dec`	Thirty-second quotation to decimal

Financial Data Charts

`bar, barh`	Bar chart
`bar3, bar3h`	3-D bar chart
`bolling`	Bollinger band chart
`candle`	Candlestick chart
`candle (fts)`	Time series candle plot
`chartfts`	Interactive display
`dateaxis`	Convert serial-date axis labels to calendar-date axis labels
`highlow`	High, low, open, close chart
`highlow (fts)`	Time series High-Low plot
`kagi`	Kagi chart
`linebreak`	Line break chart
`movavg`	Leading and lagging moving averages chart
`plot`	Plot data series
`pointfig`	Point and figure chart

`priceandvol`	Price and volume chart
`renko`	Renko chart
`volarea`	Price and volume chart

Cash Flows

Annuities (p. 13-7)	Work with annuities
Amortization and Depreciation (p. 13-7)	Work with amortization and depreciation
Present Value (p. 13-8)	Work with present values
Future Value (p. 13-8)	Work with future values
Payment Calculations (p. 13-8)	Work with payment calculations
Rates of Return (p. 13-8)	Work with rates of return
Cash Flow Sensitivities (p. 13-9)	Work with cash flow sensitivities

Annuities

`annurate`	Periodic interest rate of annuity
`annuterm`	Number of periods to obtain value

Amortization and Depreciation

`amortize`	Amortization schedule
`depfixdb`	Fixed declining-balance depreciation schedule
`depgendb`	General declining-balance depreciation schedule
`deprdv`	Remaining depreciable value

`depsoyd`	Sum of years' digits depreciation
`depstln`	Straight-line depreciation schedule

Present Value

`pvfix`	Present value with fixed periodic payments
`pvvar`	Present value of varying cash flow

Future Value

`fvdisc`	Future value of discounted security
`fvfix`	Future value with fixed periodic payments
`fvvar`	Future value of varying cash flow

Payment Calculations

`payadv`	Periodic payment given number of advance payments
`payodd`	Payment of loan or annuity with odd first period
`payper`	Periodic payment of loan or annuity
`payuni`	Uniform payment equal to varying cash flow

Rates of Return

`effrr`	Effective rate of return
`elpm`	Compute expected lower partial moments for normal asset returns

`irr`	Internal rate of return
`mirr`	Modified internal rate of return
`nomrr`	Nominal rate of return
`taxedrr`	After-tax rate of return
`xirr`	Internal rate of return for nonperiodic cash flow

Cash Flow Sensitivities

`cfconv`	Cash flow convexity
`cfdur`	Cash-flow duration and modified duration

Fixed-Income Securities

Accrued Interest (p. 13-9)	Work with accrued interest
Prices (p. 13-10)	Work with prices
Term Structure of Interest Rates (p. 13-10)	Work with term structure of interest rates
Yields (p. 13-11)	Work with yields
Spreads (p. 13-11)	Work with spreads
Interest Rate Sensitivities (p. 13-11)	Work with interest rate sensitivities

Accrued Interest

`acrubond`	Accrued interest of security with periodic interest payments
`acrudisc`	Accrued interest of discount security paying at maturity

Prices

bndprice	Price fixed income security from yield to maturity
prdisc	Price of discounted security
prmat	Price with interest at maturity
prtbill	Price of Treasury bill

Term Structure of Interest Rates

disc2zero	Zero curve given discount curve
fwd2zero	Zero curve given forward curve
prbyzero	Price bonds in portfolio by set of zero curves
pyld2zero	Zero curve given par yield curve
tbl2bond	Treasury bond parameters given Treasury bill parameters
tr2bonds	Term-structure parameters given Treasury bond parameters
zbtprice	Zero curve bootstrapping from coupon bond data given price
zbtyield	Zero curve bootstrapping from coupon bond data given yield
zero2disc	Discount curve given zero curve
zero2fwd	Forward curve given zero curve
zero2pyld	Par yield curve given zero curve

Yields

`beytbill`	Bond equivalent yield for Treasury bill
`bndyield`	Yield to maturity for fixed income security
`discrate`	Bank discount rate of money market security
`ylddisc`	Yield of discounted security
`yldmat`	Yield with interest at maturity
`yldtbill`	Yield of Treasury bill

Spreads

`bndspread`	Static spread over spot curve

Interest Rate Sensitivities

`bndconvp`	Bond convexity given price
`bndconvy`	Bond convexity given yield
`bnddurp`	Bond duration given price
`bnddury`	Bond duration given yield
`bndkrdur`	Bond key rate duration given zero curve

Portfolios

Portfolio Analysis (p. 13-12)	Perform portfolio analysis
Performance Metrics (p. 13-13)	Calculate performance metrics

Portfolio Analysis

`abs2active`	Convert constraints from absolute to active format
`active2abs`	Convert constraints from active to absolute format
`arith2geom`	Arithmetic to geometric moments of asset returns
`corr2cov`	Convert standard deviation and correlation to covariance
`cov2corr`	Convert covariance to standard deviation and correlation coefficient
`ewstats`	Expected return and covariance from return time series
`frontcon`	Mean-variance efficient frontier
`frontier`	Rolling efficient frontier
`geom2arith`	Geometric to arithmetic moments of asset returns
`holdings2weights`	Portfolio holdings into weights
`pcalims`	Linear inequalities for individual asset allocation
`pcgcomp`	Linear inequalities for asset group comparison constraints
`pcglims`	Linear inequalities for asset group minimum and maximum allocation
`pcpval`	Linear inequalities for fixing total portfolio value
`periodicreturns`	Periodic total returns from total return prices
`portalloc`	Optimal capital allocation to efficient frontier portfolios
`portcons`	Portfolio constraints

`portopt`	Portfolios on constrained efficient frontier
`portrand`	Randomized portfolio risks, returns, and weights
`portror`	Portfolio expected rate of return
`portsim`	Monte Carlo simulation of correlated asset returns
`portstats`	Portfolio expected return and risk
`portvar`	Variance for portfolio of assets
`portvrisk`	Portfolio value at risk (VaR)
`ret2tick`	Convert return series to price series
`ret2tick (fts)`	Convert return series to price series for time series object
`selectreturn`	Portfolio configurations from 3-D efficient frontier
`targetreturn`	Portfolio weight accuracy
`tick2ret`	Convert price series to return series
`tick2ret (fts)`	Convert price series to return series for time series object
`totalreturnprice`	Total return price time series
`weights2holdings`	Portfolio values and weights into holdings

Performance Metrics

`emaxdrawdown`	Compute expected maximum drawdown for Brownian motion
`inforatio`	Calculate information ratio for one or more assets
`lpm`	Compute sample lower partial moments of data

`maxdrawdown`	Compute maximum drawdown for one or more price series
`portalpha`	Compute risk-adjusted alphas and returns for one or more assets
`sharpe`	Compute Sharpe ratio for one or more assets

Financial Statistics

Expectation Conditional Maximization (p. 13-14)	Work with expectation conditional maximization
Multivariate Normal Regression (p. 13-15)	Work with multivariate normal regression
Expectation Conditional Maximization – Multivariate Normal Regression (p. 13-15)	Work with expectation conditional maximization and multivariate normal regression
Expectation Conditional Maximization – Least-Squares Regression (p. 13-16)	Work with least-squares regression
Seemingly Unrelated Regression (p. 13-16)	Work with unrelated regression

Expectation Conditional Maximization

`ecmnfish`	Fisher information matrix
`ecmnhess`	Hessian of negative log-likelihood function
`ecmninit`	Initial mean and covariance
`ecmnmle`	Mean and covariance of incomplete multivariate normal data

`ecmnobj`	Multivariate normal negative log-likelihood function
`ecmnstd`	Standard errors for mean and covariance of incomplete data

Multivariate Normal Regression

`mvnrfish`	Fisher information matrix for multivariate normal or least-squares regression
`mvnrmle`	Multivariate normal regression (ignore missing data)
`mvnrobj`	Log-likelihood function for multivariate normal regression without missing data
`mvnrstd`	Evaluate standard errors for multivariate normal regression model

Expectation Conditional Maximization – Multivariate Normal Regression

`ecmmvnrfish`	Fisher information matrix for multivariate normal regression model
`ecmmvnrmle`	Multivariate normal regression with missing data
`ecmmvnrobj`	Log-likelihood function for multivariate normal regression with missing data
`ecmmvnrstd`	Evaluate standard errors for multivariate normal regression model

Expectation Conditional Maximization – Least-Squares Regression

`ecmlsrmle`	Least-squares regression with missing data
`ecmlsrobj`	Log-likelihood function for least-squares regression with missing data

Seemingly Unrelated Regression

`convert2sur`	Convert multivariate normal regression model to seemingly unrelated regression (SUR) model

Derivatives

Option Valuation and Sensitivity (p. 13-16)	Work with option valuation and sensitivity

Option Valuation and Sensitivity

`binprice`	Binomial put and call pricing
`blkimpv`	Implied volatility for futures options from Black's model
`blkprice`	Black's model for pricing futures options
`blsdelta`	Black-Scholes sensitivity to underlying price change
`blsgamma`	Black-Scholes sensitivity to underlying delta change

`blsimpv`	Black-Scholes implied volatility
`blslambda`	Black-Scholes elasticity
`blsprice`	Black-Scholes put and call option pricing
`blsrho`	Black-Scholes sensitivity to interest rate change
`blstheta`	Black-Scholes sensitivity to time-until-maturity change
`blsvega`	Black-Scholes sensitivity to underlying price volatility
`opprofit`	Option profit

GARCH Processes

Univariate GARCH Processes (p. 13-17)	Work with univariate GARCH processes

Univariate GARCH Processes

`ugarch`	Univariate GARCH(P,Q) parameter estimation with Gaussian innovations
`ugarchllf`	Log-likelihood objective function of univariate GARCH(P,Q) processes with Gaussian innovations
`ugarchpred`	Forecast conditional variance of univariate GARCH(P,Q) processes
`ugarchsim`	Simulate univariate GARCH(P,Q) process with Gaussian innovations

Financial Time Series Object and File Construction

`ascii2fts`	Create financial time series object from ASCII data file
`fints`	Construct financial time series object
`fts2ascii`	Write elements of time-series data into ASCII file
`fts2mat`	Convert to matrix
`merge`	Merge multiple financial time series objects

Financial Time Series Arithmetic

`end`	Last date entry
`horzcat`	Concatenate financial time series objects horizontally
`length`	Get number of dates (rows)
`minus`	Financial time series subtraction
`mrdivide`	Financial time series matrix division
`mtimes`	Financial time series matrix multiplication
`plus`	Financial time series addition
`power`	Financial time series power
`rdivide`	Financial time series division
`size`	Number of dates and data series
`subsasgn`	Content assignment
`subsref`	Subscripted reference
`times`	Financial time series multiplication

`uminus`	Unary minus of financial time series object
`uplus`	Unary plus of financial time series object
`vertcat`	Concatenate financial time series objects vertically

Financial Time Series Math

`cumsum`	Cumulative sum
`exp`	Exponential values
`hist`	Histogram
`log`	Natural logarithm
`log10`	Common logarithm
`log2`	Base 2 logarithm
`max`	Maximum value
`mean`	Arithmetic average
`min`	Minimum value
`std`	Standard deviation

Financial Time Series Descriptive Statistics

`corrcoef`	Correlation coefficients
`cov`	Covariance matrix
`isempty`	True for empty financial time series objects
`nancov`	Covariance ignoring `NaN`s

nanmax	Maximum ignoring NaNs
nanmean	Mean ignoring NaNs
nanmedian	Median ignoring NaNs
nanmin	Minimum ignoring NaNs
nanstd	Standard deviation ignoring NaNs
nansum	Sum ignoring NaNs
nanvar	Variance ignoring NaNs
var	Variance

Financial Time Series Utility

chfield	Change data series name
eq (fts)	Multiple financial times series object equality
extfield	Data series extraction
fetch	Data from financial time series object
fieldnames	Get names of fields
freqnum	Convert string frequency indicator to numeric frequency indicator
freqstr	Convert numeric frequency indicator to string representation
ftsbound	Start and end dates
ftsinfo	Financial time series object information
ftsuniq	Determine uniqueness
getfield	Content of specific field
getnameidx	Find name in list

`iscompatible`	Structural equality
`isequal`	Multiple object equality
`isfield`	Check whether string is field name
`issorted`	Check whether dates and times are monotonically increasing
`rmfield`	Remove data series
`setfield`	Set content of specific field
`sortfts`	Sort financial time series

Financial Time Series Data Transformation

`boxcox`	Box-Cox transformation
`convert2sur`	Convert multivariate normal regression model to seemingly unrelated regression (SUR) model
`convertto`	Convert to specified frequency
`diff`	Differencing
`fillts`	Fill missing values in time series
`filter`	Linear filtering
`lagts`	Lag time series object
`leadts`	Lead time series object
`peravg`	Periodic average of FINTS object
`resamplets`	Downsample data
`smoothts`	Smooth data
`toannual`	Convert to annual
`todaily`	Convert to daily
`todecimal`	Fractional to decimal conversion

tomonthly	Convert to monthly
toquarterly	Convert to quarterly
toquoted	Decimal to fractional conversion
tosemi	Convert to semiannual
toweekly	Convert to weekly
tsmovavg	Moving average

Financial Time Series Indicator

adline	Accumulation/Distribution line
adosc	Accumulation/Distribution oscillator
bollinger	Time series Bollinger band
chaikosc	Chaikin oscillator
chaikvolat	Chaikin volatility
fpctkd	Fast stochastics
hhigh	Highest high
llow	Lowest low
macd	Moving Average Convergence/Divergence (MACD)
medprice	Median price
negvolidx	Negative volume index
onbalvol	On-Balance Volume (OBV)
posvolidx	Positive volume index
prcroc	Price rate of change
pvtrend	Price and Volume Trend (PVT)
rsindex	Relative Strength Index (RSI)
spctkd	Slow stochastics

`stochosc`	Stochastic oscillator
`tsaccel`	Acceleration between periods
`tsmom`	Momentum between periods
`typprice`	Typical price
`volroc`	Volume rate of change
`wclose`	Weighted close
`willad`	Williams Accumulation/Distribution line
`willpctr`	Williams %R

Financial Time Series GUI

`ftsgui`	Financial time series GUI

Financial Time Series Tool

`ftstool`	Financial time series tool

Functions — Alphabetical List

abs2active

Purpose

Convert constraints from absolute to active format

Syntax

```
ActiveConSet = abs2active(AbsConSet, Index)
```

Arguments

`AbsConSet`	Portfolio linear inequality constraint matrix expressed in absolute weight format. `AbsConSet` is formatted as `[A b]` such that `A*w <= b`, where `A` is a number of constraints (`NCONSTRAINTS`) by number of assets (`NASSETS`) weight coefficient matrix, and `b` and `w` are column vectors of length `NASSETS`. The value `w` represents a vector of absolute asset weights whose elements sum to the total portfolio value. See the output `ConSet` from `portcons` for additional details about constraint matrices.
`Index`	`NASSETS`-by-1 vector of index portfolio weights. The sum of the index weights must equal the total portfolio value (for example, a standard portfolio optimization imposes a sum-to-one budget constraint).

Description

`ActiveConSet = abs2active(AbsConSet, Index)` transforms a constraint matrix to an equivalent matrix expressed in active weight format (relative to the index). The transformation equation is

$$Aw_{absolute} = A(w_{active} + w_{index}) \leq b_{absolute}$$

Therefore

$$Aw_{active} \leq b_{absolute} - Aw_{index} = b_{active}$$

The initial constraint matrix consists of `NCONSTRAINTS` portfolio linear inequality constraints expressed in absolute weight format. The index portfolio vector contains `NASSETS` assets.

`ActiveConSet` is the transformed portfolio linear inequality constraint matrix expressed in active weight format, also of the form `[A b]` such that `A*w <= b`. The value `w` represents a vector of active asset weights (relative to the index portfolio) whose elements sum to zero.

See Also

`active2abs`, `pcalims`, `pcgcomp`, `pcglims`, `pcpval`, `portcons`

Purpose

Fraction of coupon period before settlement

Syntax

```
Fraction = accrfrac(Settle, Maturity, Period, Basis, EndMonthRule,
IssueDate, FirstCouponDate, LastCouponDate, StartDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA)

- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate` (Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.

Vector arguments must have consistent dimensions, or they must be scalars.

Description

`Fraction = accrfrac(Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate)` returns the fraction of the coupon period before settlement. This function is used for computing accrued interest.

Examples

Given data for three bonds

```
Settle = '14-Mar-1997';
Maturity = ['30-Nov-2000'
            '31-Dec-2000'
            '31-Jan-2001'];
Period = 2;
Basis = 0;
EndMonthRule = 1;
```

Execute the function.

```
Fraction = accrfrac(Settle, Maturity, Period, Basis,...
                    EndMonthRule)
Fraction =
    0.5714
    0.4033
    0.2320
```

See Also

`cfamounts`, `cfdates`, `cpncount`, `cpndaten`, `cpndatenq`, `cpndatep`, `cpndatepq`, `cpndaysn`, `cpndaysp`, `cpnpersz`

Purpose

Accrued interest of security with periodic interest payments

Syntax

```
AccruInterest = acrubond(IssueDate, Settle, FirstCouponDate, Face,
CouponRate, Period, Basis)
```

Arguments

`IssueDate`	Enter as serial date number or date string.
`Settle`	Enter as serial date number or date string.
`FirstCouponDate`	Enter as serial date number or date string.
`Face`	Redemption (par, face) value.
`CouponRate`	Enter as decimal fraction.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA)

- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Description

`AccruInterest = acrubond(IssueDate, Settle, FirstCouponDate, Face, CouponRate, Period, Basis)` returns the accrued interest for a security with periodic interest payments. This function computes the accrued interest for securities with standard, short, and long first coupon periods.

Note `cfamounts` or `accrfrac` is recommended when calculating accrued interest beyond the first period.

Examples

```
AccruInterest = acrubond('31-jan-1983',  '1-mar-1993', ...
                 '31-jul-1983',  100,  0.1,  2,  0)

AccruInterest =
                 0.8011
```

See Also

`accrfrac`, `acrudisc`, `bndprice`, `bndyield`, `cfamounts`, `datenum`

Purpose

Accrued interest of discount security paying at maturity

Syntax

```
AccruInterest = acrudisc(Settle, Maturity, Face, Discount, Period,
Basis)
```

Arguments

`Settle`	Enter as serial date number or date string. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Enter as serial date number or date string.
`Face`	Redemption (par, face) value.
`Discount`	Discount rate of the security. Enter as decimal fraction.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)

- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Description

`AccruInterest = acrudisc(Settle, Maturity, Face, Discount, Period, Basis)` returns the accrued interest of a discount security paid at maturity.

Examples

```
AccruInterest = acrudisc('05/01/1992',  '07/15/1992', ...
                100,  0.1,  2,  0)

AccruInterest =
                2.0604 (or $2.06)
```

References

Mayle, *Standard Securities Calculation Methods*, Volumes I-II, 3rd edition. Formula D.

See Also

`acrubond`, `prdisc`, `prmat`, `ylddisc`, `yldmat`

Purpose

Convert constraints from active to absolute format

Syntax

```
AbsConSet = active2abs(ActiveConSet, Index)
```

Arguments

`ActiveConSet`	Portfolio linear inequality constraint matrix expressed in active weight format. `ActiveConSet` is formatted as `[A b]` such that `A*w <= b`, where `A` is a number of constraints (`NCONSTRAINTS`) by number of assets (`NASSETS`) weight coefficient matrix, and `b` and `w` are column vectors of length `NASSETS`. The value `w` represents a vector of active asset weights (relative to the index portfolio) whose elements sum to 0. See the output `ConSet` from `portcons` for additional details about constraint matrices.
`Index`	`NASSETS`-by-1 vector of index portfolio weights. The sum of the index weights must equal the total portfolio value (for example, a standard portfolio optimization imposes a sum-to-one budget constraint).

Description

`AbsConSet = active2abs(ActiveConSet, Index)` transforms a constraint matrix to an equivalent matrix expressed in absolute weight format. The transformation equation is

$$Aw_{active} = A(w_{absolute} - w_{index}) \leq b_{active}$$

Therefore

$$Aw_{absolute} \leq b_{active} + Aw_{index} = b_{absolute}$$

The initial constraint matrix consists of `NCONSTRAINTS` portfolio linear inequality constraints expressed in active weight format (relative to the index portfolio). The index portfolio vector contains `NASSETS` assets.

`AbsConSet` is the transformed portfolio linear inequality constraint matrix expressed in absolute weight format, also of the form `[A b]` such that `A*w <= b`. The value `w` represents a vector of active asset weights (relative to the index portfolio) whose elements sum to the total portfolio value.

See Also

`abs2active`, `pcalims`, `pcgcomp`, `pcglims`, `pcpval`, `portcons`

Purpose

Accumulation/Distribution line

Syntax

```
adln = adline(highp, lowp, closep, tvolume)
adln = adline([highp lowp  closep  tvolume])
adlnts = adline(tsobj)
adlnts = adline(tsobj, ParameterName, ParameterValue, ...)
```

Arguments

`highp`	High price (vector)
`lowp`	Low price (vector)
`closep`	Closing price (vector)
`tvolume`	Volume traded (vector)
`tsobj`	Time series object

Description

`adln = adline(highp, lowp, closep, tvolume)` computes the Accumulation/Distribution line for a set of stock price and volume traded data. The prices required for this function are the high (`highp`), low (`lowp`), and closing (`closep`) prices.

`adln = adline([highp lowp closep tvolume])` accepts a four-column matrix as input. The first column contains the high prices, the second contains the low prices, the third contains the closing prices, and the fourth contains the volume traded.

`adlnts = adline(tsobj)` computes the Williams Accumulation/Distribution line for a set of stock price data contained in the financial time series object `tsobj`. The object must contain the high, low, and closing prices plus the volume traded. The function assumes that the series are named `High`, `Low`, `Close`, and `Volume`. All are required. `adlnts` is a financial time series object with the same dates as `tsobj` but with a single series named `ADLine`.

`adlnts = adline(tsobj, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

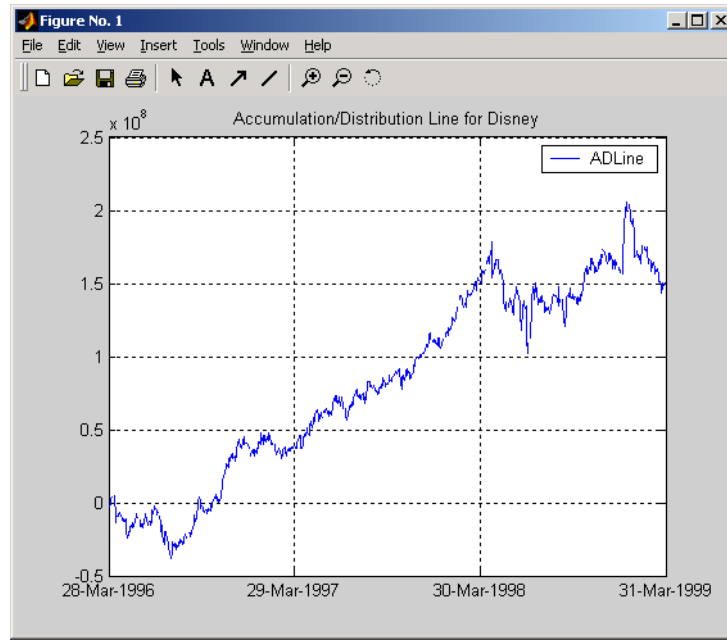
- `HighName`: high prices series name
- `LowName`: low prices series name
- `CloseName`: closing prices series name
- `VolumeName`: volume traded series name

Parameter values are the strings that represent the valid parameter names.

Examples

Compute the Accumulation/Distribution line for Disney stock and plot the results:

```
load disney.mat
dis_ADLine = adline(dis)
plot(dis_ADLine)
title('Accumulation/Distribution Line for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second Edition, McGraw-Hill, 1995, pp. 56-58.

See Also

`adosc`, `willad`, `willpctr`

Purpose

Accumulation/Distribution oscillator

Syntax

```
ado = adosc(highp, lowp, openp, closep)
ado = adosc([highp lowp openp closep])
adots = adosc(tsobj)
adots = adosc(tsojb, ParameterName, ParameterValue, ...)
```

Arguments

`highp`	High price (vector)
`lowp`	Low price (vector)
`openp`	Opening price (vector)
`closep`	Closing price (vector)
`tsobj`	Time series object

Description

`ado = adosc(highp, lowp, openp, closep)` returns a vector, `ado`, that represents the Accumulation/Distribution (A/D) oscillator. The A/D oscillator is calculated based on the high, low, opening, and closing prices of each period. Each period is treated individually.

`ado = adosc([highp lowp openp closep])` accepts a four-column matrix as input. The order of the columns must be high, low, opening, and closing prices.

`adots = adosc(tsobj)` calculates the Accumulation/Distribution (A/D) oscillator, adots, for the set of stock price data contained in the financial time series object `tsobj`. The object must contain the high, low, opening, and closing prices. The function assumes that the series are named `High`, `Low`, `Open`, and `Close`. All are required. `adots` is a financial time series object with similar dates to `tsobj` and only one series named `ADOsc`.

`adots = adosc(tsobj, ParameterName, ParameterValue, ...)` accepts parameter name-parameter value pairs as input. These pairs

specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

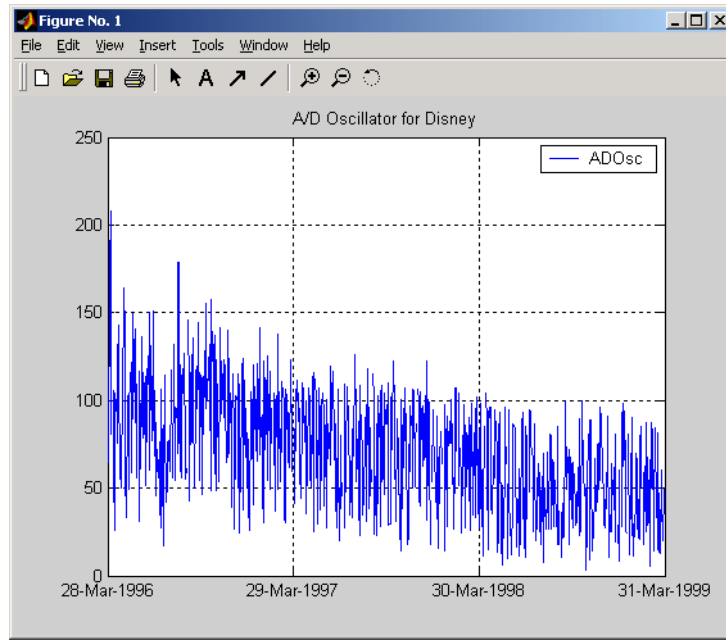
- `HighName`: high prices series name
- `LowName`: low prices series name
- `OpenName`: opening prices series name
- `CloseName`: closing prices series name

Parameter values are the strings that represents the valid parameter names.

Examples

Compute the Accumulation/Distribution oscillator for Disney stock and plot the results:

```
load disney.mat
dis_ADOsc = adosc(dis)
plot(dis_ADOsc)
title('A/D Oscillator for Disney')
```



See Also

`adline`, `willad`

Purpose

Amortization schedule

Syntax

```
[Principal, Interest, Balance, Payment] = amortize(Rate,
NumPeriods, PresentValue, FutureValue, Due)
```

Arguments

`Rate`	Interest rate per period, as a decimal fraction.
`NumPeriods`	Number of payment periods.
`PresentValue`	Present value of the loan.
`FutureValue`	(Optional) Future value of the loan. Default = 0.
`Due`	(Optional) When payments are due: 0 = end of period (default), or 1 = beginning of period.

Description

`[Principal, Interest, Balance, Payment] = amortize(Rate, NumPeriods, PresentValue, FutureValue, Due)` returns the principal and interest payments of a loan, the remaining balance of the original loan amount, and the periodic payment.

`Principal`	Principal paid in each period. A `1`-by-`NumPeriods` vector.
`Interest`	Interest paid in each period. A `1`-by-`NumPeriods` vector.
`Balance`	Remaining balance of the loan in each payment period. A `1`-by-`NumPeriods` vector.
`Payment`	Payment per period. A scalar.

Examples

Compute an amortization schedule for a conventional 30-year, fixed-rate mortgage with fixed monthly payments. Assume a fixed rate of 12% APR and an initial loan amount of $100,000.

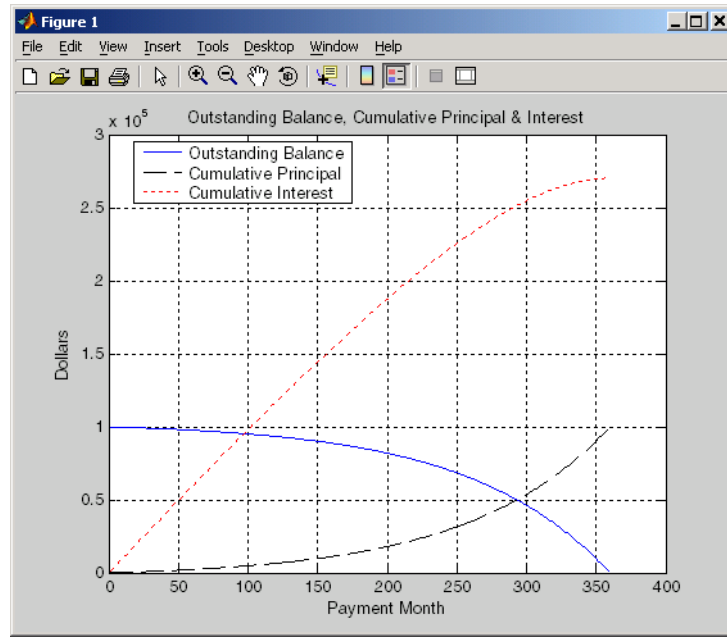
```
Rate         = 0.12/12;   % 12 percent APR = 1 percent per month
NumPeriods   = 30*12;     % 30 years = 360 months
PresentValue = 100000;

[Principal, Interest, Balance, Payment] = amortize(Rate, ...
NumPeriods, PresentValue);
```

The output argument `Payment` contains the fixed monthly payment.

```
format bank

Payment

Payment =

        1028.61
```

Finally, summarize the amortization schedule graphically by plotting the current outstanding loan balance, the cumulative principal, and the interest payments over the life of the mortgage. In particular, note that total interest paid over the life of the mortgage exceeds $270,000, far in excess of the original loan amount.

```
plot(Balance,'b'), hold('on')
plot(cumsum(Principal),'--k')
plot(cumsum(Interest),':r')

xlabel('Payment Month')
ylabel('Dollars')
grid('on')
title('Outstanding Balance, Cumulative Principal & Interest')
legend('Outstanding Balance', 'Cumulative Principal', ...
'Cumulative Interest')
```



The solid blue line represents the declining principal over the 30-year period. The dotted red line indicates the increasing cumulative interest payments. Finally, the dashed black line represents the cumulative principal payments, reaching $100,000 after 30 years.

See Also

`annurate`, `annuterm`, `payadv`, `payodd`, `payper`

annurate

Purpose

Periodic interest rate of annuity

Syntax

```
Rate = annurate(NumPeriods, Payment, PresentValue, FutureValue,
Due)
```

Arguments

`NumPeriods`	Number of payment periods.
`Payment`	Payment per period.
`PresentValue`	Present value of the loan or annuity.
`FutureValue`	(Optional) Future value of the loan or annuity. Default = 0.
`Due`	(Optional) When payments are due: 0 = end of period (default), or 1 = beginning of period.

Description

`Rate = annurate(NumPeriods, Payment, PresentValue, FutureValue, Due)` returns the periodic interest rate paid on a loan or annuity.

Examples

Find the periodic interest rate of a four-year, $5000 loan with a $130 monthly payment made at the end of each month.

```
Rate = annurate(4*12, 130, 5000, 0, 0)

Rate =
      0.0094
```

(`Rate` multiplied by 12 gives an annual interest rate of 11.32% on the loan.)

See Also

`amortize`, `annuterm`, `bndyield`, `irr`

Purpose

Number of periods to obtain value

Syntax

```
NumPeriods = annuterm(Rate, Payment, PresentValue, FutureValue,
Due)
```

Arguments

`Rate`	Interest rate per period, as a decimal fraction.
`Payment`	Payment per period.
`PresentValue`	Present value.
`FutureValue`	(Optional) Future value. Default = 0.
`Due`	(Optional) When payments are due: 0 = end of period (default), or 1 = beginning of period.

Description

`NumPeriods = annuterm(Rate, Payment, PresentValue, FutureValue, Due)` calculates the number of periods needed to obtain a future value. To calculate the number of periods needed to pay off a loan, enter the payment or the present value as a negative value.

Examples

A savings account has a starting balance of $1500. $200 is added at the end of each month and the account pays 9% interest, compounded monthly. How many years will it take to save $5,000?

```
NumPeriods = annuterm(0.09/12, 200, 1500, 5000, 0)

NumPeriods =
         15.68 months or 1.31 years.
```

See Also

`annurate`, `amortize`, `fvfix`, `pvfix`

arith2geom

Purpose

Arithmetic to geometric moments of asset returns

Syntax

```
[mg, Cg] = arith2geom(ma, Ca);
[mg, Cg] = arith2geom(ma, Ca, t);
```

Arguments

`ma`	Arithmetic mean of asset-return data (n-vector).
`Ca`	Arithmetic covariance of asset-return data (n-by-n symmetric, positive-semidefinite matrix.
`t`	(Optional) Target period of geometric moments in terms of periodicity of arithmetic moments with default value 1 (scalar).

Description

`arith2geom` transforms moments associated with a simple Brownian motion into equivalent continuously-compounded moments associated with a geometric Brownian motion with a possible change in periodicity.

`[mg, Cg] = arith2geom(ma, Ca, t)` returns `mg`, continuously-compounded or "geometric" mean of asset returns over the target period (n-vector), and `Cg`, which is a continuously-compounded or "geometric" covariance of asset returns over the target period (n-by-n matrix).

Arithmetic returns over period t_A are modeled as multivariate normal random variables

$$\mathbf{X} \sim N(\mathbf{m}_A, \mathbf{C}_A)$$

with moments

$$E[\mathbf{X}] = \mathbf{m}_A$$

and

$$\mathrm{cov}(\mathbf{X}) = \mathbf{C}_A$$

Geometric returns over period t_G are modeled as multivariate lognormal random variables

$$\mathbf{Y} \sim LN(1 + \mathbf{m}_G, \mathbf{C}_G)$$

with moments

$$E[\mathbf{Y}] = 1 + \mathbf{m}_G$$

$$\mathrm{cov}(\mathbf{Y}) = \mathbf{C}_G$$

Given $t = t_G / t_A$, the transformation from geometric to arithmetic moments is

$$1 + \mathbf{m}_{G_i} = \exp(t\mathbf{m}_{A_i} + \frac{1}{2}t\mathbf{C}_{A_{ii}})$$

$$\mathbf{C}_{G_{ij}} = (1 + \mathbf{m}_{G_i})(1 + \mathbf{m}_{G_j})(\exp(t\mathbf{C}_{Aij}) - 1)$$

For $i,j = 1,\ldots, n$.

Note If $t = 1$, then $\mathbf{Y} = \exp(\mathbf{X})$.

This function has no restriction on the input mean `ma` but requires the input covariance `Ca` to be a symmetric positive-semidefinite matrix.

The functions `arith2geom` and `geom2arith` are complementary so that, given `m`, `C`, and `t`, the sequence

```
[mg, Cg] = arith2geom(m, C, t);
[ma, Ca] = geom2arith(mg, Cg, 1/t);
```

yields `ma` = `m` and `Ca` = `C`.

Examples

Example 1. Given arithmetic mean `m` and covariance `C` of monthly total returns, obtain annual geometric mean `mg` and covariance `Cg`. In this case, the output period (1 year) is 12 times the input period (1 month) so that `t = 12` with

```
[mg, Cg] = arith2geom(m, C, 12);
```

Example 2. Given annual arithmetic mean `m` and covariance `C` of asset returns, obtain monthly geometric mean `mg` and covariance `Cg`. In this case, the output period (1 month) is 1/12 times the input period (1 year) so that `t = 1/12` with

```
[mg, Cg] = arith2geom(m, C, 1/12);
```

Example 3. Given arithmetic means `m` and standard deviations `s` of daily total returns (derived from 260 business days per year), obtain annualized continuously-compounded mean `mg` and standard deviations `sg` with

```
[mg, Cg] = arith2geom(m, diag(s .^2), 260);
sg = sqrt(diag(Cg));
```

Example 4. Given arithmetic mean `m` and covariance `C` of monthly total returns, obtain quarterly continuously-compounded return moments. In this case, the output is 3 of the input periods so that `t = 3` with

```
[mg, Cg] = arith2geom(m, C, 3);
```

Example 5. Given arithmetic mean `m` and covariance `C` of 1254 observations of daily total returns over a 5-year period, obtain annualized continuously-compounded return moments. Since the periodicity of the arithmetic data is based on 1254 observations for a 5-year period, a 1-year period for geometric returns implies a target period of `t = 1254/5` so that

```
[mg, Cg] = arith2geom(m, C, 1254/5);
```

See Also

`geom2arith`

Purpose

Create financial time series object from ASCII data file

Syntax

```
tsobj = ascii2fts(filename, descrow, colheadrow, skiprows)
tsobj = ascii2fts(filename, timedata, descrow, colheadrow,
skiprows)
```

Arguments

`filename`	ASCII data file
`descrow`	(Optional) Row number in the data file that contains the description to be used for the description field of the financial time series object
`colheadrow`	(Optional) Row number that has the column headers/names
`skiprows`	(Optional) Scalar or vector of row numbers to be skipped in the data file
`timedata`	Set to `'T'` if time-of-day data is present in the ASCII data file or to `'NT'` if no time-of-day data is present.

Description

`tsobj = ascii2fts(filename, descrow, colheadrow, skiprows)` creates a financial time series object `tsobj` from the ASCII file named `filename`. This form of the function can only read a data file without time-of-day information and create a financial time series object without time information. If time information is present in the ASCII file, an error message appears.

The general format of the text data file is

- Can contain header text lines.
- Can contain column header information. The column header information must immediately precede the data series columns unless `skiprows` is specified.

- Leftmost column must be the date column.
- Dates must be in a valid date string format:
  - `'ddmmmyy'` or `'ddmmmyyyy'`
  - `'mm/dd/yy'` or `'mm/dd/yyyy'`
  - `'dd-mmm-yy'` or `'dd-mmm-yyyy'`
  - `'mmm.dd,yy'` or `'mmm.dd,yyyy'`
- Each column must be separated either by spaces or a tab.

`tsobj = ascii2fts(filename, timedata, descrow, colheadrow, skiprows)` creates a financial time series object containing time-of-day data. Set `timedata` to `'T'` to create a financial time series object containing time-of-day data.

Examples

Example 1. If your data file contains no description or column header rows,

```
1/3/95   36.75   36.9063   36.6563   36.875    1167900
1/4/95   37      37.2813   36.625    37.1563   1994700  ...
```

you can create a financial time series object from it with the simplest form of the `ascii2fts` function:

```
myinc = ascii2fts('my_inc.dat');

myinc =

desc:  my_inc.dat
freq:  Unknown (0)

'dates:  (2)'  'series1: (2)'  'series2: (2)'   'series3: (2)'...
'03-Jan-1995'  [   36.7500]    [    36.9063]    [   36.6563]
'04-Jan-1995'  [        37]    [    37.2813]    [   36.6250]
```

Example 2: If your data file contains description and column header information with the data series immediately following the column header row,

```
International Business Machines Corporation (IBM)
Daily prices (1/3/95 to 4/5/99)
DATE     OPEN    HIGH      LOW       CLOSE     VOLUME
1/3/95   36.75   36.9063   36.6563   36.875    1167900
1/4/95   37      37.2813   36.625    37.1563   1994700  ...
```

you must specify the row numbers containing the description and column headers:

```
ibm = ascii2fts('ibm9599.dat', 1, 3);

ibm =

desc:  International Business Machines Corporation (IBM)
freq:  Unknown (0)
'dates:  (2)'  'OPEN:  (2)'    'HIGH:  (2)'    'LOW:  (2)' ...
'03-Jan-1995'  [  36.7500]    [   36.9063]    [  36.6563]
'04-Jan-1995'  [       37]    [   37.2813]    [  36.6250]
```

Example 3: If your data file contains rows between the column headers and the data series, for example,

```
Staples, Inc. (SPLS)
Daily prices
DATE     OPEN    HIGH     LOW      CLOSE    VOLUME
Starting date: 04/08/1996
Ending date:   04/07/1999
4/8/96   19.50   19.75    19.25    19.375   548500
4/9/96   19.75   20.125   19.375   20       1135900  ...
```

you need to indicate to `ascii2fts` the rows in the file that must be skipped. Assume that you have called the data file containing the Staples data above `staples.dat`. The command

```
spls = ascii2fts('staples.dat', 1, 3, [4 5]);
```

indicates that the fourth and fifth rows in the file should be skipped in creating the financial time series object:

```
spls =

desc:  Staples, Inc. (SPLS)
freq:  Unknown (0)

'dates:  (2)'  'OPEN:  (2)'    'HIGH:  (2)'    'LOW:  (2)'
'08-Apr-1996'  [   19.5000]    [  19.7500]     [19.2500]
'09-Apr-1996'  [   19.7500]    [  20.1250]     [19.3750]
```

Example 4: Create a financial time series object containing time-of-day information.

First create a data file with time information:

```
dates = ['01-Jan-2001';'01-Jan-2001'; '02-Jan-2001'; ...
'02-Jan-2001'; '03-Jan-2001';'03-Jan-2001'];
times = ['11:00';'12:00';'11:00';'12:00';'11:00';'12:00'];
serial_dates_times = [datenum(dates), datenum(times)];
data = round(10*rand(6,2));
stat = fts2ascii('myfts_file2.txt',serial_dates_times,data, ...
{'dates';'times';'Data1';'Data2'},'My FTS with Time');
```

Now read the data file back and create a financial time series object:

```
MyFts = ascii2fts('myfts_file2.txt','t',1,2,1)

MyFts =

    desc:  My FTS with Time
    freq:  Unknown (0)

    'dates:  (6)'    'times:  (6)'   'Data1:  (6)'  'Data2:  (6)'
    '01-Jan-2001'    '11:00'         [          9]   [          4]
```

```
'     "     '    '12:00'        [          7]   [          9]
'02-Jan-2001'    '11:00'        [          2]   [          1]
'     "     '    '12:00'        [          4]   [          4]
'03-Jan-2001'    '11:00'        [          9]   [          8]
'     "     '    '12:00'        [          9]   [          0]
```

See Also

fints, fts2ascii

Purpose

Bar chart

Syntax

```
bar(tsobj)
bar(tsobj, width)
bar(..., 'style')
hbar = bar(...)

barh(...)
hbarh = barh(...)
```

Arguments

`tsobj`	Financial time series object.
`width`	Width of the bars and separation of bars within a group. (Default = 0.8.) If width is 1, the bars within a group touch one another. Values > 1 produce overlapping bars.
`style`	`'grouped'` (default) or `'stacked'`.

Description

`bar, barh` draw vertical and horizontal bar charts.

`bar(tsobj)` draws the columns of data series of the object `tsobj`. The number of data series dictates the number of vertical bars per group. Each group is the data for one particular date.

`bar(tsobj, width)` specifies the width of the bars.

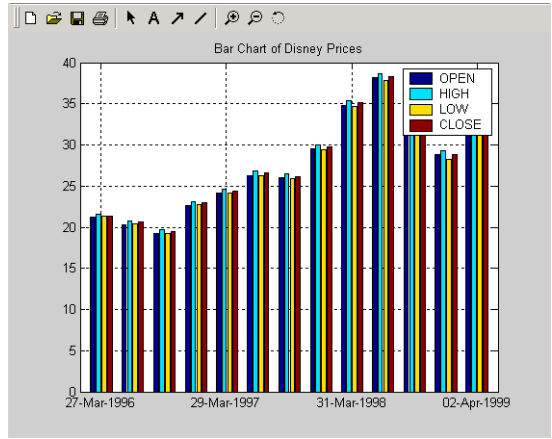
`bar(..., 'style')` changes the style of the bar chart.

`hbar = bar(...)` returns a vector of bar handles.

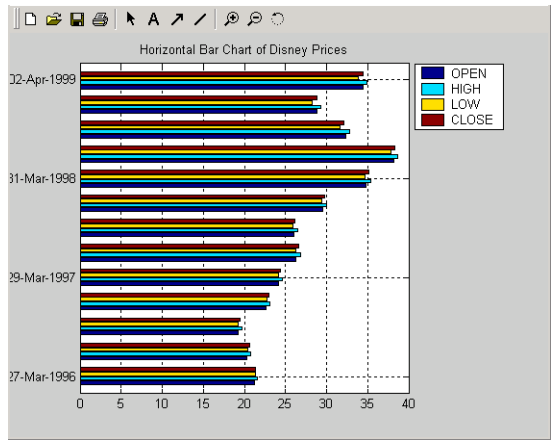
Use the MATLAB command `shading faceted` to put edges on the bars. Use `shading flat` to turn edges off.

Examples

Create bar charts for Disney stock showing high, low, opening, and closing prices.




```
load disney
bar(q_dis)
title('Bar Chart of Disney Prices')
```




```
load disney
bar(q_dis)
title('Horizontal Bar Chart of Disney Prices')
```

See Also `bar3`, `bar3h`, `candle`, `highlow`

bar3, bar3h

Purpose

3-D bar chart

Syntax

```
bar3(tsobj)
bar3(tsobj, width)
bar3(..., 'style')
hbar3 = bar3(...)

bar3h(...)
hbar3h = bar3h(...)
```

Arguments

`tsobj`	Financial time series object.
`width`	Width of the bars and separation of bars within a group. (Default = 0.8.) If width is 1, the bars within a group touch one another. Values > 1 produce overlapping bars.
`style`	`'detached'` (default), `'grouped'`, or `'stacked'`.

Description

`bar3, bar3h` draw three-dimensional vertical and horizontal bar charts.

`bar3(tsobj)` draws the columns of data series of the object `tsobj`. The number of data series dictates the number of vertical bars per group. Each group is the data for one particular date.

`bar3(tsobj, width)` specifies the width of the bars.

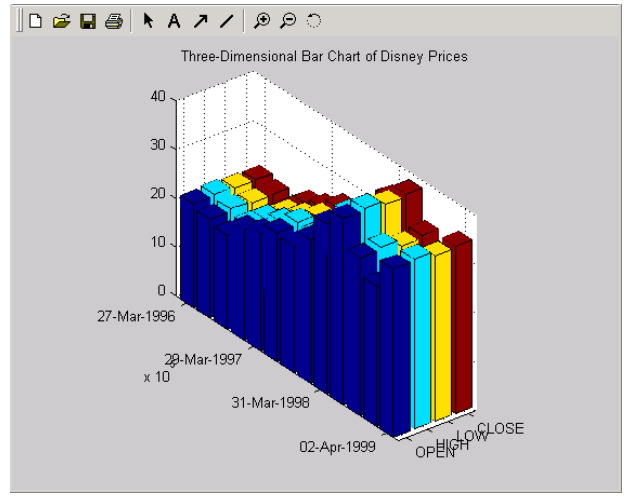
`bar3(..., 'style')` changes the style of the bar chart.

`hbar3 = bar3(...)` returns a vector of bar handles.

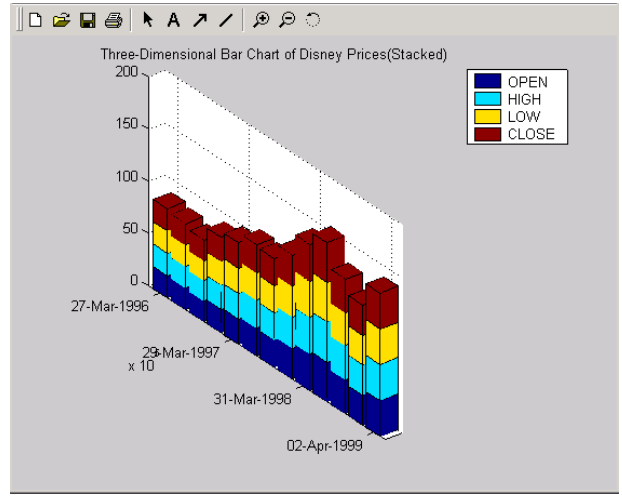
Use the MATLAB command `shading faceted` to put edges on the bars. Use `shading flat` to turn edges off.

Examples

Create three-dimensional bar charts for Disney stock showing high, low, opening, and closing prices.




```
load disney
bar3(q_dis, 'stacked')
title('Three-Dimensional Bar Chart of Disney Prices')
```



```
load disney
bar3(q_dis, 'stacked')
title('Three-Dimensional Bar Chart of Disney Prices (Stacked)')
```

See Also

bar, barh, candle, highlow

Purpose

Bond equivalent yield for Treasury bill

Syntax

```
Yield = beytbill(Settle, Maturity, Discount)
```

Arguments

`Settle`	Enter as serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Enter as serial date numbers or date strings.
`Discount`	Discount rate of the Treasury bill. Enter as decimal fraction.

Description

`Yield = beytbill(Settle, Maturity, Discount)` returns the bond equivalent yield for a Treasury bill.

Examples

The settlement date of a Treasury bill is February 11, 2000, the maturity date is August 7, 2000, and the discount rate is 5.77%. The bond equivalent yield is

```
Yield = beytbill('2/11/2000', '8/7/2000', 0.0577)

Yield =
        0.0602
```

See Also

`datenum`, `prtbill`, `yldtbill`

binprice

Purpose

Binomial put and call pricing

Syntax

```
[AssetPrice, OptionValue] = binprice(Price, Strike, Rate, Time,
Increment, Volatility, Flag, DividendRate, Dividend, ExDiv)
```

Arguments

`Price`	Underlying asset price. A scalar.
`Strike`	Option exercise price. A scalar.
`Rate`	Risk-free interest rate. A scalar. Enter as a decimal fraction.
`Time`	Option's time until maturity in years. A scalar.
`Increment`	Time increment. A scalar. `Increment` is adjusted so that the length of each interval is consistent with the maturity time of the option. (`Increment` is adjusted so that `Time` divided by `Increment` equals an integer number of increments.)
`Volatility`	Asset's volatility. A scalar.
`Flag`	Specifies whether the option is a call (`Flag = 1`) or a put (`Flag = 0`). A scalar.
`DividendRate`	(Optional) The dividend rate, as a decimal fraction. A scalar. Default = 0. If you enter a value for `DividendRate`, set `Dividend` and `ExDiv = 0` or do not enter them. If you enter values for `Dividend` and `ExDiv`, set `DividendRate = 0`.

`Dividend`	(Optional) The dividend payment at an ex-dividend date, `ExDiv`. A row vector. For each dividend payment, there must be a corresponding ex-dividend date. Default = 0. If you enter values for `Dividend` and `ExDiv`, set `DividendRate = 0`.
`ExDiv`	(Optional) Ex-dividend date, specified in number of periods. A row vector. Default = 0.

Description

`[AssetPrice, OptionValue] = binprice(Price, Strike, Rate, Time, Increment, Volatility, Flag, DividendRate, Dividend, ExDiv)` prices an option using the Cox-Ross-Rubinstein binomial pricing model.

Examples

For a put option, the asset price is $52, option exercise price is $50, risk-free interest rate is 10%, option matures in 5 months, volatility is 40%, and there is one dividend payment of $2.06 in 3-1/2 months.

```
[Price, Option] = binprice(52, 50, 0.1, 5/12, 1/12, 0.4, 0, 0,...
2.06, 3.5)
```

returns the asset price and option value at each node of the binary tree.

```
Price =

   52.0000   58.1367   65.0226   72.7494   79.3515   89.0642
         0   46.5642   52.0336   58.1706   62.9882   70.6980
         0         0   41.7231   46.5981   49.9992   56.1192
         0         0         0   37.4120   39.6887   44.5467
         0         0         0         0   31.5044   35.3606
         0         0         0         0         0   28.0688
Option =

    4.4404    2.1627    0.6361         0         0         0
         0    6.8611    3.7715    1.3018         0         0
```

```
         0         0   10.1591    6.3785    2.6645         0
         0         0         0   14.2245   10.3113    5.4533
         0         0         0         0   18.4956   14.6394
         0         0         0         0         0   21.9312
```

References

Cox, J., S. Ross, and M. Rubenstein, “Option Pricing: A Simplified Approach”, *Journal of Financial Economics 7*, Sept. 1979, pp. 229-263.

Hull, John C., *Options*, *Futures*, *and Other Derivative Securities*, 2nd edition, Chapter 14.

See Also

`blkprice`, `blsprice`

Purpose

Implied volatility for futures options from Black's model

Syntax

```
Volatility = blsimpv(Price, Strike, Rate, Time, Value, Limit, ...
Tolerance, Class)
```

Arguments

`Price`	Current price of the underlying asset (a futures contract).
`Strike`	Exercise price of the futures option.
`Rate`	Annualized, continuously compounded risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time to expiration of the option, expressed in years.
`Value`	Price of a European futures option from which the implied volatility of the underlying asset is derived.
`Limit`	(Optional) Positive scalar representing the upper bound of the implied volatility search interval. If `Limit` is empty or unspecified, the default = 10, or 1000% per annum.
`Tolerance`	(Optional) Implied volatility termination tolerance. A positive scalar. Default = 1e-6.
`Class`	(Optional) Option class (call or put) indicating the option type from which the implied volatility is derived. May be either a logical indicator or a cell array of characters. To specify call options, set `Class = true` or `Class = {'call'}`; to specify put options, set `Class = false` or `Class = {'put'}`. If `Class` is empty or unspecified, the default is a call option.

Description

`Volatility = blkimpv(Price, Strike, Rate, Time, CallPrice, MaxIterations, Tolerance)` computes the implied volatility of a futures price from the market value of European futures options using Black's model.

`Volatility` is the implied volatility of the underlying asset derived from European futures option prices, expressed as a decimal number. If no solution is found, `blkimpv` returns `NaN`.

Any input argument may be a scalar, vector, or matrix. When a value is a scalar, that value is used to compute the implied volatility of all the options. If more than one input is a vector or matrix, the dimensions of all nonscalar inputs must be identical.

`Rate` and `Time` must be expressed in consistent units of time.

Examples

Consider a European call futures option that expires in four months, trading at $1.1166, with an exercise price of $20. Assume that the current underlying futures price is also $20 and that the risk-free rate is 9% per annum. Furthermore, assume that you are interested in implied volatilities no greater than 0.5 (50% per annum). Under these conditions, the following commands all return an implied volatility of 0.25, or 25% per annum:

```
Volatility = blkimpv(20, 20, 0.09, 4/12, 1.1166, 0.5)
Volatility = blkimpv(20, 20, 0.09, 4/12, 1.1166, 0.5, [],
{'Call'})
Volatility = blkimpv(20, 20, 0.09, 4/12, 1.1166, 0.5, [], true)
```

References

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003, pp. 287-288.

Black, Fischer, "The Pricing of Commodity Contracts," *Journal of Financial Economics*, March 3, 1976, pp. 167-79.

See Also

`blkprice`, `blsimpv`, `blsprice`

Purpose

Black's model for pricing futures options

Syntax

```
[Call, Put] = blkprice(Price, Strike, Rate, Time, Volatility)
```

Arguments

`Price`	Current price of the underlying asset (a futures contract).
`Strike`	Strike or exercise price of the futures option.
`Rate`	Annualized, continuously compounded, risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time until expiration of the option, expressed in years. Must be greater than 0.
`Volatility`	Annualized futures price volatility, expressed as a positive decimal number.

Description

`[Call, Put] = blkprice(ForwardPrice, Strike, Rate, Time, Volatility)` uses Black's model to compute European put and call futures option prices.

Any input argument may be a scalar, vector, or matrix. When a value is a scalar, that value is used to compute the implied volatility from all options. If more than one input is a vector or matrix, the dimensions of all non-scalar inputs must be identical.

`Rate`, `Time`, and `Volatility` must be expressed in consistent units of time.

Examples

Consider European futures options with exercise prices of $20 that expire in four months. Assume that the current underlying futures price is also $20 with a volatility of 25% per annum. The risk-free rate is 9% per annum. Using this data

```
[Call, Put] = blkprice(20, 20, 0.09, 4/12, 0.25)
```

returns equal call and put prices of $1.1166.

References

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003, pp. 287-288.

Black, Fischer, "The Pricing of Commodity Contracts," *Journal of Financial Economics,* March 3, 1976, pp. 167-179.

See Also

`binprice`, `blsprice`

Purpose

Black-Scholes sensitivity to underlying price change

Syntax

```
[CallDelta, PutDelta] = blsdelta(Price, Strike, Rate, Time,
Volatility, Yield)
```

Arguments

`Price`	Current price of the underlying asset.
`Strike`	Exercise price of the option.
`Rate`	Annualized, continuously compounded risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time to expiration of the option, expressed in years.
`Volatility`	Annualized asset price volatility (annualized standard deviation of the continuously compounded asset return), expressed as a positive decimal number.
`Yield`	(Optional) Annualized, continuously compounded yield of the underlying asset over the life of the option, expressed as a decimal number. (Default = 0.) For example, for options written on stock indices, `Yield` could represent the dividend yield. For currency options, `Yield` could be the foreign risk-free interest rate.

Description

`[CallDelta, PutDelta] = blsdelta(Price, Strike, Rate, Time, Volatility, Yield)` returns delta, the sensitivity in option value to change in the underlying asset price. Delta is also known as the hedge ratio.

Note `blsdelta` can handle other types of underlies like Futures and Currencies. When pricing Futures (Black model), enter the input argument `Yield` as:

```
Yield = Rate
```

When pricing currencies (Garman-Kohlhagen model), enter the input argument `Yield` as:

```
Yield = ForeignRate
```

where `ForeignRate` is the continuously compounded, annualized risk free interest rate in the foreign country.

Examples

```
[CallDelta, PutDelta] = blsdelta(50, 50, 0.1, 0.25, 0.3, 0)

CallDelta =
    0.5955

PutDelta =
   -0.4045
```

References

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003.

See Also

`blsgamma`, `blslambda`, `blsprice`, `blsrho`, `blstheta`, `blsvega`

Purpose

Black-Scholes sensitivity to underlying delta change

Syntax

```
Gamma = blsgamma(Price, Strike, Rate, Time, Volatility, Yield)
```

Arguments

`Price`	Current price of the underlying asset.
`Strike`	Exercise price of the option.
`Rate`	Annualized, continuously compounded risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time to expiration of the option, expressed in years.
`Volatility`	Annualized asset price volatility (annualized standard deviation of the continuously compounded asset return), expressed as a positive decimal number.
`Yield`	(Optional) Annualized, continuously compounded yield of the underlying asset over the life of the option, expressed as a decimal number. (Default = 0.) For example, for options written on stock indices, `Yield` could represent the dividend yield. For currency options, `Yield` could be the foreign risk-free interest rate.

Description

`Gamma = blsgamma(Price, Strike, Rate, Time, Volatility, Yield)` returns gamma, the sensitivity of delta to change in the underlying asset price.

Note `blsgamma` can handle other types of underlies like Futures and Currencies. When pricing Futures (Black model), enter the input argument `Yield` as:

```
Yield = Rate
```

When pricing currencies (Garman-Kohlhagen model), enter the input argument `Yield` as:

```
Yield = ForeignRate
```

where `ForeignRate` is the continuously compounded, annualized risk free interest rate in the foreign country.

Examples

```
Gamma = blsgamma(50, 50, 0.12, 0.25, 0.3, 0)

Gamma =
   0.0512
```

References

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003.

See Also

`blsdelta`, `blslambda`, `blsprice`, `blsrho`, `blstheta`, `blsvega`

Purpose

Black-Scholes implied volatility

Syntax

```
Volatility = blsimpv(Price, Strike, Rate, Time, Value, Limit, ...
Yield, Tolerance, Class)
```

Arguments

`Price`	Current price of the underlying asset.
`Strike`	Exercise price of the option.
`Rate`	Annualized, continuously compounded risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time to expiration of the option, expressed in years.
`Value`	Price of a European option from which the implied volatility of the underlying asset is derived.
`Limit`	(Optional) Positive scalar representing the upper bound of the implied volatility search interval. If `Limit` is empty or unspecified, the default = 10, or 1000% per annum.
`Yield`	(Optional) Annualized, continuously compounded yield of the underlying asset over the life of the option, expressed as a decimal number. (Default = 0.) For example, for options written on stock indices, `Yield` could represent the dividend yield. For currency options, `Yield` could be the foreign risk-free interest rate.

`Tolerance`	(Optional) Implied volatility termination tolerance. A positive scalar. Default = 1e-6.
`Class`	(Optional) Option class (call or put) indicating the option type from which the implied volatility is derived. May be either a logical indicator or a cell array of characters. To specify call options, set `Class = true` or `Class = {'call'}`; to specify put options, set `Class = false` or `Class = {'put'}`. If `Class` is empty or unspecified, the default is a call option.

Description

`Volatility = blsimpv(Price, Strike, Rate, Time, Value, Limit, Yield, Tolerance, Class)` using a Black-Scholes model computes the implied volatility of an underlying asset from the market value of European call and put options.

`Volatility` is the implied volatility of the underlying asset derived from European option prices, expressed as a decimal number. If no solution is found, `blsimpv` returns `NaN`.

Any input argument may be a scalar, vector, or matrix. When a value is a scalar, that value is used to price all the options. If more than one input is a vector or matrix, the dimensions of all non-scalar inputs must be identical.

`Rate`, `Time`, and `Yield` must be expressed in consistent units of time.

Examples

Consider a European call option trading at $10 with an exercise price of $95 and three months until expiration. Assume that the underlying stock pays no dividend and trades at $100. The risk-free rate is 7.5% per annum. Furthermore, assume that you are interested in implied volatilities no greater than 0.5 (50% per annum).

Under these conditions, the following statements all compute an implied volatility of 0.3130, or 31.30% per annum.

```
Volatility = blsimpv(100, 95, 0.075, 0.25, 10, 0.5)
```

```
Volatility = blsimpv(100, 95, 0.075, 0.25, 10, 0.5, 0, [], {'Call'})
Volatility = blsimpv(100, 95, 0.075, 0.25, 10, 0.5, 0, [], true)
```

References

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003.

Luenberger, David G., *Investment Science*, Oxford University Press, 1998.

See Also

`blsdelta`, `blsgamma`, `blslambda`, `blsprice`, `blsrho`, `blstheta`

blslambda

Purpose

Black-Scholes elasticity

Syntax

```
[CallEl, PutEl] = blslambda(Price, Strike, Rate, Time, Volatility,
Yield)
```

Arguments

`Price`	Current price of the underlying asset.
`Strike`	Exercise price of the option.
`Rate`	Annualized, continuously compounded risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time to expiration of the option, expressed in years.
`Volatility`	Annualized asset price volatility (annualized standard deviation of the continuously compounded asset return), expressed as a positive decimal number.
`Yield`	(Optional) Annualized, continuously compounded yield of the underlying asset over the life of the option, expressed as a decimal number. (Default = 0.) For example, for options written on stock indices, `Yield` could represent the dividend yield. For currency options, `Yield` could be the foreign risk-free interest rate.

Description

`[CallEl, PutEl] = blslambda(Price, Strike, Rate, Time, Volatility, yield)` returns the elasticity of an option. `CallEl` is the call option elasticity or leverage factor, and `PutEl` is the put option elasticity or leverage factor. Elasticity (the leverage of an option position) measures the percent change in an option price per one percent change in the underlying asset price.

Examples

```
[CallEl, PutEl] = blslambda(50, 50, 0.12, 0.25, 0.3)

CallEl =
    8.1274

PutEl =
   -8.6466
```

References

Daigler, *Advanced Options Trading*, Chapter 4.

See Also

`blsdelta`, `blsgamma`, `blsprice`, `blsrho`, `blstheta`, `blsvega`

blsprice

Purpose

Black-Scholes put and call option pricing

Syntax

```
[Call, Put] = blsprice(Price, Strike, Rate, Time, Volatility, Yield)
```

Arguments

`Price`	Current price of the underlying asset.
`Strike`	Exercise price of the option.
`Rate`	Annualized, continuously compounded risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time to expiration of the option, expressed in years.
`Volatility`	Annualized asset price volatility (annualized standard deviation of the continuously compounded asset return), expressed as a positive decimal number.
`Yield`	(Optional) Annualized, continuously compounded yield of the underlying asset over the life of the option, expressed as a decimal number. (Default = 0.) For example, for options written on stock indices, `Yield` could represent the dividend yield. For currency options, `Yield` could be the foreign risk-free interest rate.

Description

`[Call, Put] = blsprice(Price, Strike, Rate, Time, Volatility, Yield)` computes European put and call option prices using a Black-Scholes model.

Any input argument may be a scalar, vector, or matrix. When a value is a scalar, that value is used to price all the options. If more than one input is a vector or matrix, the dimensions of all non-scalar inputs must be identical.

`Rate`, `Time`, `Volatility`, and `Yield` must be expressed in consistent units of time.

Note `blsprice` can handle other types of underlies like Futures and Currencies. When pricing Futures (Black model), enter the input argument `Yield` as:

```
Yield = Rate
```

When pricing currencies (Garman-Kohlhagen model), enter the input argument `Yield` as:

```
Yield = ForeignRate
```

where `ForeignRate` is the continuously compounded, annualized risk free interest rate in the foreign country.

Examples

Consider European stock options that expire in three months with an exercise price of $95. Assume that the underlying stock pays no dividend, trades at $100, and has a volatility of 50% per annum. The risk-free rate is 10% per annum. Using this data

```
[Call, Put] = blsprice(100, 95, 0.1, 0.25, 0.5)
```

returns call and put prices of $13.70 and $6.35, respectively.

References

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003.

Luenberger, David G., *Investment Science*, Oxford University Press, 1998.

See Also

`blkprice`, `blsdelta`, `blsgamma`, `blsimpv`, `blslambda`, `blsrho`, `blstheta`, `blsvega`

blsrho

Purpose

Black-Scholes sensitivity to interest rate change

Syntax

```
[CallRho, PutRho]= blsrho(Price, Strike, Rate, Time, Volatility,
Yield)
```

Arguments

`Price`	Current price of the underlying asset.
`Strike`	Exercise price of the option.
`Rate`	Annualized, continuously compounded risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time to expiration of the option, expressed in years.
`Volatility`	Annualized asset price volatility (annualized standard deviation of the continuously compounded asset return), expressed as a positive decimal number.
`Yield`	(Optional) Annualized, continuously compounded yield of the underlying asset over the life of the option, expressed as a decimal number. (Default = 0.) For example, for options written on stock indices, `Yield` could represent the dividend yield. For currency options, `Yield` could be the foreign risk-free interest rate.

Description

`[CallRho, PutRho]= blsrho(Price, Strike, Rate, Time, Volatility, Yield)` returns the call option rho `CallRho`, and the put option rho `PutRho`. Rho is the rate of change in value of derivative securities with respect to interest rates.

Examples

```
[CallRho, PutRho] = blsrho(50, 50, 0.12, 0.25, 0.3, 0)
```

```
CallRho =
    6.6686

PutRho =
   -5.4619
```

References

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003.

See Also

`blsdelta`, `blsgamma`, `blslambda`, `blsprice`, `blstheta`, `blsvega`

blstheta

Purpose

Black-Scholes sensitivity to time-until-maturity change

Syntax

```
[CallTheta, PutTheta] = blstheta(Price, Strike, Rate, Time,
Volatility, Yield)
```

Arguments

`Price`	Current price of the underlying asset.
`Strike`	Exercise price of the option.
`Rate`	Annualized, continuously compounded risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time to expiration of the option, expressed in years.
`Volatility`	Annualized asset price volatility (annualized standard deviation of the continuously compounded asset return), expressed as a positive decimal number.
`Yield`	(Optional) Annualized, continuously compounded yield of the underlying asset over the life of the option, expressed as a decimal number. (Default = 0.) For example, for options written on stock indices, `Yield` could represent the dividend yield. For currency options, `Yield` could be the foreign risk-free interest rate.

Description

`[CallTheta, PutTheta] = blstheta(Price, Strike, Rate, Time, Volatility, Yield)` returns the call option theta `CallTheta`, and the put option theta `PutTheta`. Theta is the sensitivity in option value with respect to time.

Examples

```
[CallTheta, PutTheta] = blstheta(50, 50, 0.12, 0.25, 0.3, 0)

CallTheta =
   -8.9630

PutTheta =
   -3.1404
```

References

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003.

See Also

`blsdelta`, `blsgamma`, `blslambda`, `blsprice`, `blsrho`, `blsvega`

blsvega

Purpose

Black-Scholes sensitivity to underlying price volatility

Syntax

```
Vega = blsvega(Price, Strike, Rate, Time, Volatility, Yield)
```

Arguments

`Price`	Current price of the underlying asset.
`Strike`	Exercise price of the option.
`Rate`	Annualized, continuously compounded risk-free rate of return over the life of the option, expressed as a positive decimal number.
`Time`	Time to expiration of the option, expressed in years.
`Volatility`	Annualized asset price volatility (annualized standard deviation of the continuously compounded asset return), expressed as a positive decimal number.
`Yield`	(Optional) Annualized, continuously compounded yield of the underlying asset over the life of the option, expressed as a decimal number. (Default = 0.) For example, for options written on stock indices, `Yield` could represent the dividend yield. For currency options, `Yield` could be the foreign risk-free interest rate.

Description

`Vega = blsvega(Price, Strike, Rate, Time, Volatility, Yield)` returns vega, the rate of change of the option value with respect to the volatility of the underlying asset.

Examples

```
Vega = blsvega(50, 50, 0.12, 0.25, 0.3, 0)

Vega =
    9.6035
```

References

Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003.

See Also

`blsdelta`, `blsgamma`, `blslambda`, `blsprice`, `blsrho`, `blstheta`

bndconvp

Purpose

Bond convexity given price

Syntax

```
[YearConvexity, PerConvexity] = bndconvp(Price, CouponRate, Settle,
Maturity, Period, Basis, EndMonthRule, IssueDate,
FirstCouponDate, LastCouponDate, StartDate, Face)
```

Arguments

`Price`	Clean price (excludes accrued interest).
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European)

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.
`Face`	(Optional) Face or par value. Default = 100.

All specified arguments must be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalar arguments. Use an empty matrix (`[]`) as a placeholder for an optional argument. Fill unspecified entries in input vectors with `NaN`. Dates can be serial date numbers or date strings.

Description

`[YearConvexity, PerConvexity] = bndconvp(Price, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)` computes the convexity of `NUMBONDS` fixed income securities given a clean price for each bond. This function determines the convexity for a bond whether or not the first or last coupon periods in the coupon structure are short or long (that is, whether or not the coupon structure is synchronized to maturity). This function also determines the convexity of a zero coupon bond.

`YearConvexity` is the yearly (annualized) convexity; `PerConvexity` is the periodic convexity reported on a semiannual bond basis (in accordance with SIA convention). Both outputs are `NUMBONDS`-by-`1` vectors.

Examples

Find the convexity of three bonds given their prices.

```
Price = [106; 100; 98];
CouponRate = 0.055;
Settle = '02-Aug-1999';
Maturity = '15-Jun-2004';
```

```
Period = 2;
Basis = 0;

[YearConvexity, PerConvexity] = bndconvp(Price,...
CouponRate,Settle, Maturity, Period, Basis)

YearConvexity =

   21.4447
   21.0363
   20.8951

PerConvexity =

   85.7788
   84.1454
   83.5803
```

See Also

bndconvy, bnddurp, bnddury, cfconv, cfdur

bndconvy

Purpose

Bond convexity given yield

Syntax

```
[YearConvexity, PerConvexity] = bndconvy(Yield, CouponRate, Settle,
Maturity, Period, Basis, EndMonthRule, IssueDate,
FirstCouponDate, LastCouponDate, StartDate, Face)
```

Arguments

`Yield`	Yield to maturity on a semiannual basis.
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European)

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.
`Face`	(Optional) Face or par value. Default = 100.

All specified arguments must be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalar arguments. Use an empty matrix (`[]`) as a placeholder for an optional argument. Fill unspecified entries in input vectors with `NaN`. Dates can be serial date numbers or date strings.

Description

`[YearConvexity, PerConvexity] = bndconvy(Yield, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)` computes the convexity of `NUMBONDS` fixed income securities given the yield to maturity for each bond. This function determines the convexity for a bond whether or not the first or last coupon periods in the coupon structure are short or long (that is, whether or not the coupon structure is synchronized to maturity). This function also determines the convexity of a zero coupon bond.

`YearConvexity` is the yearly (annualized) convexity; `PerConvexity` is the periodic convexity reported on a semiannual bond basis (in accordance with SIA convention). Both outputs are `NUMBONDS`-by-1 vectors.

Examples

Find the convexity of a bond at three different yield values.

```
Yield = [0.04; 0.055; 0.06];
CouponRate = 0.055;
Settle = '02-Aug-1999';
Maturity = '15-Jun-2004';
```

```
Period = 2;
Basis = 0;

[YearConvexity, PerConvexity]=bndconvy(Yield, CouponRate,...
Settle, Maturity, Period, Basis)

YearConvexity =

   21.4825
   21.0358
   20.8885

PerConvexity =

   85.9298
   84.1434
   83.5541
```

See Also

bndconvp, bnddurp, bnddury, cfconv, cfdur

bnddurp

Purpose

Bond duration given price

Syntax

```
[ModDuration, YearDuration, PerDuration] = bnddurp(Price,
CouponRate, Settle, Maturity, Period, Basis, EndMonthRule,
IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)
```

Arguments

`Price`	Clean price (excludes accrued interest).
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European)

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.
`Face`	(Optional) Face or par value. Default = 100.

All specified arguments must be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalar arguments. Use an empty matrix (`[]`) as a placeholder for an optional argument. Fill unspecified entries in input vectors with `NaN`. Dates can be serial date numbers or date strings.

Description

`[ModDuration, YearDuration, PerDuration] = bnddurp(Price, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)` computes the duration of `NUMBONDS` fixed income securities given a clean price for each bond. This function determines the Macaulay and modified duration for a bond whether or not the first or last coupon periods in the coupon structure are short or long (this is, whether or not the coupon structure is synchronized to maturity). This function also determines the Macaulay and modified duration for a zero coupon bond.

`ModDuration` is the modified duration in years, reported on a semiannual bond basis (in accordance with SIA convention); `YearDuration` is the Macaulay duration in years; `PerDuration` is the periodic Macaulay duration reported on a semiannual bond basis (in accordance with SIA convention). Outputs are `NUMBONDS`-by-1 vectors.

Examples

Find the duration of three bonds given their prices.

```
Price = [106; 100; 98];
CouponRate = 0.055;
Settle = '02-Aug-1999';
```

```
Maturity = '15-Jun-2004';
Period = 2;
Basis = 0;

[ModDuration, YearDuration, PerDuration] = bnddurp(Price,...
CouponRate, Settle, Maturity, Period, Basis)

ModDuration =

    4.2400
    4.1925
    4.1759

YearDuration =

    4.3275
    4.3077
    4.3007

PerDuration =

    8.6549
    8.6154
    8.6014
```

See Also

bndconvp, bndconvy, bnddury, bndkrdur

bnddury

Purpose

Bond duration given yield

Syntax

```
[ModDuration, YearDuration, PerDuration] = bnddury(Yield,
CouponRate, Settle, Maturity, Period, Basis, EndMonthRule,
IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)
```

Arguments

`Yield`	Yield to maturity on a semiannual basis.
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European)

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.
`Face`	(Optional) Face or par value. Default = 100.

All specified arguments must be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalar arguments. Use an empty matrix (`[]`) as a placeholder for an optional argument. Fill unspecified entries in input vectors with `NaN`. Dates can be serial date numbers or date strings.

Description

`[ModDuration, YearDuration, PerDuration] = bnddury(Yield, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)` computes the Macaulay and modified duration of `NUMBONDS` fixed income securities given yield to maturity for each bond. This function determines the duration for a bond whether or not the first or last coupon periods in the coupon structure are short or long (that is, whether or not the coupon structure is synchronized to maturity). This function also determines the Macaulay and modified duration for a zero coupon bond.

`ModDuration` is the modified duration in years, reported on a semiannual bond basis (in accordance with SIA convention); `YearDuration` is the Macaulay duration in years; `PerDuration` is the periodic Macaulay duration reported on a semiannual bond basis (in accordance with SIA convention). Outputs are `NUMBONDS`-by-1 vectors.

Examples

Find the duration of a bond at three different yield values.

```
Yield = [0.04; 0.055; 0.06];
CouponRate = 0.055;
```

```
Settle = '02-Aug-1999';
Maturity = '15-Jun-2004';
Period = 2;
Basis = 0;

[ModDuration,YearDuration,PerDuration]=bnddury(Yield,...
CouponRate, Settle, Maturity, Period, Basis)

ModDuration =

    4.2444
    4.1924
    4.1751

YearDuration =

    4.3292
    4.3077
    4.3004

PerDuration =

    8.6585
    8.6154
    8.6007
```

See Also

bndconvp, bndconvy, bnddurp, bndkrdur

bndkrdur

Purpose

Bond key rate duration given zero curve

Syntax

```
KRDUR = bndkrdur(ZeroData, CouponRate,
Settle, Maturity)
KRDUR = bndkrdur(ZeroData, CouponRate, Settle,
Maturity, 'Parameter1', Value1, 'Parameter2',
Value2, ...)
```

Arguments

`ZeroData`	Zero curve represented as a `numRates`-by-`2` matrix where the first column is a MATLAB date number and the second column is accompanying zero rates.
`CouponRate`	`numBonds`-by-`1` vector of coupon rates in decimal form.
`Settle`	Scalar MATLAB date number for the settlement date for all the bonds and the zero data. `Settle` must be the same settlement date for all the bonds and the zero curve.
`Maturity`	`numBonds`-by-`1` vector of maturity dates.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Acceptable values are 0, 1, 2 (default), 3, 4, 6, and 12.
`InterpMethod`	(Optional) Interpolation method used to obtain points from the zero curve. Acceptable values are: • `'linear'` (default) • `'cubic'` • `'pchip'`

`ShiftValue`	(Optional) Scalar value that zero curve is shifted up and down to compute duration. Default is .01 (100 basis points).
`KeyRates`	(Optional) Rates to perform the duration calculation, specified as a time to maturity. By default, `KeyRates` is set to each of the zero dates.
`CurveCompounding`	(Optional) Compounding frequency of the curve. Default is semiannual.
`CurveBasis`	(Optional) Basis of the curve, where the choices are identical to `Basis` below. Default is 0 (actual/actual).
`Basis`	(Optional) Day-count basis of the bond instrument. A vector of integers: • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA) • 11 = 30/360E (ISMA) • 12 = actual/365 (ISDA)

`EndMonthRule`	(Optional) End-of-month rule. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. The values are: • `0` = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. • `1` = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When you specify both `FirstCouponDate` and `LastCouponDate`, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.
`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.
`Face`	(Optional) Face or par value. Default = 100. `Face` has no impact on key rate duration.

Note You must enter the optional arguments as parameter/value pairs.

Description

```
KRDUR = bndkrdur(ZeroData, CouponRate, Settle, Maturity)
```

```
KRDUR = bndkrdur(ZeroData, CouponRate, Settle, Maturity,
'Parameter1', Value1, 'Parameter2', Value2, ...)
```

The output argument `KRDUR` is a `numBonds`-by-`numRates` matrix of key rate durations.

`bndkrdur` computes the key rate durations for one or more bonds given a zero curve and a set of key rates. By default, the key rates are each of the zero curve rates. For each key rate, the duration is computed by shifting the zero curve up and down by a specified amount (`ShiftValue`) at that particular key rate, computing the present value of the bond in each case with the new zero curves, and then evaluating the following:

$$\text{krdur_i} = \frac{(\text{PV_down - PV_up})}{(\text{PV x ShiftValue x 2})}$$

Note The shift to the curve is computed by shifting the particular key rate by the `ShiftValue` and then interpolating the values of the curve in the interval between the previous and next key rates. For the first key rate, any curve values before the date are equal to the `ShiftValue`; likewise, for the last key rate, any curve values after the date are equal to the `ShiftValue`.

Examples

Find the key rate duration of a bond for key rate times of 2, 5, 10, and 30 years.

```
ZeroRates = [0.0476 .0466 .0465 .0468 .0473 .0478 ...
.0493 .0539 .0572 .0553 .0530]';
```

```
ZeroDates = daysadd('31-Dec-1998',[30 360 360*2 360*3 360*5 ...
360*7 360*10 360*15 360*20 360*25 360*30],1);

ZeroData = [ZeroDates ZeroRates];

krdur = bndkrdur(ZeroData,.0525,'12/31/1998',...
'11/15/2028','KeyRates',[2 5 10 30])

krdur =

    0.2986    0.8791    4.1354    9.5811
```

References

Golub, B.W. and L.M. Tilman, *Risk Management: Approaches for Fixed Income Markets* Wiley, 2000.

Tuckman, B. *Fixed Income Securities: Tools for Today's Markets* Wiley, 2002.

See Also

`bndconvp`, `bndconvy`, `bnddurp`, `bnddury`

Purpose

Price fixed income security from yield to maturity

Syntax

```
[Price, AccruedInt] = bndprice(Yield, CouponRate, Settle, Maturity)
[Price, AccruedInt] = bndprice(Yield, CouponRate, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
LastCouponDate, StartDate, Face)
```

Arguments

Required and optional inputs can be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalar arguments. Optional inputs can also be passed as empty matrices (`[]`) or omitted at the end of the argument list. The value `NaN` in any optional input invokes the default value for that entry. Dates can be serial date numbers or date strings.

`Yield`	Bond yield to maturity is on a semiannual basis for `basis` values `0` through `7` and an annual basis for `basis` values `8` through `12`.
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.

`Basis`

(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`

(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate`

(Optional) Date when a bond was issued.

`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.
`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.
`Face`	(Optional) Face or par value. Default = 100.

Description

`[Price, AccruedInt] = bndprice(Yield, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)` given bonds with SIA date parameters and semiannual yields to maturity, returns the clean prices and accrued interest due.

`Price` is the clean price of the bond (current price without accrued interest).

`AccruedInt` is the accrued interest payable at settlement.

`Price` and `Yield` are related by the formula

```
Price + Accrued_Interest = sum(Cash_Flow*(1+Yield/2)^(-Time))
```

where the sum is over the bonds' cash flows and corresponding times in units of semiannual coupon periods.

Examples

Price a treasury bond at three different yield values.

```
Yield = [0.04; 0.05; 0.06];
CouponRate = 0.05;
Settle = '20-Jan-1997';
Maturity = '15-Jun-2002';
Period = 2;
Basis = 0;

[Price, AccruedInt] = bndprice(Yield, CouponRate, Settle,...
Maturity, Period, Basis)

Price =

  104.8106
   99.9951
   95.4384

AccruedInt =

  0.4945
  0.4945
  0.4945
```

See Also

`cfamounts`, `bndyield`

Purpose

Static spread over spot curve

Syntax

```
Spread = bndspread(SpotInfo, Price, Coupon, Settle, Maturity,
Period, Basis, EndMonthRule, IssueDate, FirstCouponDate,
LastCouponDate)
```

Arguments

`SpotInfo`	Two-column matrix: `[SpotDates ZeroRates]` Zero rates correspond to maturities on the spot dates, continuously compounded. You will obtain the best results if you choose evenly spaced rates close together, for example, by using the three-month deposit rates.
`Price`	Price for every $100 notional amount of bonds whose spreads are computed.
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A scalar or vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.

`Basis`

(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`

(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate`

(Optional) Date when a bond was issued.

`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

Description

`Spread = bndspread(SpotInfo, Price, Coupon, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)` computes the static spread to benchmark in basis points.

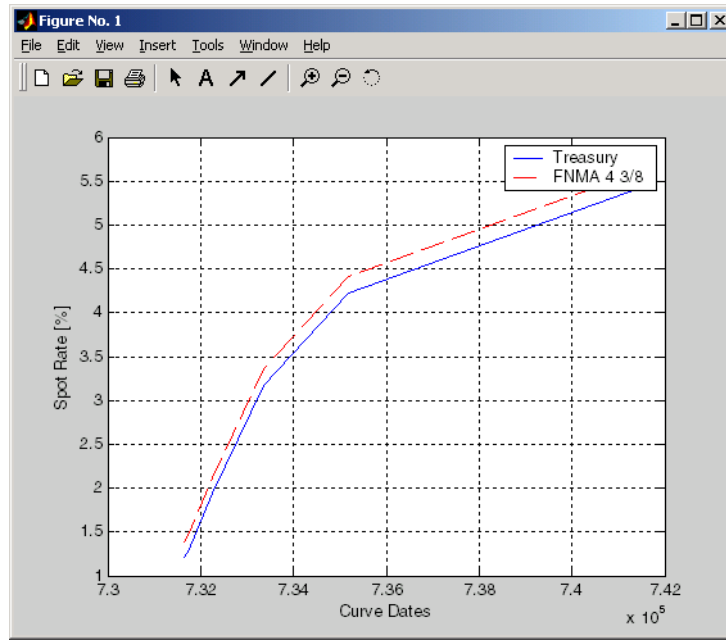
Examples

Compute a FNMA 4 3/8 spread over a Treasury spot-curve.

```
% Build spot curve.

RefMaturity = [datenum('02/27/2003');
               datenum('05/29/2003');
               datenum('10/31/2004');
               datenum('11/15/2007');
               datenum('11/15/2012');
               datenum('02/15/2031')];

RefCpn = [0;
          0;
          2.125;
          3;
          4;
```

```
          5.375] / 100;

RefPrices =  [99.6964;
              99.3572;
             100.3662;
              99.4511;
              99.4299;
             106.5756];

RefBonds = [RefPrices, RefMaturity, RefCpn];
Settle   = datenum('26-Nov-2002');
[ZeroRates, CurveDates] = zbtprice(RefBonds(:, 2:end), ...
RefPrices, Settle)

% FNMA 4 3/8 maturing 10/06 at 4.30 pm Tuesday, Nov 26, 2002
Price    = 105.484;
Coupon   = 0.04375;
Maturity = datenum('15-Oct-2006');

% All optional inputs are supposed to be accounted by default,
% except the accrued interest under 30/360 (SIA), so:
Period = 2;
Basis  = 1;
SpotInfo = [CurveDates, ZeroRates];

% Compute static spread over treasury curve, taking into account
% the shape of curve as derived by bootstrapping method embedded
% within bndspread.

SpreadInBP = bndspread(SpotInfo, Price, Coupon, Settle, ...
Maturity, Period, Basis)

plot(CurveDates, ZeroRates*100, 'b', CurveDates, ...
ZeroRates*100+SpreadInBP/100, 'r--')
legend({'Treasury'; 'FNMA 4 3/8'})
xlabel('Curve Dates')
ylabel('Spot Rate [%]')
```

```
grid;

ZeroRates =

    0.0121
    0.0127
    0.0194
    0.0317
    0.0423
    0.0550

CurveDates =

      731639
      731730
      732251
      733361
      735188
      741854

SpreadInBP =

   18.7582
```



See Also

`bndprice`, `bndyield`

Purpose

Yield to maturity for fixed income security

Syntax

```
Yield = bndyield(Price, CouponRate, Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
StartDate, Face)
```

Arguments

Required and optional inputs can be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalar arguments. Optional inputs can also be passed as empty matrices (`[]`) or omitted at the end of the argument list. The value `NaN` in any optional input invokes the default value for that entry. Dates can be serial date numbers or date strings.

`Price`	Clean price of the bond (current price without accrued interest).
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.

`Basis`

(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`

(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate`

(Optional) Date when a bond was issued.

`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.
`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.
`Face`	(Optional) Face or par value. Default = 100.

Description

`Yield = bndyield(Price, CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)` given `NUMBONDS` bonds with SIA date parameters and clean prices (excludes accrued interest), returns the bond equivalent yields to maturity.

`Yield` is a `NUMBONDS`-by-1 vector of the bond equivalent yields to maturity with semiannual compounding.

`Price` and `Yield` are related by the formula

```
Price + Accrued_Interest = sum(Cash_Flow*(1+Yield/2)^(-Time))
```

where the sum is over the bonds' cash flows and corresponding times in units of semiannual coupon periods.

Examples

Compute the yield of a treasury bond at three different price values.

```
Price = [95; 100; 105];
CouponRate = 0.05;
Settle = '20-Jan-1997';
Maturity = '15-Jun-2002';
Period = 2;
Basis = 0;

Yield = bndyield(Price, CouponRate, Settle,...
Maturity, Period, Basis)

Yield =

    0.0610
    0.0500
    0.0396
```

See Also

`bndprice`, `cfamounts`

Purpose

Bollinger band chart

Syntax

```
bolling(Asset, Samples, Alpha)
[Movavgv, UpperBand, LowerBand] = bolling(Asset, Samples, Alpha,
Width)
```

Arguments

`Asset`	Vector of asset data.
`Samples`	Number of samples to use in computing the moving average.
`Alpha`	(Optional) Exponent used to compute the element weights of the moving average. Default = 0 (simple moving average).
`Width`	(Optional) Number of standard deviations to include in the envelope. A multiplicative factor specifying how tight the bands should be around the simple moving average. Default = 2.

Description

`bolling(Asset, Samples, Alpha, Width)` plots Bollinger bands for given `Asset` data. This form of the function does not return any data.

`[Movavgv, UpperBand, LowerBand] = bolling(Asset, Samples, Alpha, Width)` returns `Movavgv` with the moving average of the `Asset` data, `UpperBand` with the upper band data, and `LowerBand` with the lower band data. This form of the function does not plot any data.

Note The standard deviations are normalized by N-1, where N = the sequence length.

Examples

If `Asset` is a column vector of closing stock prices

```
bolling(Asset, 20, 1)
```

plots linear 20-day moving average Bollinger bands based on the stock prices.

```
[Movavgv, UpperBand, LowerBand] = bolling(Asset, 20, 1)
```

returns `Movavgv`, `UpperBand`, and `LowerBand` as vectors containing the moving average, upper band, and lower band data, without plotting the data.

See Also

`candle`, `dateaxis`, `highlow`, `movavg`, `pointfig`

Purpose

Time series Bollinger band

Syntax

```
[mid, uppr, lowr] = bollinger(data, wsize, wts, nstd)
[midfts, upprfts, lowrfts] = bollinger(tsobj, wsize, wts, nstd)
```

Arguments

`data`	Data vector.
`wsize`	(Optional) Window size. Default = 20.
`wts`	(Optional) Weight factor. Determines the type of moving average used. Default = 0 (box). 1 = linear.
`nstd`	(Optional) Number of standard deviations for upper and lower bands. Default = 2.
`tsobj`	Financial time series object.

Description

`[mid, uppr, lowr] = bollinger(data, wsize, wts, nstd)` calculates the middle (`mid`), upper (`uppr`), and lower (`lowr`) bands that make up the Bollinger bands from the vector `data`.

`mid` is the vector that represents the middle band, a simple moving average with a window size of `wsize`. `uppr` and `lowr` are vectors that represent the upper and lower bands. `uppr` is a vector representing the upper band that is `+nstd` times. `lowr` is a vector representing the lower band that is `-nstd` times.

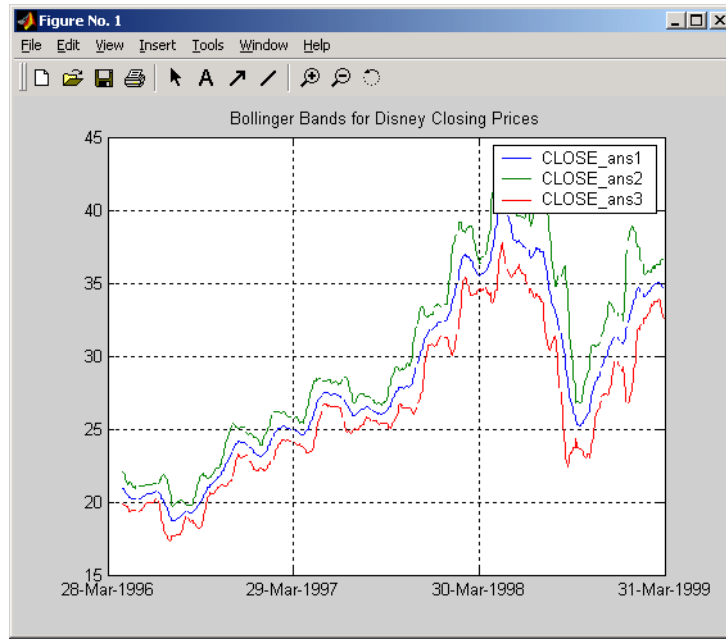
`[midfts, upprfts, lowrfts] = bollinger(tsobj, wsize, wts, nstd)` calculates the middle, upper, and lower bands that make up the Bollinger bands from a financial time series object `tsobj`.

`midfts` is a financial time series object that represents the middle band for all series in `tsobj`. Both `upprfts` and `lowrfts` are financial time series objects that represent the upper and lower bands of all series, which are `+nstd` times and `-nstd` times moving standard deviations away from the middle band.

Examples

Compute the Bollinger bands for Disney stock closing prices and plot the results:

```
load disney.mat
[dis_Mid,dis_Uppr,dis_Lowr]= bollinger(dis);
dis_CloseBolling = [dis_Mid.CLOSE, dis_Uppr.CLOSE,...
dis_Lowr.CLOSE];
plot(dis_CloseBolling)
title('Bollinger Bands for Disney Closing Prices')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second Edition, McGraw-Hill, 1995, pp. 72-74.

See Also

`tsmovavg`

Purpose

Box-Cox transformation

Syntax

```
[transdat, lambda] = boxcox(data)
[transfts, lambdas] = boxcox(tsobj)
transdat = boxcox(lambda, data)
transfts = boxcox(lambda, tsobj)
```

Arguments

`data`	Data vector. Must be positive.
`tsobj`	Financial time series object.

Description

`boxcox` transforms nonnormally distributed data to a set of data that has approximately normal distribution. The Box-Cox transformation is a family of power transformations.

If λ is not = `0`, then

$$data(\lambda) = \frac{data^{\lambda} - 1}{\lambda}$$

If λ is = `0`, then

$$data(\lambda) = \log(data)$$

The logarithm is the natural logarithm (log base e). The algorithm calls for finding the λ value that maximizes the Log-Likelihood Function (LLF). The search is conducted using `fminsearch`.

`[transdat, lambda] = boxcox(data)` transforms the data vector `data` using the Box-Cox transformation method into `transdat`. It also estimates the transformation parameter λ.

`[transfts, lambda] = boxcox(tsojb)` transforms the financial time series object `tsobj` using the Box-Cox transformation method into `transfts`. It also estimates the transformation parameter λ.

If the input data is a vector, `lambda` is a scalar. If the input is a financial time series object, `lambda` is a structure with fields similar to the components of the object; for example, if the object contains series names `Open` and `Close`, `lambda` has fields `lambda.Open` and `lambda.Close`.

`transdat = boxcox(lambda, data)` and `transfts = boxcox(lambda, tsobj)` transform the data using a certain specified λ for the Box-Cox transformation. This syntax does not find the optimum λ that maximizes the LLF.

See Also

`fminsearch`

Purpose

Next or previous business day

Syntax

```
Busday = busdate(Date, Direction, Holiday, Weekend)
```

Arguments

`Date`	Reference date. Enter scalar, vector, or matrix of reference business dates as serial date numbers or date strings.
`Direction`	(Optional) Scalar, vector, or matrix of search directions. 1 = next (default) or -1 = previous business day.
`Holiday`	(Optional) Vector of holidays and nontrading-day dates. All dates in Holiday must be the same format: either serial date numbers or date strings. (Using serial date numbers improves performance.) If `Holiday` is not specified, the non-trading day default vector is determined by the routine `holidays` function.
`Weekend`	(Optional) Vector of length 7, containing 0 and 1, the value 1 indicating weekend days. The first element of this vector corresponds to Sunday. Thus, when Saturday and Sunday form the weekend (default), `Weekend = [1 0 0 0 0 0 1]`.

Description

`Busday = busdate(Date, Direction, Holiday, Weekend)` returns the scalar, vector, or matrix of the next or previous business day(s), depending on `Holiday`.

Use the function `datestr` to convert serial date numbers to formatted date strings.

Examples

Example 1.

```
Busday = busdate('3-Jul-2001', 1)
Busday =

     731037

datestr(Busday)

ans =

05-Jul-2001
```

Example 2. You can indicate that Saturday is a business day by appropriately setting the `Weekend` argument.

```
Weekend = [1 0 0 0 0 0 0];
```

July 4, 2003 falls on a Friday. Use `busdate` to verify that Saturday, July 5, is actually a business day.

```
Date = datestr(busdate('3-Jul-2003', 1, , Weekend))
```

See Also

`holidays`, `isbusday`

Purpose

Business days in serial date format

Syntax

```
bdates = busdays(sdate, edate, bdmode)
bdates = busdays(sdate, edate, bdmode, holvec)
```

Arguments

`sdate`	Start date in string or serial date format.
`edate`	End date in string or serial date format.
`bdmode`	(Optional) Frequency of business days: • `DAILY`, `Daily`, `daily`, `D`, `d`, `1` (default) • `WEEKLY`, `Weekly`, `weekly`, `W`, `w`, `2` • `MONTHLY`, `Monthly`, `monthly`, `M`, `m`, `3` • `QUARTERLY`, `Quarterly`, `quarterly`, `Q`, `q`, `4` • `SEMIANNUAL`, `Semiannual`, `semiannual`, `S`, `s`, `5` • `ANNUAL`, `Annual`, `annual`, `A`, `a`, `6` Strings must be enclosed in single quotation marks.
`holvec`	(Optional) Holiday dates vector in string or serial date format.

Description

`bdates = busdays(sdate, edate, bdmode)` generates a vector of business days, `bdates`, in serial date format between the last business date of the period that contains the start date, and the last business date of period that contains the end date. If `holvec` is not supplied, the dates are generated based on United States holidays. If you do not supply `bdmode`, `busdays` generates a daily vector.

For example:

```
vec = datestr(busdays('1/2/01','1/9/01','weekly'))
vec =
05-Jan-2001
12-Jan-2001
```

The end of the week is considered to be a Friday. Between 1/2/01 (Monday) and 1/9/01 (Tuesday) there is only one end-of-week day, 1/5/01 (Friday).

Because 1/9/01 is part of following week, the following Friday (1/12/01) is also reported.

`bdates = busdays(sdate, edate, bdmode, holvec)` lets you supply a vector of holidays, `holvec`, used to generate business days. `holvec` can either be in serial date format or date string format. If you use this syntax, you need to supply the frequency `bdmode`.

The output, `bdates`, is a column vector of business dates in serial date format.

Setting `holvec` to `''` (empty string) or `[]` (empty vector) results in `BUSDAYS` using a default holiday schedule. The default holiday schedule is the NYSE holiday schedule.

Purpose

Candlestick chart

Syntax

```
candle(High, Low, Close, Open)
candle(High, Low, Close, Open, Color, Dates, Dateform)
```

Arguments

`High`	High prices for a security. A column vector.
`Low`	Low prices for a security. A column vector.
`Close`	Closing prices for a security. A column vector.
`Open`	Opening prices for a security. A column vector.
`Color`	(Optional) Candlestick color. A string. MATLAB software supplies a default color if none is specified. The default color differs depending on the background color of the figure window. See `ColorSpec` in the MATLAB documentation for color names.
`Dates`	(Optional) Column vector of dates for user specified X-axis tick labels.
`Dateform`	(Optional) Date string format used as the *x*-axis tick labels. (See `datetick` in the MATLAB documentation.) You can specify a `dateform` only when `tsobj` does not contain time-of-day data. If `tsobj` contains time-of-day data, `dateform` is restricted to `'dd-mmm-yyyy HH:MM'`.

Description

`candle(High, Low, Close, Open)` plots a candlestick chart given column vectors with the high, low, closing, and opening prices of a security.

If the closing price is greater than the opening price, the body (the region between the opening and closing price) is unfilled.

If the opening price is greater than the closing price, the body is filled.

`candle(High, Low, Close, Open, Color, Dates, Dateform)` plots a candlestick chart given column vectors with the high, low, closing, and opening prices of a security. In addition, the optional arguments `Color`, `Dates`, and `Dateform` specify the color of the candle box and the date string format used as the *x*-axis tick labels.

Examples

Given `High`, `Low`, `Close`, and `Open` as equal-size vectors of stock price data

```
candle(High, Low, Close, Open, 'cyan')
```

plots a candlestick chart with cyan candles.

See Also

`bolling`, `candle`, `dateaxis`, `highlow`, `movavg`, `pointfig`

Purpose

Time series candle plot

Syntax

```
candle(tsobj)
candle(tsobj, color)
candle(tsobj, color, dateform)
candle(tsobj, color, dateform, ParameterName, ParameterValue, ...)
hcdl = candle(tsobj, color, dateform, ParameterName,
ParameterValue, ...)
```

Arguments

`tsobj`	Financial time series object
`color`	(Optional) A three-element row vector representing RGB or a color identifier. (See `plot` in the MATLAB documentation.)
`dateform`	(Optional) Date string format used as the *x*-axis tick labels. (See `datetick` in the MATLAB documentation.) You can specify a `dateform` only when `tsobj` does not contain time-of-day data. If `tsobj` contains time-of-day data, `dateform` is restricted to `'dd-mmm-yyyy HH:MM'`.

Description

`candle(tsobj)` generates a candle plot of the data in the financial time series object `tsobj`. `tsobj` must contain at least four data series representing the high, low, open, and closing prices. These series must have the names `High`, `Low`, `Open`, and `Close` (case-insensitive).

`candle(tsobj, color)` additionally specifies the color of the candle box.

`candle(tsobj, color, dateform)` additionally specifies the date string format used as the *x*-axis tick labels. See `datestr` for a list of date string formats.

`candle(tsobj, color, dateform, ParameterName, ParameterValue, ...)` indicates the actual name(s) of the required data series if the data series do not have the default names. `ParameterName` can be

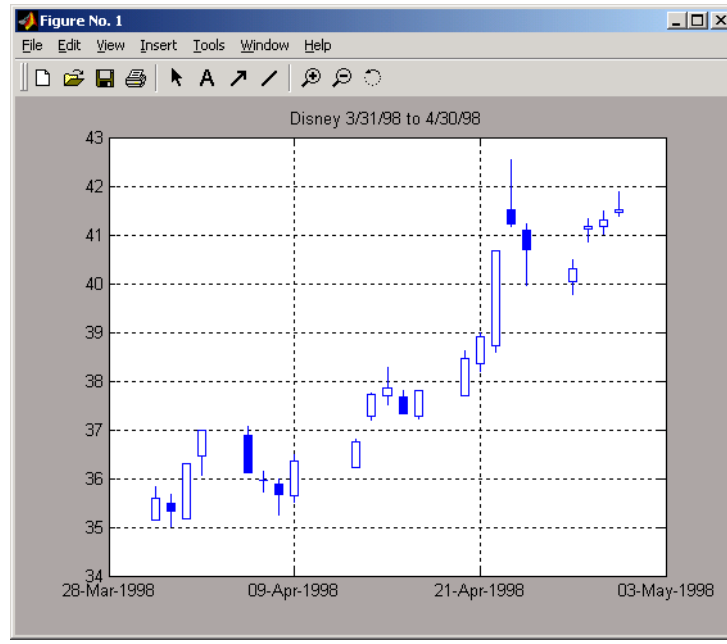
- `HighName`: high prices series name
- `LowName`: low prices series name
- `OpenName`: open prices series name
- `CloseName`: closing prices series name

`hcdl = candle(tsobj, color, dateform, ParameterName, ParameterValue, ...)` returns the handle to the patch objects and the line object that make up the candle plot. `hdcl` is a three-element column vector representing the handles to the two patches and one line that forms the candle plot.

Examples

Create a candle plot for Disney stock for the dates March 31, 1998 through April 30, 1998:

```
load disney.mat
candle(dis('3/31/98::4/30/98'))
title('Disney 3/31/98 to 4/30/98')
```



See Also

`candle`, `chartfts`, `highlow`, `plot`

Purpose

Cash flow and time mapping for bond portfolio

Syntax

```
[CFlowAmounts, CFlowDates, TFactors, CFlowFlags] =
cfamounts(CouponRate, Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
StartDate, Face)
```

Arguments

`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European)

- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.
`Face`	(Optional) Face or par value. Default = 100.

Required arguments must be number of bonds (`NUMBONDS`) by 1 or 1-by-`NUMBONDS` conforming vectors or scalars. Optional arguments must be either `NUMBONDS`-by-1 or 1-by-`NUMBONDS` conforming vectors, scalars, or empty matrices.

Description

`[CFlowAmounts, CFlowDates, TFactors, CFlowFlags] = cfamounts(CouponRate, Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate, Face)` returns matrices of cash flow amounts, cash flow dates, time factors, and cash flow flags for a portfolio of `NUMBONDS` fixed income securities. The elements contained in the cash flow matrix, time factor matrix, and cash flow flag matrix correspond to the cash flow dates for each security. The first element of each row in the cash flow matrix is the accrued interest payable on each bond. This is zero in the case of all zero coupon bonds. This function determines all cash flows and time mappings for a bond whether or not the coupon structure contains odd first or last periods. All output matrices are padded with `NaN`s as necessary to ensure that all rows have the same number of elements.

`CFlowAmounts` is the cash flow matrix of a portfolio of bonds. Each row represents the cash flow vector of a single bond. Each element in a column represents a specific cash flow for that bond.

`CFlowDates` is the cash flow date matrix of a portfolio of bonds. Each row represents a single bond in the portfolio. Each element in a column represents a cash flow date of that bond.

`TFactors` is the matrix of time factors for a portfolio of bonds. Each row corresponds to the vector of time factors for each bond. Each element in a column corresponds to the specific time factor associated with each cash flow of a bond. Time factors are useful in determining the present value of a stream of cash flows. The term *time factor* refers to the exponent *TF* in the discounting equation

$$PV = CF/(1 + z/2)^{TF}$$

where:

PV =	Present value of a cash flow.
CF =	The cash flow amount.
z =	The risk-adjusted annualized rate or yield corresponding to given cash flow. The yield is quoted on a semiannual basis.
TF =	Time factor for a given cash flow. Time is measured in semiannual periods from the settlement date to the cash flow date. In computing time factors, you use SIA actual/actual day count conventions for all time factor calculations.

`CFlowFlags` is the matrix of cash flow flags for a portfolio of bonds. Each row corresponds to the vector of cash flow flags for each bond. Each element in a column corresponds to the specific flag associated with each cash flow of a bond. Flags identify the type of each cash flow (for example, nominal coupon cash flow, front or end partial or "stub" coupon, maturity cash flow). Possible values are shown in the table.

Flag	Cash Flow Type
0	Accrued interest due on a bond at settlement.

Flag	Cash Flow Type
1	Initial cash flow amount smaller than normal due to "stub" coupon period. A stub period is created when the time from issue date to first coupon is shorter than normal.
2	Larger than normal initial cash flow amount because first coupon period is longer than normal.
3	Nominal coupon cash flow amount.
4	Normal maturity cash flow amount (face value plus the nominal coupon amount).
5	End "stub" coupon amount (last coupon period abnormally short and actual maturity cash flow is smaller than normal).
6	Larger than normal maturity cash flow because last coupon period longer than normal.
7	Maturity cash flow on a coupon bond when the bond has less than one coupon period to maturity.
8	Smaller than normal maturity cash flow when bond has less than one coupon period to maturity.
9	Larger than normal maturity cash flow when bond has less than one coupon period to maturity.
10	Maturity cash flow on a zero coupon bond.

Examples

Consider a portfolio containing a corporate bond paying interest quarterly and a treasury bond paying interest semiannually. Compute the cash flow structure and the time factors for each bond.

```
Settle = '01-Nov-1993';
Maturity = ['15-Dec-1994';'15-Jun-1995'];
CouponRate= [0.06; 0.05];
Period = [4; 2];
```

```
Basis = [1; 0];
[CFlowAmounts, CFlowDates, TFactors, CFlowFlags] = ...
cfamounts(CouponRate,Settle, Maturity, Period, Basis)

CFlowAmounts =

  -0.7667    1.5000    1.5000    1.5000    1.5000  101.5000
  -1.8989    2.5000    2.5000    2.5000  102.5000       NaN

CFlowDates =

728234     728278     728368     728460     728552     728643
728234     728278     728460     728643     728825        NaN

TFactors =

0    0.2404    0.7403    1.2404    1.7403    2.2404
0    0.2404    1.2404    2.2404    3.2404       NaN

CFlowFlags =

0     3     3     3     3     4
0     3     3     3     4   NaN
```

See Also

accrfrac, cfdates, cpncount, cpndaten, cpndatenq, cpndatep, cpndatepq, cpndaysn, cpndaysp, cpnpersz

Purpose

Cash flow convexity

Syntax

```
CFlowConvexity = cfconv(CashFlow, Yield)
```

Arguments

`CashFlow`	A vector of real numbers.
`Yield`	Periodic yield. A scalar. Enter as a decimal fraction.

Description

`CFlowConvexity = cfconv(CashFlow, Yield)` returns the convexity of a cash flow in periods.

Examples

Given a cash flow of nine payments of $2.50 and a final payment $102.50, with a periodic yield of 2.5%

```
CashFlow = [2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 102.5];

Convex = cfconv(CashFlow, 0.025)

Convex =

    90.4493 (periods)
```

See Also

`bndconvp`. `bndconvy`, `bnddurp`, `bnddury`, `cfdur`

Purpose

Cash flow dates for fixed-income security

Syntax

```
CFlowDates = cfdates(Settle, Maturity, Period, Basis, EndMonthRule,
IssueDate, FirstCouponDate, LastCouponDate, StartDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA)

	• 11 = 30/360E (ISMA) • 12 = actual/365 (ISDA)
`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.
`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.

Required arguments must be number of bonds (NUMBONDS)-by-1 or 1-by-NUMBONDS conforming vectors or scalars. Optional arguments must be either NUMBONDS-by-1 or 1-by-NUMBONDS conforming vectors, scalars, or empty matrices.

Any input can contain multiple values, but if so, all other inputs must contain the same number of values or a single value that applies to all. For example, if Maturity contains N dates, then Settle must contain N dates or a single date.

Description

CFlowDates = cfdates(Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate) returns a matrix of cash flow dates for a bond or set of bonds. cfdates determines all cash flow dates for a bond whether or not the coupon payment structure is normal or the first and/or last coupon period is long or short.

CFlowDates is an N-row matrix of serial date numbers, padded with NaNs as necessary to ensure that all rows have the same number of elements. Use the function datestr to convert serial date numbers to formatted date strings.

Note The cash flow flags for a portfolio of bonds were formerly available as the cfdates second output argument, CFlowFlags. You can now use cfamounts to get these flags. If you specify a CFlowFlags argument, cfdates displays a message directing you to use cfamounts.

Examples

```
CFlowDates = cfdates('14 Mar 1997', '30 Nov 1998', 2, 0, 1)
CFlowDates =
      729541      729724      729906      730089
datestr(CFlowDates)
ans =
31-May-1997
30-Nov-1997
31-May-1998
30-Nov-1998
```

Given three securities with different maturity dates and the same default arguments

```
Maturity = ['30-Sep-1997'; '31-Oct-1998'; '30-Nov-1998'];
CFlowDates = cfdates('14-Mar-1997', Maturity)
CFlowDates =
      729480      729663         NaN         NaN
      729510      729694      729875      730059
      729541      729724      729906      730089
```

Look at the cash-flow dates for the last security.

```
datestr(CFlowDates(3,:))
ans =
31-May-1997
30-Nov-1997
31-May-1998
30-Nov-1998
```

See Also

accrfrac, cfamounts, cftimes, cpncount, cpndaten, cpndatenq, cpndatep, cpndatepq, cpndaysn, cpndaysp, cpnpersz

Purpose

Cash-flow duration and modified duration

Syntax

```
[Duration, ModDuration] = cfdur(CashFlow, Yield)
```

Arguments

`CashFlow`	A vector or matrix of real numbers. When using a matrix, each column of the matrix is a separate cash flow.
`Yield`	Periodic yield. A scalar or vector. Enter as a decimal fraction.

Description

`[Duration, ModDuration] = cfdur(CashFlow, Yield)` calculates the duration and modified duration of a cash flow in periods.

Examples

Given a cash flow of nine payments of $2.50 and a final payment $102.50, with a periodic yield of 2.5%

```
CashFlow=[2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 102.5];

[Duration, ModDuration] = cfdur(CashFlow, 0.025)

Duration =
           8.9709 (periods)

ModDuration =
             8.7521 (periods)
```

See Also

`bndconvp`, `bndconvy`, `bnddurp`, `bnddury`, `cfconv`

Purpose

Portfolio form of cash flow amounts

Syntax

```
[CFBondDate, AllDates, AllTF, IndByBond] = cfport(CFlowAmounts,
CFlowDates, TFactors)
```

Arguments

`CFlowAmounts`	Number of bonds (`NUMBONDS`) by number of cash flows (`NUMCFS`) matrix with entries listing cash flow amounts corresponding to each date in `CFlowDates`.
`CFlowDates`	`NUMBONDS`-by-`NUMCFS` matrix with rows listing cash flow dates for each bond and padded with `NaN`s.
`TFactors`	(Optional) `NUMBONDS`-by-`NUMCFS` matrix with entries listing the time between settlement and the cash flow date measured in semiannual coupon periods.

Description

`[CFBondDate, AllDates, AllTF, IndByBond] = cfport(CFlowAmounts, CFlowDates, TFactors)` computes a vector of all cash flow dates of a bond portfolio, and a matrix mapping the cash flows of each bond to those dates. Use the matrix for pricing the bonds against a curve of discount factors.

`CFBondDate` is a `NUMBONDS` by number of dates (`NUMDATES`) matrix of cash flows indexed by bond and by date in `AllDates`. Each row contains a bond's cash flow values at the indices corresponding to entries in `AllDates`. Other indices in the row contain zeros.

`AllDates` is a `NUMDATES`-by-1 list of all dates that have any cash flow from the bond portfolio.

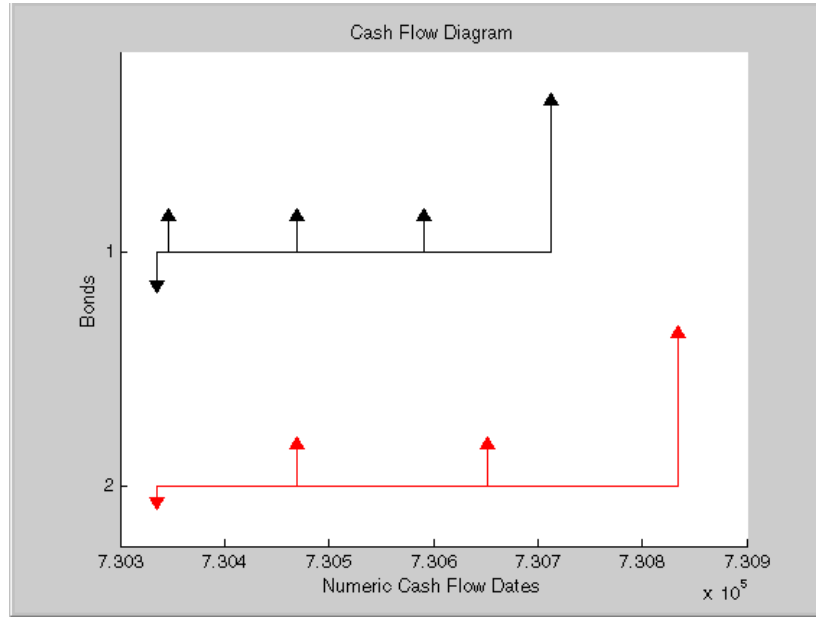
AllTF is a NUMDATES-by-1 list of time factors corresponding to the dates in AllDates. If TFactors is not entered, AllTF contains the number of days from the first date in AllDates.

IndByBond is a NUMBONDS-by-NUMCFS matrix of indices. The *i*th row contains a list of indices into AllDates where the *i*th bond has cash flows. Since some bonds have more cash flows than others, the matrix is padded with NaNs.

Examples

Use cfamounts to calculate the cash flow amounts, cash flow dates, and time factors for each of two bonds. Then use cfplot to plot the cash flow diagram.

```
Settle = '03-Aug-1999';
Maturity = ['15-Aug-2000';'15-Dec-2000'];
CouponRate= [0.06; 0.05];
Period = [3;2];
Basis = [1;0];
[CFlowAmounts, CFlowDates, TFactors] = cfamounts(CouponRate,...
Settle, Maturity, Period, Basis);
cfplot(CFlowDates,CFlowAmounts)
xlabel('Numeric Cash Flow Dates')
ylabel('Bonds')
title('Cash Flow Diagram')
```



Finally, call `cfport` to map the cash flow amounts to the cash flow dates.

Each row in the resultant `CFBondDate` matrix represents a bond. Each column represents a date on which one or more of the bonds has a cash flow. A 0 means the bond did not have a cash flow on that date. The dates associated with the columns are listed in `AllDates`. For example, the first bond had a cash flow of `2.000` on `730347`. The second bond had no cash flow on this date.

For each bond, `IndByBond` indicates the columns of `CFBondDate`, or dates in `AllDates`, for which a bond has a cash flow.

```
[CFBondDate, AllDates, AllTF, IndByBond] = ...
cfport(CFlowAmounts, CFlowDates, TFactors)

CFBondDate =

  -1.8000   2.0000   2.0000   2.0000        0  102.0000         0
```

```
  -0.6694       0  2.5000       0  2.5000         0  102.5000

AllDates =

      730335
      730347
      730469
      730591
      730652
      730713
      730835

AllTF =

         0
    0.0663
    0.7322
    1.3989
    1.7322
    2.0663
    2.7322

IndByBond =

     1     2     3     4     6
     1     3     5     7   NaN
```

See Also

cfamounts

Purpose

Time factors corresponding to bond cash flow dates

Syntax

```
TFactors = cftimes(Settle, Maturity, Period, Basis, EndMonthRule,
IssueDate, FirstCouponDate, LastCouponDate, StartDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA)

- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.
`StartDate`	(Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.

Description

`TFactors = cftimes(Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate)` determines the time factors corresponding to the cash flows of a bond or set of bonds. The time factor of a cash flow is the difference between the settlement date and the cash flow date in units of semiannual coupon periods. In computing time factors, you use SIA actual/actual day count conventions for all time factor calculations.

Examples

```
Settle = '15-Mar-1997';
Maturity = '01-Sep-1999';
Period = 2;
TFactors = cftimes(Settle, Maturity, Period)

TFactors =

    0.9239    1.9239    2.9239    3.9239    4.9239
```

See Also

`accrfrac`, `cfdates`, `cfamounts`, `cpncount`, `cpndaten`, `cpndatenq`, `cpndatep`, `cpndatepq`, `cpndaysn`, `cpndaysp`, `cpnpersz`, `date2time`

Purpose

Chaikin oscillator

Syntax

```
chosc = chaikosc(highp, lowp, closep, tvolume)
chosc = chaikosc([highp lowp closep tvolume])
choscts = chaikosc(tsobj)
choscts = chaikosc(tsobj, ParameterName, ParameterValue, ... )
```

Arguments

`highp`	High price (vector)
`lowp`	Low price (vector)
`closep`	Closing price (vector)
`tvolume`	Volume traded (vector)
`tsobj`	Financial time series object

Description

The Chaikin oscillator is calculated by subtracting the 10-period exponential moving average of the Accumulation/Distribution (A/D) line from the three-period exponential moving average of the A/D line.

`chosc = chaikosc(highp, lowp, closep, tvolume)` calculates the Chaikin oscillator (vector), `chosc`, for the set of stock price and volume traded data (`tvolume`). The prices that must be included are the high (`highp`), low (`lowp`), and closing (`closep`) prices.

`chosc = chaikosc([highp lowp closep tvolume])` accepts a four-column matrix as input.

`choscts = chaikosc(tsobj)` calculates the Chaikin Oscillator, `choscts`, from the data contained in the financial time series object `tsobj`. `tsobj` must at least contain data series with names `High`, `Low`, `Close`, and `Volume`. These series must represent the high, low, and closing prices, plus the volume traded. `choscts` is a financial time series object with the same dates as `tsobj` but only one series named `ChaikOsc`.

`choscts = chaikosc(tsobj, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

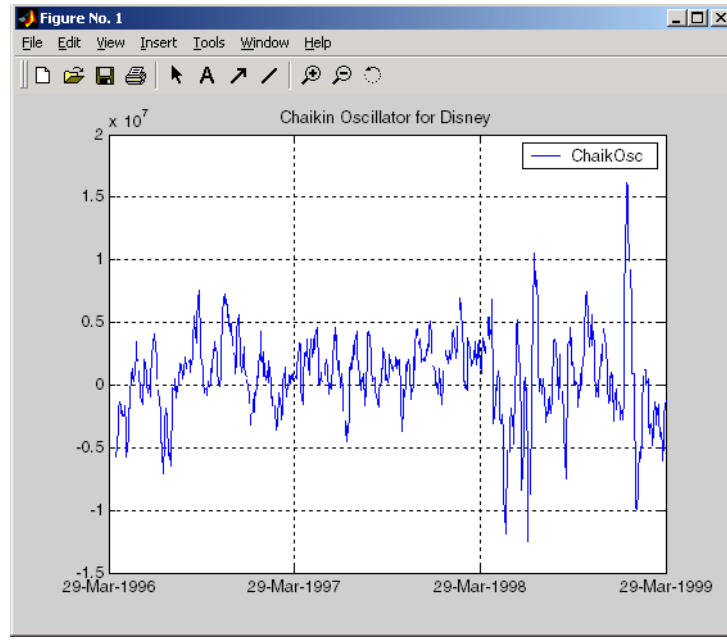
- `HighName`: high prices series name
- `LowName`: low prices series name
- `CloseName`: closing prices series name
- `VolumeName`: volume traded series name

Parameter values are the strings that represent the valid parameter names.

Examples

Compute the Chaikin oscillator for Disney stock and plot the results.

```
load disney.mat
dis_CHAIKosc = chaikosc(dis)
plot(dis_CHAIKosc)
title('Chaikin Oscillator for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 91-94.

See Also

`adline`

chaikvolat

Purpose

Chaikin volatility

Syntax

```
chvol = chaikvolat(highp, lowp)
chvol = chaikvolat([highp lowp])
chvol = chaikvolat(high, lowp, nperdiff, manper)
chvol = chaikvolat([high lowp], nperdiff, manper)
chvts = chaikvolat(tsobj)
chvts = chaikvolat(tsobj, nperdiff, manper, ParameterName,
ParameterValue, ...)
```

Arguments

`highp`	High price (vector).
`lowp`	Low price (vector).
`nperdiff`	Period difference (vector). Default = 10.
`manper`	Length of exponential moving average in periods (vector). Default = 10.
`tsobj`	Financial time series object.

Description

`chvol = chaikvolat(highp, lowp)` calculates the Chaikin volatility from the series of stock prices, `highp` and `lowp`. The vector `chvol` contains the Chaikin volatility values, calculated on a 10-period exponential moving average and 10-period difference.

`chvol = chaikvolat([highp lowp])` accepts a two-column matrix as the input.

`chvol = chaikvolat(high, lowp, nperdiff, manper)` manually sets the period difference `nperdiff` and the length of the exponential moving average `manper` in periods.

`chvol = chaikvolat([high lowp], nperdiff, manper)` accepts a two-column matrix as the first input.

`chvts = chaikvolat(tsobj)` calculates the Chaikin volatility from the financial time series object `tsobj`. The object must contain at least two series named `High` and `Low`, representing the high and low prices per period. `chvts` is a financial time series object containing the Chaikin volatility values, based on a 10-period exponential moving average and 10-period difference. `chvts` has the same dates as `tsobj` and a series called `ChaikVol`.

`chvts = chaikvolat (tsobj,nperdiff, manper, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

- `HighName`: high prices series name
- `LowName`: low prices series name

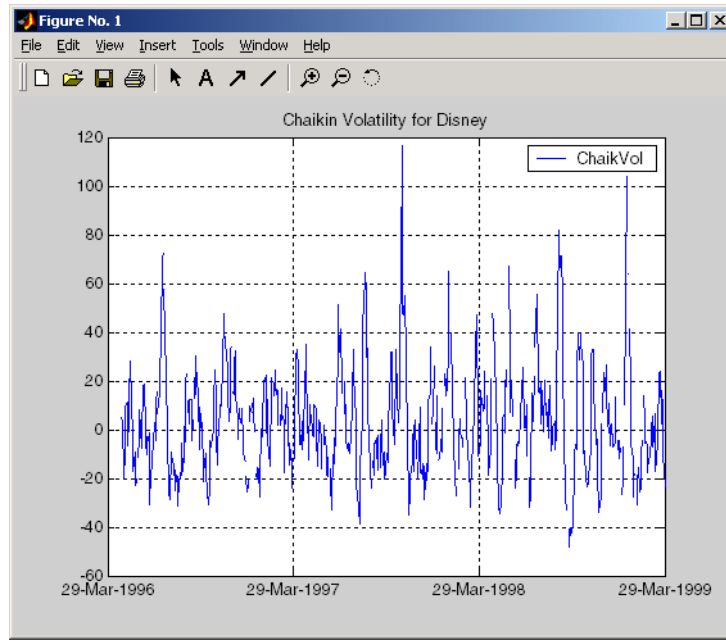
Parameter values are the strings that represent the valid parameter names.

`nperdiff`, the period difference, and `manper`, the length of the exponential moving average in periods, can also be set with this form of `chaikvolat`.

Examples

Compute the Chaikin volatility for Disney stock and plot the results:

```
load disney.mat
dis_CHAIKvol = chaikvolat(dis)
plot(dis_CHAIKvol)
title('Chaikin Volatility for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second Edition, McGraw-Hill, 1995, pp. 304-305.

See Also

`chaikosc`

Purpose

Interactive display

Syntax

```
chartfts(tsobj)
```

Description

`chartfts(tsobj)` produces a figure window that contains one or more plots. You can use the mouse to observe the data at a particular time point of the plot.

Examples

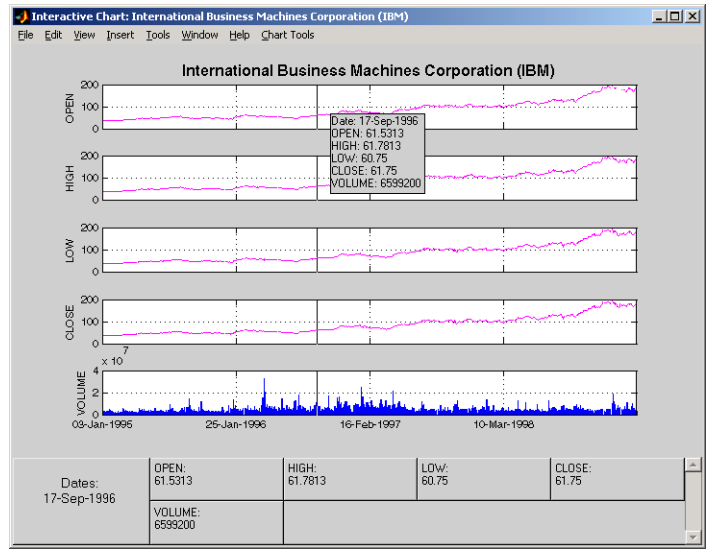
Create a financial time series object from the supplied data file `ibm9599.dat`:

```
ibmfts = ascii2fts('ibm9599.dat', 1, 3, 2);
```

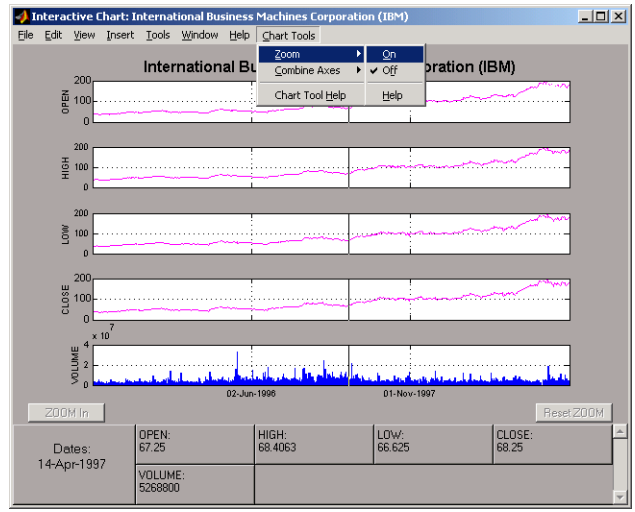
Chart the financial time series object `ibmfts`:

```
chartfts(ibmfts)
```

With the **Zoom** feature set `off`, a mouse click on the indicator line displays object data in a pop-up box.



With the **Zoom** feature set on, mouse clicks indicate the area of the chart to zoom.



You can find a tutorial on using `chartfts` in "Visualizing Financial Time Series Objects" on page 7-18. See "Zoom Tool" on page 7-21 for details on performing the zoom. Also see "Combine Axes Tool" on page 7-24 for information about combining axes for specified plots.

See Also

`candle`, `highlow`, `plot`

chfield

Purpose

Change data series name

Syntax

```
newfts = chfield(oldfts, oldname, newname)
```

Arguments

`oldfts`	Name of an existing financial time series object.
`oldname`	Name of the existing component in `oldfts`. A MATLAB string or column cell array.
`newname`	New name for the component in `oldfts`. A MATLAB string or column cell array.

Description

`newfts = chfield(oldfts, oldname, newname)` changes the name of the financial time series object component from `oldname` to `newname`.

Set `newfts = oldfts` to change the name of an existing component without changing the name of the financial time series object.

To change the names of several components at once, specify the series of old and new component names in corresponding column cell arrays.

You cannot change the names of the object components `desc`, `freq`, and `dates`.

See Also

`fieldnames`, `isfield`, `rmfield`

Purpose

Convert multivariate normal regression model to seemingly unrelated regression (SUR) model

Syntax

```
DesignSUR = convert2sur(Design, Group)
```

Arguments

`Design`

A matrix or a cell array that depends on the number of data series `NUMSERIES`.

- If `NUMSERIES = 1`, `convert2sur` returns the `Design` matrix.
- If `NUMSERIES > 1`, `Design` is a cell array with `NUMSAMPLES` cells, where each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values.

`Group`

Contains information about how data series are to be grouped, with separate parameters for each group. Specify groups either by series or by groups:

- To identify groups by series, construct an index vector that has `NUMSERIES` elements. Element `i = 1, ..., NUMSERIES` in the vector, and has the index `j = 1, ..., NUMGROUPS` of the group in which series *i* is a member.
- To identify groups by groups, construct a cell array with `NUMGROUPS` elements. Each cell contains a vector with the indexes of the series that populate a given group.

  In either case, the number of series is `NUMSERIES` and the number of groups is `NUMGROUPS`, with $1 \leq$ `NUMGROUPS` $\leq$ `NUMSERIES`.

Description

`DesignSUR = convert2sur(Design, Group)` converts a multivariate normal regression model into a seemingly unrelated regression model with a specified grouping of the data series. `DesignSUR` is either a matrix or a cell array that depends on the value of `NUMSERIES`:

- If `NUMSERIES = 1`, `DesignSUR = Design`, which is a `NUMSAMPLES`-by-`NUMPARAMS` matrix.
- If `NUMSERIES > 1` and `NUMGROUPS` groups are to be formed, `Design` is a cell array with `NUMSAMPLES` cells, where each cell contains a `NUMSERIES`-by-`(NUMGROUPS * NUMPARAMS)` matrix of known values.

The original collection of parameters that are common to all series are replicated to form collections of parameters for each group.

Examples

This example has ten series in three groups, and two model parameters. Suppose

Group 1 has series 1, 3, 4, 8.

Group 2 has series 2, 6, 10.

Group 3 has series 5, 7, 9.

Either:

```
Group = [ 1, 2, 1, 1, 3, 2, 3, 1, 3, 2];
```

or

```
Group = cell(3,1);
Group{1} = [1, 3, 4, 8];
Group{2} = [2, 6, 10];
Group{3} = [5, 7, 9];
```

A regression with `DesignSUR` would have 3 x 2 = 6 model parameters.

Purpose

Convert to specified frequency

Syntax

```
newfts = convertto(oldfts, newfreq)
newfts = convertto(oldfts, newfreq, 'param1','value1','param2',
'value2', ... )
```

Arguments

`oldfts`	Name of an existing financial time series object.
`newfreq`	`1`, `DAILY`, `Daily`, `daily`, `D`, `d`
	`2`, `WEEKLY`, `Weekly`, `weekly`, `W`, `w`
	`3`, `MONTHLY`, `Monthly`, `monthly`, `M`, `m`
	`4`, `QUARTERLY`, `Quarterly`, `quarterly`, `Q`, `q`
	`5`, `SEMIANNUAL`, `Semiannual`, `semiannual`, `S`, `s`
	`6`, `ANNUAL`, `Annual`, `annual`, `A`, `a`

Description

`convertto` converts a financial time series of any frequency to one of a specified frequency.

`newfts = convertto(oldfts, newfreq)` converts the object `oldfts` to the new time series object `newfts` with the frequency `newfreq`.

Refer to the documentation for each frequency conversion function to determine the valid parameter/value pairs.

See Also

`toannual`, `todaily`, `tomonthly`, `toquarterly`, `tosemi`, `toweekly`

corrcoef

Purpose

Correlation coefficients

Syntax

```
r = corrcoef(X)
r = corrcoef(X,Y),
```

Arguments

X	Matrix where each row is an observation and each column is a variable.
Y	Matrix where each row is an observation and each column is a variable.

Description

`corrcoef` for financial time series objects is based on the MATLAB `corrcoef` function. See `corrcoef` in the MATLAB documentation.

`r=corrcoef(X)` calculates a matrix `r` of correlation coefficients for an array `X`, in which each row is an observation and each column is a variable.

`r=corrcoef(X,Y)`, where `X` and `Y` are column vectors, is the same as `r=corrcoef([X Y])`. `corrcoef` converts `X` and `Y` to column vectors if they are not; that is, `r = corrcoef(X,Y)` is equivalent to `r=corrcoef([X(:)  Y(:)])` in that case.

If `c` is the covariance matrix, `c= cov(X)`, then `corrcoef(X)` is the matrix whose (*i,j*) 'th element is `c`*i,j*/`sqrt(c`*i,i*`*c(`*j,j*`))`.

`[r,p]=corrcoef(...)` also returns `p`, a matrix of `p`-values for testing the hypothesis of no correlation. Each `p`-value is the probability of getting a correlation as large as the observed value by random chance, when the true correlation is zero. If `p(`*i,j*`)` is less than 0.05, then the correlation `r(`*i,j*`)` is significant.

`[r,p,rlo,rup]=corrcoef(...)` also returns matrices `rlo` and `rup`, of the same size as `r`, containing lower and upper bounds for a 95% confidence interval for each coefficient.

`[...]=corrcoef(...,'PARAM1',VAL1,'PARAM2',VAL2,...)` specifies additional parameters and their values. Valid parameters are:

- `'alpha'` — A number between 0 and 1 to specify a confidence level of 100*(1-ALPHA)%. Default is 0.05 for 95% confidence intervals.
- `'rows'` — Either `'all'` (default) to use all rows, `'complete'` to use rows with no `NaN` values, or `'pairwise'` to compute `r(i,j)` using rows with no `NaN` values in column *i* or *j*.

The p-value is computed by transforming the correlation to create a t-statistic having `N` – 2 degrees of freedom, where `N` is the number of rows of `X`. The confidence bounds are based on an asymptotic normal distribution of 0.5*log((1 + r)/(1 – r)), with an approximate variance equal to 1/(N – 3). These bounds are accurate for large samples when `X` has a multivariate normal distribution. The `'pairwise'` option can produce an `r` matrix that is not positive definite.

Examples

Generate random data having correlation between column 4 and the other columns.

```
x = randn(30,4);        % uncorrelated data
x(:,4) = sum(x,2);      % introduce correlation
f = fints((today:today+29)', x);  % create a fints object using x
[r,p] = corrcoef(x)     % compute sample correlation and p-values
[i,j] = find(p<0.05);   % find significant correlations
[i,j]                   % display their (row,col) indices
```

Note Class support for inputs `X`,`Y`: float: double and single.

See Also

`cov`, `std`, `var`

Purpose

Convert standard deviation and correlation to covariance

Syntax

```
ExpCovariance = corr2cov(ExpSigma, ExpCorrC)
```

Arguments

`ExpSigma`	Vector of length n with the standard deviations of each process. n is the number of random processes.
`ExpCorrC`	(Optional) n-by-n correlation coefficient matrix. If `ExpCorrC` is not specified, the processes are assumed to be uncorrelated, and the identity matrix is used.

Description

`corr2cov` converts standard deviation and correlation to covariance.

`ExpCovariance` is an n-by-n covariance matrix, where n is the number of processes.

```
ExpCov(i,j) = ExpCorrC(i,j)*(ExpSigma(i)*ExpSigma(j)
```

Examples

```
ExpSigma = [0.5  2.0];

ExpCorrC = [1.0 -0.5
           -0.5  1.0];

ExpCovariance = corr2cov(ExpSigma, ExpCorrC)
```

Expected results:

```
ExpCovariance =

    0.2500   -0.5000
   -0.5000    4.0000
```

See Also

`corrcoef`, `cov`, `cov2corr`, `ewstats`, `std`

Purpose

Covariance matrix

Syntax

```
cov(X)
cov(X,Y)
```

Arguments

X	Financial times series object.
Y	Financial times series object.

Description

`cov` for financial time series objects is based on the MATLAB `cov` function. See `cov` in the MATLAB documentation.

If `X` is a financial time series object with one series, `cov(X)` returns the variance. For a financial time series object containing multiple series, where each row is an observation, and each series a variable, `cov(X)` is the covariance matrix.

`diag(cov(X))` is a vector of variances for each series and `sqrt(diag(cov(X)))` is a vector of standard deviations.

`cov(X, Y)`, where `X` and `Y` are financial time series objects with the same number of elements, is equivalent to `cov([X(:)  Y(:)])`.

`cov(X)` or `cov(X, Y)` normalizes by `(N -1)` if `N > 1`, where `N` is the number of observations. This makes `cov(X)` the best unbiased estimate of the covariance matrix if the observations are from a normal distribution. For `N = 1`, `cov` normalizes by `N`.

`cov(X, 1)` or `cov(X, Y, 1)` normalizes by `N` and produces the second moment matrix of the observations about their mean. `cov(X, Y, 0)` is the same as `cov(X, Y)` and `cov(X, 0)` is the same as `cov(X)`. The mean is removed from each column before calculating the result.

Examples

To create a covariance matrix for the following dates:

```
dates = {'01-Jan-2007';'02-Jan-2007';'03-Jan-2007'};
A = [-1 1 2 ; -2 3 1 ; 4 0 3]
f = fints(dates, A);

c = cov(f)

c =
   10.3333   -4.1667    3.0000
   -4.1667    2.3333   -1.5000
    3.0000   -1.5000    1.0000
```

See Also

`corrcoef`, `mean`, `std`, `var`

Purpose

Convert covariance to standard deviation and correlation coefficient

Syntax

```
[ExpSigma, ExpCorrC] = cov2corr(ExpCovariance)
```

Arguments

`ExpCovariance`	n-by-n covariance matrix; for example, from `cov` or `ewstats`. n is the number of random processes.

Description

`[ExpSigma, ExpCorrC] = cov2corr(ExpCovariance)` converts covariance to standard deviations and correlation coefficients.

`ExpSigma` is a 1-by-n vector with the standard deviation of each process.

`ExpCorrC` is an n-by-n matrix of correlation coefficients.

```
ExpSigma(i) = sqrt(ExpCovariance(i,i))
ExpCorrC(i,j) = ExpCovariance(i,j)/(ExpSigma(i)*ExpSigma(j))
```

Examples

```
ExpCovariance = [0.25 -0.5
                 -0.5   4.0];

[ExpSigma, ExpCorrC] = cov2corr(ExpCovariance)
```

Expected results:

```
  ExpSigma =

    0.5000    2.0000

ExpCorrC =

    1.0000   -0.5000
   -0.5000    1.0000
```

See Also `corr2cov`, `corrcoef`, `cov`, `ewstats`, `std`

Purpose

Coupon payments remaining until maturity

Syntax

```
NumCouponsRemaining = cpncount(Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
StartDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA)

- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate` (Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.

Required arguments must be number of bonds (NUMBONDS)-by-1 or 1-by-NUMBONDS conforming vectors or scalars. Optional arguments must be either NUMBONDS-by-1 or 1-by-NUMBONDS conforming vectors, scalars, or empty matrices.

Description

`NumCouponsRemaining = cpncount(Settle, Maturity, Period, Basis, EndMonthRule)` returns the whole number of coupon payments between the settlement and maturity dates for a coupon bond or set of bonds.

Examples

```
NumCouponsRemaining = cpncount('14 Mar 1997', '30 Nov 2000',...
2, 0, 0)

n =
     8
```

Given three coupon bonds with different maturity dates and the same default arguments

```
Maturity = ['30 Sep 2000'; '31 Oct 2001'; '30 Nov 2002'];

NumCouponsRemaining = cpncount('14 Sep 1997', Maturity)

NumCouponsRemaining =

      7
      9
     11
```

See Also

accrfrac, cfamounts, cfdates, cftimes, cpndaten, cpndatenq, cpndatep, cpndatepq, cpndaysn, cpndaysp, cpnpersz

Purpose

Next coupon date for fixed-income security

Syntax

```
NextCouponDate = cpndaten(Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA)

- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

Required arguments must be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalars. Optional arguments must be either `NUMBONDS`-by-`1` or `1`-by-`NUMBONDS` conforming vectors, scalars, or empty matrices.

Description

```
NextCouponDate = cpndaten(Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)
```

returns the next coupon date after the settlement date. This function finds the next coupon date whether or not the coupon structure is synchronized with the maturity date.

`NextCouponDate` is returned as a serial date number. The function `datestr` converts a serial date number to a formatted date string.

Examples

```
NextCouponDate = cpndaten('14 Mar 1997', '30 Nov 2000', 2, 0, 0);

datestr(NextCouponDate)

ans =

30-May-1997

NextCouponDate = cpndaten('14 Mar 1997', '30 Nov 2000', 2, 0, 1);

datestr(NextCouponDate)

ans =

31-May-1997

Maturity = ['30 Sep 2000'; '31 Oct 2000'; '30 Nov 2000'];

NextCouponDate = cpndaten('14 Mar 1997', Maturity);

datestr(NextCouponDate)

ans =

31-Mar-1997
30-Apr-1997
31-May-1997
```

See Also

`accrfrac`, `cfamounts`, `cfdates`, `cftimes`, `cpncount`, `cpndatenq`, `cpndatep`, `cpndatepq`, `cpndaysn`, `cpndaysp`, `cpnpersz`

Purpose

Next quasi coupon date for fixed income security

Syntax

```
NextQuasiCouponDate = cpndatenq(Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA)

- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

Required arguments must be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalars. Optional arguments must be either `NUMBONDS`-by-`1` or `1`-by-`NUMBONDS` conforming vectors, scalars, or empty matrices. Fill unspecified entries in input vectors with the value `NaN`. Dates can be serial date numbers or date strings.

Description

`NextQuasiCouponDate = cpndatenq(Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)` determines the next quasi coupon date for a portfolio of `NUMBONDS` fixed income securities whether or not the first or last coupon is normal, short, or long. For zero coupon bonds `cpndatenq` returns quasi coupon dates as if the bond had a semiannual coupon structure. Successive quasi coupon dates determine the length of the standard coupon period for the fixed income security of interest and do not necessarily coincide with actual coupon payment dates.

Outputs are `NUMBONDS`-by-`1` vectors.

If `Settle` is a coupon date, this function never returns the settlement date. It returns the quasi coupon date strictly after settlement.

`NextQuasiCouponDate` is returned as a serial date number. The function `datestr` converts a serial date number to a formatted date string.

Examples

Given a pair of bonds with the characteristics

```
Settle = char('30-May-1997','10-Dec-1997');
Maturity = char('30-Nov-2002','10-Jun-2004');
```

Compute `NextCouponDate` for this pair of bonds.

```
NextCouponDate = cpndaten(Settle, Maturity);

datestr(NextCouponDate)

ans =

31-May-1997
10-Jun-1998
```

Compute the next quasi coupon dates for these two bonds.

```
NextQuasiCouponDate = cpndatenq(Settle, Maturity);
```

```
datestr(NextQuasiCouponDate)

ans =

31-May-1997
10-Jun-1998
```

Because no `FirstCouponDate` has been specified, the results are identical.

Now supply an explicit `FirstCouponDate` for each bond.

```
FirstCouponDate = char('30-Nov-1997','10-Dec-1998');
```

Compute the next coupon dates.

```
NextCouponDate = cpndaten(Settle, Maturity, 2, 0, 1, [],...
FirstCouponDate);

datestr(NextCouponDate)

ans =

30-Nov-1997
10-Dec-1998
```

The next coupon dates are identical to the specified first coupon dates.

Now recompute the next quasi coupon dates.

```
NextQuasiCouponDate = cpndatenq(Settle, Maturity, 2, 0, 1, [],...
FirstCouponDate);

datestr(NextQuasiCouponDate)

ans =

31-May-1997
```

```
10-Jun-1998
```

These results illustrate the distinction between actual coupon payment dates and quasi coupon dates. `FirstCouponDate` (and `LastCouponDate`, as well), when specified, is associated with an actual coupon payment and also serves as the synchronization date for determining all quasi coupon dates. Since each bond in this example pays semiannual coupons, and the first coupon date occurs more than six months after settlement, each will have an intermediate quasi coupon date before the actual first coupon payment occurs.

See Also

`accrfrac`, `cfamounts`, `cfdates`, `cftimes`, `cpncount`, `cpndaten`, `cpndatep`, `cpndatepq`, `cpndaysn`, `cpndaysp`, `cpnpersz`

cpndatep

Purpose

Previous coupon date for fixed-income security

Syntax

```
PreviousCouponDate = cpndatep(Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA)

- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

Required arguments must be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalars. Optional arguments must be either `NUMBONDS`-by-`1` or `1`-by-`NUMBONDS` conforming vectors, scalars, or empty matrices.

Description

```
PreviousCouponDate = cpndatep(Settle, Maturity, Period,
Basis, EndMonthRule, IssueDate, FirstCouponDate,
```

LastCouponDate) returns the previous coupon date on or before settlement for a portfolio of bonds. This function finds the previous coupon date whether or not the coupon structure is synchronized with the maturity date.

For zero coupon bonds the previous coupon date is the issue date, if available. However, if the issue date is not supplied, the previous coupon date for zero coupon bonds is the previous quasi coupon date calculated as if the frequency is semiannual.

PreviousCouponDate is returned as a serial date number. The function datestr converts a serial date number to a formatted date string.

Examples

```
PreviousCouponDate = cpndatep('14 Mar 1997', '30 Jun 2000',...
2, 0, 0);

datestr(PreviousCouponDate)

ans =

30-Dec-1996

PreviousCouponDate = cpndatep('14 Mar 1997', '30 Jun 2000',...
2, 0, 1);

datestr(PreviousCouponDate)

ans =

31-Dec-1996

Maturity = ['30 Apr 2000'; '31 May 2000'; '30 Jun 2000'];
PreviousCouponDate = cpndatep('14 Mar 1997', Maturity);

datestr(PreviousCouponDate)

ans =
```

```
31-Oct-1996
30-Nov-1996
31-Dec-1996
```

See Also

accrfrac, cfamounts, cfdates, cftimes, cpncount, cpndaten, cpndatenq, cpndatepq, cpndaysn, cpndaysp, cpnpersz

Purpose

Previous quasi coupon date for fixed income security

Syntax

```
PreviousQuasiCouponDate = cpndatepq(Settle, Maturity, Period,
Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA)

- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`	(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.
`IssueDate`	(Optional) Date when a bond was issued.
`FirstCouponDate`	(Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.
`LastCouponDate`	(Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

Required arguments must be number of bonds (`NUMBONDS`)-by-`1` or `1`-by-`NUMBONDS` conforming vectors or scalars. Optional arguments must be either `NUMBONDS`-by-`1` or `1`-by-`NUMBONDS` conforming vectors, scalars, or empty matrices. Fill unspecified entries in input vectors with the value `NaN`. Dates can be serial date numbers or date strings.

Description

`PreviousQuasiCouponDate = cpndatepq(Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate)` determines the previous quasi coupon date on or before settlement for a set of `NUMBONDS` fixed income securities. This function finds the previous quasi coupon date for a bond with a coupon structure in which the first or last period is either normal, short, or long (whether or not the coupon structure is synchronized to maturity). For zero coupon bonds this function returns quasi coupon dates as if the bond had a semiannual coupon structure.

The term "previous quasi coupon date" refers to the previous coupon date for a bond calculated as if no issue date were specified. Although the issue date is not actually a coupon date, when issue date is specified, the previous actual coupon date for a bond is normally calculated as being either the previous coupon date or the issue date, whichever is greater. This function always returns the previous quasi coupon date regardless of issue date. If the settlement date is a coupon date, this function returns the settlement date.

`PreviousQuasiCouponDate` is returned as a serial date number. The function `datestr` converts a serial date number to a formatted date string.

Examples

Given a pair of bonds with the characteristics

```
Settle = char('30-May-1997','10-Dec-1997');
Maturity = char('30-Nov-2002','10-Jun-2004');
```

With no `FirstCouponDate` explicitly supplied, compute the `PreviousCouponDate` for this pair of bonds.

```
PreviousCouponDate = cpndatep(Settle, Maturity);

datestr(PreviousCouponDate)

ans =

30-Nov-1996
```

```
10-Dec-1997
```

Note that since the settlement date for the second bond is also a coupon date, cpndatep returns this date as the previous coupon date.

Now establish a FirstCouponDate and IssueDate for this pair of bonds.

```
FirstCouponDate = char('30-Nov-1997','10-Dec-1998');
IssueDate = char('30-May-1996', '10-Dec-1996');
```

Recompute the PreviousCouponDate for this pair of bonds.

```
PreviousCouponDate = cpndatep(Settle, Maturity, 2, 0, 1, ...
IssueDate, FirstCouponDate);

datestr(PreviousCouponDate)

ans =

30-May-1996
10-Dec-1996
```

Since both of these bonds settled before the first coupon had been paid, cpndatep returns the IssueDate as the PreviousCouponDate.

Using the same data, compute PreviousQuasiCouponDate.

```
PreviousQuasiCouponDate = cpndatepq(Settle, Maturity, 2, 0, 1,...
IssueDate, FirstCouponDate);

datestr(PreviousQuasiCouponDate)

ans =

30-Nov-1996
10-Dec-1997
```

For the first bond the settlement date is not a normal coupon date. The `PreviousQuasiCouponDate` is the coupon date before or on the settlement date. Since the coupon structure is synchronized to `FirstCouponDate`, the previous quasi coupon date is `30-Nov-1996`. `PreviousQuasiCouponDate` disregards `IssueDate` and `FirstCouponDate` in this case. For the second bond the settlement date (10-Dec-1997) occurs on a date when a coupon would normally be paid in the absence of an explicit `FirstCouponDate`. `cpndatepq` returns this date as `PreviousQuasiCouponDate`.

See Also

`accrfrac`, `cfamounts`, `cfdates`, `cftimes`, `cpncount`, `cpndaten`, `cpndatenq`, `cpndatep`, `cpndaysn`, `cpndaysp`, `cpnpersz`

Purpose

Number of days to next coupon date

Syntax

```
NumDaysNext = cpndaysn(Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
StartDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA)

- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate` (Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.

Required arguments must be number of bonds (NUMBONDS)-by-1 or 1-by-NUMBONDS conforming vectors or scalars. Optional arguments must be either NUMBONDS-by-1 or 1-by-NUMBONDS conforming vectors, scalars, or empty matrices.

Description

`NumDaysNext = cpndaysn(Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate)` returns the number of days from the settlement date to the next coupon date for a bond or set of bonds. For zero coupon bonds coupon dates are computed as if the bonds have a semiannual coupon structure.

Examples

```
NumDaysNext = cpndaysn('14 Sep 2000', '30 Jun 2001', 2, 0, 0)

NumDaysNext =

   107

NumDaysNext = cpndaysn('14 Sep 2000', '30 Jun 2001', 2, 0, 1)

NumDaysNext =

   108

Maturity = ['30 Apr 2001'; '31 May 2001'; '30 Jun 2001'];

NumDaysNext = cpndaysn('14 Sep 2000', Maturity)

NumDaysNext =

    47
    77
   108
```

See Also

accrfrac, cfamounts, cftimes, cfdates, cpncount, cpndaten, cpndatenq, cpndatep, cpndatepq, cpndaysp, cpnpersz

Purpose

Number of days since previous coupon date

Syntax

```
NumDaysPrevious = cpndaysp(Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
StartDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA)

- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate` (Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.

Required arguments must be a number of bonds (NUMBONDS)-by-1 or 1-by-NUMBONDS conforming vectors or scalars. Optional arguments must be either NUMBONDS-by-1 or 1-by-NUMBONDS conforming vectors, scalars, or empty matrices.

Description

`NumDaysPrevious = cpndaysp(Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate)` returns the number of days between the previous coupon date and the settlement date for a bond or set of bonds. When the coupon frequency is 0 (a zero coupon bond), the previous coupon date is calculated as if the frequency were semiannual.

Examples

```
NumDaysPrevious = cpndaysp('14 Mar 2000', '30 Jun 2001', 2, 0, 0)

NumDaysPrevious =

    75

NumDaysPrevious = cpndaysp('14 Mar 2000', '30 Jun 2001', 2, 0, 1)

NumDaysPrevious =

    74

Maturity = ['30 Apr 2001'; '31 May 2001'; '30 Jun 2001'];

NumDaysPrevious = cpndaysp('14 Mar 2000', Maturity)

NumDaysPrevious =

   135
   105
    74
```

See Also

accrfrac, cfamounts, cfdates, cftimes, cpncount, cpndaten, cpndatenq, cpndatep, cpndatepq, cpndaysn, cpnpersz

Purpose

Number of days in coupon period

Syntax

```
NumDaysPeriod = cpnpersz(Settle, Maturity, Period, Basis,
EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate,
StartDate)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. A vector of serial date numbers or date strings.
`Period`	(Optional) Coupons per year of the bond. A vector of integers. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA)

- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`IssueDate` (Optional) Date when a bond was issued.

`FirstCouponDate` (Optional) Date when a bond makes its first coupon payment. When `FirstCouponDate` and `LastCouponDate` are both specified, `FirstCouponDate` takes precedence in determining the coupon payment structure.

`LastCouponDate` (Optional) Last coupon date of a bond before the maturity date. In the absence of a specified `FirstCouponDate`, a specified `LastCouponDate` determines the coupon structure of the bond. The coupon structure of a bond is truncated at the `LastCouponDate` regardless of where it falls and will be followed only by the bond's maturity cash flow date.

`StartDate` (Future implementation; optional) Date when a bond actually starts (the date from which a bond's cash flows can be considered). To make an instrument forward-starting, specify this date as a future date. If `StartDate` is not explicitly specified, the effective start date is the settlement date.

Required arguments must be a number of bonds (NUMBONDS)-by-1 or 1-by-NUMBONDS conforming vectors or scalars. Optional arguments must be either NUMBONDS-by-1 or 1-by-NUMBONDS conforming vectors, scalars, or empty matrices.

Description

`NumDaysPeriod = cpnpersz(Settle, Maturity, Period, Basis, EndMonthRule, IssueDate, FirstCouponDate, LastCouponDate, StartDate)` returns the number of days in the coupon period containing the settlement date. For zero coupon bonds coupon dates are computed as if the bonds have a semiannual coupon structure.

Examples

```
NumDaysPeriod = cpnpersz('14 Sep 2000', '30 Jun 2001', 2, 0, 0)

NumDaysPeriod =

   183

NumDaysPeriod = cpnpersz('14 Sep 2000', '30 Jun 2001', 2, 0, 1)

NumDaysPeriod =

   184


Maturity = ['30 Apr 2001'; '31 May 2001'; '30 Jun 2001'];

NumDaysPeriod = cpnpersz('14 Sep 2000', Maturity)

NumDaysPeriod =

   184
   183
   184
```

See Also

accrfrac, cfamounts, cfdates, cpncount, cpndaten, cpndatenq, cpndatep, cpndatepq, cpndaysn, cpndaysp

Purpose

Create trading calendars

Syntax

```
createholidays(Filename, Codefile, InfoFile, TargetDir,
IncludeWkds, Wprompt, NoGUI)
```

Arguments

`Filename`	The data file name.
`Codefile`	The codes file name.
`InfoFile`	The info file name.
`TargetDir`	The target directory where to write the new `holidays.m` files.
`IncludeWkds`	Option to include weekends in the holiday list. Values are: • 0 – Do not include weekends in the holiday list. • 1 – Include weekends in the holiday list.
`Wprompt`	Option to prompt for the file location for each `holiday.m` file that is created. Values are: • 0 – Do not prompt for the file location. • 1 – Prompt for the file location.
`NoGUI`	Run `createholidays` function without displaying the Trading Calendars graphical user interface. Values are: • 0 – Display the GUI. • 1 – Do not display the GUI.

Description

`createholidays(Filename, Codefile, InfoFile, TargetDir, IncludeWkds, Wprompt, NoGUI)` programatically generates the market-specific `holidays.m` files without displaying the interface.

Examples

```
createholidays('FinancialCalendar\My_datafile.csv',...
'FinancialCalendar\My_codesfile.csv',...
'FinancialCalendar\My_infofile.csv','c:\work',1,1,1)
```

will create `holidays*.m` files from `My_datafile.csv` in the directory `c:\work`. Weekends will be included in the holidays list based on the input flag `INCLUDEWDKS = 1`.

Note To use `createholidays`, you must obtain data, codes, and info files from `http://www.FinancialCalendar.com` trading calendars.

See Also

`holidays`

Purpose

Cumulative sum

Syntax

```
newfts = cumsum(oldfts)
```

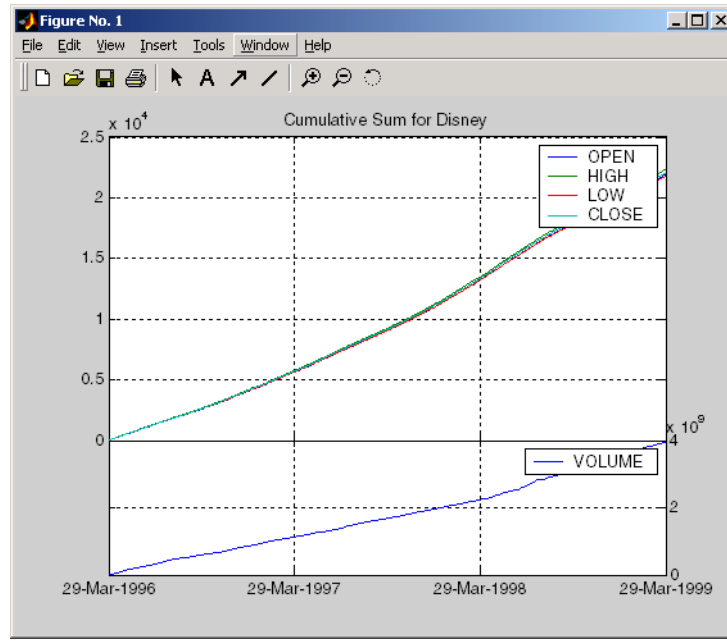
Description

`newfts = cumsum(oldfts)` calculates the cumulative sum of each individual time series data series in the financial time series object `oldfts` and returns the result in another financial time series object `newfts`. `newfts` contains the same data series names as `oldfts`.

Examples

Compute the cumulative sum for Disney stock and plot the results:

```
load disney.mat
cs_dis = cumsum(fillts(dis));
plot(cs_dis)
title('Cumulative Sum for Disney')
```



See Also `cumsum` in the MATLAB documentation

Purpose

Decimal currency values to fractional values

Syntax

```
Fraction = cur2frac(Decimal, Denominator)
```

Description

`Fraction = cur2frac(Decimal, Denominator)` converts decimal currency values to fractional values. `Fraction` is returned as a string.

Examples

```
Fraction = cur2frac(12.125, 8)
```

returns `Fraction = 12.1`, a string.

See Also

`cur2str`, `frac2cur`

Purpose

Bank-formatted text

Syntax

```
String = cur2str(Value, Digits)
```

Description

`String = cur2str(Value, Digits)` returns the given value in bank format. By default, `Digits = 2`. A negative `Digits` rounds the value to the left of the decimal point. `String` is returned as a string with a leading dollar sign ($). Negative numbers are displayed in parentheses.

Examples

```
String = cur2str(-8264, 2)
```

returns `String = ($8264.00)`

See Also

`cur2frac`, `frac2cur`

Purpose

Time and frequency from dates

Syntax

```
[TFactors, F] = date2time(Settle, Maturity, Compounding, Basis,
EndMonthRule)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings.
`Maturity`	A vector of serial maturity dates.
`Compounding`	Scalar value representing the rate at which the input zero rates were compounded when annualized. This argument determines the formula for the discount factors: • `Compounding` = `1`, `2`, `3`, `4`, `6`, `12` • `Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units, for example, `T = F` is one year. • `Compounding` = `365` • `Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis. • `Compounding` = `-1` • `Disc = exp(-T*Z)`, where `T` is time in years.

`Basis` (Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

Description

`[TFactors, F] = date2time(Settle, Maturity, Compounding, Basis, EndMonthRule)` computes time factors appropriate to compounded rate quotes between the settlement and maturity dates.

`TFactors` is a vector of time factors.

`F` is a scalar of related compounding frequencies.

`date2time` is the inverse of `time2date`.

See Also

`cftimes`, `disc2rate`, `rate2disc`, `time2date`

dateaxis

Purpose

Convert serial-date axis labels to calendar-date axis labels

Syntax

```
dateaxis(Aksis, DateForm, StartDate)
```

Arguments

`Aksis`	(Optional) Determines which axis tick labels—*x*, *y*, or *z*—to replace. Enter as a string. Default = `'x'`.
`DateForm`	(Optional) Specifies which date format to use. Enter as an integer from 0 to 17. If no `DateForm` argument is entered, this function determines the date format based on the span of the axis limits. For example, if the difference between the axis minimum and maximum is less than 15, the tick labels are converted to three-letter day-of-the-week abbreviations (`DateForm = 8`). See `DateForm` format descriptions below.
`StartDate`	(Optional) Assigns the date to the first axis tick value. Enter as a string. The tick values are treated as serial date numbers. The default `StartDate` is the lower axis limit converted to the appropriate date number. For example, a tick value of 1 is converted to the date 01-Jan-0000. Entering `StartDate` as `'06-apr-1999'` assigns the date April 6, 1999 to the first tick value and the axis tick labels are set accordingly.

Description

`dateaxis(Aksis, DateForm, StartDate)` replaces axis tick labels with date labels on a graphic figure.

See the MATLAB `set` command for information on modifying the axis tick values and other axis parameters.

DateForm	Format	Description
0	01-Mar-1999 15:45:17	day-month-year hour:minute:second
1	01-mar-1999	day-month-year
2	03/01/99	month/day/year
3	Mar	month, three letters
4	M	month, single letter
5	3	month
6	03/01	month/day
7	1	day of month
8	Wed	day of week, three letters
9	W	day of week, single letter
10	1999	year, four digits
11	99	year, two digits
12	Mar99	month year
13	15:45:17	hour:minute:second
14	03:45:17 PM	hour:minute:second AM or PM
15	15:45	hour:minute
16	03:45 PM	hour:minute AM or PM
17	95/03/01	year month day

Examples

```
dateaxis('x') or dateaxis
```

converts the *x*-axis labels to an automatically determined date format.

```
dateaxis('y', 6)
```

converts the *y*-axis labels to the month/day format.

```
dateaxis('x', 2, '03/03/1999')
```

converts the *x*-axis labels to the month/day/year format. The minimum *x*-tick value is treated as March 3, 1999.

See Also

`bolling`, `candle`, `datenum`, `datestr`, `highlow`, `movavg`, `pointfig`

Purpose

Display date entries

Syntax

```
datedisp(NumMat, DateForm)
CharMat = datedisp(NumMat, DateForm)
```

Arguments

`NumMat`	Numeric matrix to display.
`DateForm`	(Optional) Date format. See `datestr` for available and default format flags.

Description

`datedisp(NumMat, DateForm)` displays a matrix with the serial dates formatted as date strings, using a matrix with mixed numeric entries and serial date number entries. Integers between `datenum('01-Jan-1900')` and `datenum('01-Jan-2200')` are assumed to be serial date numbers, while all other values are treated as numeric entries.

`CharMat` is a character array representing `NumMat`. If no output variable is assigned, the function prints the array to the display.

Examples

```
NumMat = [730730, 0.03, 1200 730100;
          730731, 0.05, 1000 NaN]

NumMat =

   1.0e+05 *

    7.3073    0.0000    0.0120    7.3010
    7.3073    0.0000    0.0100       NaN

datedisp(NumMat)

01-Sep-2000   0.03   1200   11-Dec-1998
```

```
   02-Sep-2000   0.05   1000      NaN
```

See Also

datenum, datestr

Purpose

Indices of date numbers in matrix

Syntax

```
Indices = datefind(Subset, Superset, Tolerance)
```

Arguments

`Subset`	Subset matrix of date numbers used to find matching date numbers in `Superset`. These date numbers must be a nonrepeating subset of those in `Superset`.
`Superset`	Superset matrix of nonrepeating date numbers whose elements are sought.
`Tolerance`	(Optional) Tolerance (`+/-`) for matching the date numbers in `Superset`. A positive integer. Default = `0`.

Description

`Indices = datefind(Subset, Superset, Tolerance)` returns a vector of indices to the date numbers in `Superset` that are present in `Subset`, plus or minus the `Tolerance`. If no date numbers match, `Indices = []`.

Although this function was designed for use with sequential date numbers, you can use it with any nonrepeating integers.

Examples

```
Superset = datenum(1999, 7, 1:31);

Subset = [datenum(1999, 7, 10); datenum(1999, 7, 20)];

Indices = datefind(Subset, Superset, 1)

Indices =

           9
          10
```

```
11
19
20
21
```

See Also

`datenum`

Purpose

Date of day in future or past month

Syntax

```
TargetDate = datemnth(StartDate, NumberMonths, DayFlag, Basis,
EndMonthRule)
```

Arguments

`StartDate`	Enter as serial date numbers or date strings.
`NumberMonths`	Vector containing number of months in future (positive) or past (negative). Values must be in integer form.
`DayFlag`	(Optional) Vector containing values that specify how the actual day number for the target date in future or past month is determined. 0 (default) = day number should be the day in the future or past month corresponding to the actual day number of the start date. 1 = day number should be the first day of the future or past month. 2 = day number should be the last day of the future or past month. This flag has no effect if `EndMonthRule` is set to 1.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA)

- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month rule. A vector. 1 = rule in effect, meaning that if you are beginning on the last day of a month, and the month has 30 or fewer days, you will end on the last actual day of the future or past month regardless of whether that month has 28, 29, 30 or 31 days) 0 = rule off (default), meaning that the rule is not in effect.

Any input can contain multiple values, but if so, all other inputs must contain the same number of values or a single value that applies to all. For example, if `StartDate` is an n-row character array of date strings, then `NumberMonths` must be an `n-by-1` vector of integers or a single integer. `TargetDate` is then an `n-by-1` vector of date numbers.

Description

`TargetDate = datemnth(StartDate, NumberMonths, DayFlag, Basis, EndMonthRule)` returns the serial date number of the target date in the future or past.

Use `datestr` to convert serial date numbers to formatted date strings.

Examples

```
Day = datemnth('3 jun 2001', 6, 0, 0, 0)
Day =
      731188
```

```
datestr(Day)
ans =
03-Dec-2001

Day = datemnth('3 jun 2001', 6, 1, 0, 1); datestr(Day)
ans =
01-Dec-2001

Day = datemnth('31 jan 2001', 5, 0, 0, 0); datestr(Day)
ans =
30-Jun-2001

Day = datemnth('31 jan 2001', 5, 1, 0, 0); datestr(Day)
ans =
01-Jun-2001

Day = datemnth('31 jan 2001', 5, 1, 0, 1); datestr(Day)
ans =
30-Jun-2001

Day = datemnth('31 jan 2001', 5, 2, 0, 1); datestr(Day)
ans =
30-Jun-2001

Months = [1; 3; 5; 7; 9];
Day = datemnth('31 jan 2001', Months); datestr(Day)
ans =
28-Feb-2001
30-Apr-2001
30-Jun-2001
31-Aug-2001
31-Oct-2001
```

See Also

datestr, datevec, days360, days365, daysact, daysdif, wrkdydif

Purpose

Create date number

Syntax

```
N = datenum(V)
N = datenum(S, F)
N = datenum(S, F, P)
N = datenum([S, P, F])
N = datenum(Y, M, D)
N = datenum(Y, M, D, H, MN, S)
N = datenum(S)
N = datenum(S, P)
```

Description

`datenum` is one of three conversion functions that enable you to express dates and times in any of three formats in MATLAB software: a string (or *date string*), a vector of date and time components (or *date vector*), or as a numeric offset from a known date in time (or *serial date number*). Here is an example of a date and time expressed in the three MATLAB formats:

```
Date String:           '24-Oct-2003 12:45:07'
Date Vector:           [2003  10  24  12  45  07]
Serial Date Number:    7.3188e+005
```

A serial date number represents the whole and fractional number of days from a specific date and time, where `datenum('Jan-1-0000 00:00:00')` returns the number 1. (The year 0000 is merely a reference point and is not intended to be interpreted as a real year in time.)

`N = datenum(V)` converts one or more date vectors `V` to serial date numbers `N`. Input `V` can be an `m`-by-`6` or `m`-by-`3` matrix containing `m` full or partial date vectors respectively. A full date vector has six elements, specifying year, month, day, hour, minute, and second, in that order. A partial date vector has three elements, specifying year, month, and day, in that order. Each element of `V` must be a positive double-precision number. `datenum` returns a column vector of `m` date numbers, where `m` is the total number of date vectors in `V`.

`N = datenum(S, F)` converts one or more date strings `S` to serial date numbers `N` using format string `F` to interpret each date string. Input `S`

can be a one-dimensional character array or cell array of date strings. All date strings in `S` must have the same format, and that format must match one of the date string formats shown in the help for the `datestr` function. `datenum` returns a column vector of `m` date numbers, where `m` is the total number of date strings in `S`. MATLAB software considers date string years that are specified with only two characters (e.g., `'79'`) to fall within 100 years of the current year.

See the `datestr` reference page to find valid string values for `F`. These values are listed in Table 1 in the column labeled "Dateform String." You can use any string from that column except for those that include the letter `Q` in the string (for example, '`QQ-YYYY`'). Certain formats may not contain enough information to compute a date number. In these cases, hours, minutes, seconds, and milliseconds default to 0, the month defaults to January, the day to 1, and the year to the current year.

`N = datenum(S, F, P)` converts one or more date strings `S` to date numbers `N` using format `F` and pivot year `P`. The pivot year is used in interpreting date strings that have the year specified as two characters. It is the starting year of the 100-year range in which a two-character date string year resides. The default pivot year is the current year minus 50 years.

`N = datenum([S, P, F])` is the same as the syntax shown above, except the order of the last two arguments are switched.

`N = datenum(Y, M, D)` returns the serial date numbers for corresponding elements of the `Y`, `M`, and `D` (year, month, day) arrays. `Y`, `M`, and `D` must be arrays of the same size (or any can be a scalar) of type `double`. You can also specify the input arguments as a date vector, `[Y M D]`.

For this and the following syntax, values outside the normal range of each array are automatically carried to the next unit. Values outside the normal range of each array are automatically carried to the next unit. For example, month values greater than 12 are carried to years. Month values less than 1 are set to be 1. All other units can wrap and have valid negative values.

`N = datenum(Y, M, D, H, MN, S)` returns the serial date numbers for corresponding elements of the `Y`, `M`, `D`, `H`, `MN`, and `S` (year, month, day, hour, minute, and second) array values. `datenum` does not accept milliseconds in a separate input, but as a fractional part of the seconds (`S`) input. Inputs `Y`, `M`, `D`, `H`, `MN`, and `S` must be arrays of the same size (or any can be a scalar) of type `double`. You can also specify the input arguments as a date vector, `[Y M D H MN S]`.

`N = datenum(S)` converts date string `S` into a serial date number. String `S` must be in one of the date formats 0, 1, 2, 6, 13, 14, 15, 16, or 23, as defined in the reference page for the `datestr` function. MATLAB software considers date string years that are specified with only two characters (e.g., `'79'`) to fall within 100 years of the current year. If the format of date string `S` is known, use the syntax `N = datenum(S, F)`.

`N = datenum(S, P)` converts date string `S`, using pivot year `P`. If the format of date string `S` is known, use the syntax `N = datenum(S, F, P)`.

Note The last two calling syntaxes are provided for backward compatibility and are significantly slower than the syntaxes that include a format argument `F`.

Examples

Convert a date string to a serial date number:

```
n = datenum('19-May-2001', 'dd-mmm-yyyy')

n =
      730990
```

Specifying year, month, and day, convert a date to a serial date number:

```
n = datenum(2001, 12, 19)

n =
      731204
```

Convert a date vector to a serial date number:

```
format bank
datenum('March 28, 2005  3:37:07.033 PM')
ans =
     732399.65
```

Convert a date string to a serial date number using the default pivot year:

```
n = datenum('12-jun-17', 'dd-mmm-yy')

n =
      736858
```

Convert the same date string to a serial date number using 1400 as the pivot year:

```
n = datenum('12-jun-17', 'dd-mmm-yy', 1400)

n =
      517712
```

Specify format `'dd.mm.yyyy'` to be used in interpreting a nonstandard date string:

```
n = datenum('19.05.2000', 'dd.mm.yyyy')

n =
      730625
```

See Also

`datedisp`, `datestr`, `datevec`, `daysact`, `now`, `today`

Purpose

Create date string

Syntax

```
S = datestr(V)
S = datestr(N)
S = datestr(D, F)
S = datestr(S1, F, P)
S = datestr(..., 'local')
```

Description

`datestr` is one of three conversion functions that enable you to express dates and times in any of three formats in MATLAB software: a string (or *date string*), a vector of date and time components (or *date vector*), or as a numeric offset from a known date in time (or *serial date number*). Here is an example of a date and time expressed in the three MATLAB formats:

```
Date String:           '24-Oct-2003 12:45:07'
Date Vector:           [2003  10  24  12  45  07]
Serial Date Number:    7.3188e+005
```

A serial date number represents the whole and fractional number of days from 1-Jan-0000 to a specific date. The year 0000 is merely a reference point and is not intended to be interpreted as a real year in time.

`S = datestr(V)` converts one or more date vectors `V` to date strings `S`. Input `V` must be an `m`-by-`6` matrix containing `m` full (six-element) date vectors. Each element of `V` must be a positive double-precision number. `datestr` returns a column vector of `m` date strings, where `m` is the total number of date vectors in `V`.

`S = datestr(N)` converts one or more serial date numbers `N` to date strings `S`. Input argument `N` can be a scalar, vector, or multidimensional array of positive double-precision numbers. `datestr` returns a column vector of `m` date strings, where `m` is the total number of date numbers in `N`.

`S = datestr(D, F)` converts one or more date vectors, serial date numbers, or date strings `D` into the same number of date strings `S`. Input

argument F is a format number or string that determines the format of the date string output. Valid values for F are given in the table Standard MATLAB® Date Format Definitions on page 14-209, below. Input F may also contain a free-form date format string consisting of format tokens shown in the table Free-Form Date Format Specifiers on page 14-212, below.

Date strings with 2-character years are interpreted to be within the 100 years centered around the current year.

`S = datestr(S1, F, P)` converts date string S1 to date string S, applying format F to the output string, and using pivot year P as the starting year of the 100-year range in which a two-character year resides. The default pivot year is the current year minus 50 years. All date strings in S1 must have the same format.

`S = datestr(..., 'local')` returns the string in a localized format. The default is US English ('**en_US**'). This argument must come last in the argument sequence.

Note The vectorized calling syntax can offer significant performance improvement for large arrays.

Standard MATLAB Date Format Definitions

dateform (number)	dateform (string)	Example
0	'dd-mmm-yyyy HH:MM:SS'	01-Mar-2000 15:45:17
1	'dd-mmm-yyyy'	01-Mar-2000
2	'mm/dd/yy'	03/01/00
3	'mmm'	Mar
4	'm'	M

Standard MATLAB Date Format Definitions (Continued)

dateform (number)	dateform (string)	Example
5	'mm'	03
6	'mm/dd'	03/01
7	'dd'	01
8	'ddd'	Wed
9	'd'	W
10	'yyyy'	2000
11	'yy'	00
12	'mmmyy'	Mar00
13	'HH:MM:SS'	15:45:17
14	'HH:MM:SS PM'	3:45:17 PM
15	'HH:MM'	15:45
16	'HH:MM PM'	3:45 PM
17	'QQ-YY'	Q1-01
18	'QQ'	Q1
19	'dd/mm'	01/03
20	'dd/mm/yy'	01/03/00
21	'mmm.dd,yyyy HH:MM:SS'	Mar.01,2000 15:45:17
22	'mmm.dd,yyyy'	Mar.01,2000
23	'mm/dd/yyyy'	03/01/2000
24	'dd/mm/yyyy'	01/03/2000
25	'yy/mm/dd'	00/03/01
26	'yyyy/mm/dd'	2000/03/01

Standard MATLAB Date Format Definitions (Continued)

dateform (number)	dateform (string)	Example
27	'QQ-YYYY'	Q1-2001
28	'mmmyyyy'	Mar2000
29 (ISO 8601)	'yyyy-mm-dd'	2000-03-01
30 (ISO 8601)	'yyyymmddTHHMMSS'	20000301T154517
31	'yyyy-mm-dd HH:MM:SS'	2000-03-01 15:45:17

Note `dateform` numbers 0, 1, 2, 6, 13, 14, 15, 16, and 23 produce a string suitable for input to `datenum` or `datevec`. Other date string formats do not work with these functions unless you specify a date form in the function call.

Note For date formats that specify only a time (for example., `dateform` numbers 13, 14, 15, and 16), MATLAB software sets the date to January 1 of the current year.

Time formats like `'h:m:s'`, `'h:m:s.s'`, `'h:m pm'`, ... can also be part of the input array `S`. If you do not specify a format string `F`, or if you specify `F` as `-1`, the date string format defaults to the following:

1	If `S` contains date information only, for example, 01-Mar-1995
16	If `S` contains time information only, for example, 03:45 PM
0	If `S` is a date vector, or a string that contains both date and time information, for example, 01-Mar-1995 03:45

The following table shows the string symbols to use in specifying a free-form format for the output date string. MATLAB interprets these symbols according to your computer's language setting and the current MATLAB language setting.

Note You cannot use more than one format specifier for any date or time field. For example, `datestr(n, 'dddd dd mmmm')` specifies two formats for the day of the week, and thus returns an error.

Free-Form Date Format Specifiers

Symbol	Interpretation	Example
`yyyy`	Show year in full.	`1990, 2002`
`yy`	Show year in two digits.	`90, 02`
`mmmm`	Show month using full name.	`March, December`
`mmm`	Show month using first three letters.	`Mar, Dec`
`mm`	Show month in two digits.	`03, 12`
`m`	Show month using capitalized first letter.	`M, D`
`dddd`	Show day using full name.	`Monday, Tuesday`

Free-Form Date Format Specifiers (Continued)

Symbol	Interpretation	Example
ddd	Show day using first three letters.	Mon, Tue
dd	Show day in two digits.	05, 20
d	Show day using capitalized first letter.	M, T
HH	Show hour in two digits (no leading zeros when free-form specifier AM or PM is used (see last entry in this table)).	05, 5 AM
MM	Show minute in two digits.	12, 02
SS	Show second in two digits.	07, 59
FFF	Show millisecond in three digits.	.057
AM or PM	Append AM or PM to date string (see note below).	3:45:02 PM

Note Free-form specifiers AM and PM from the table above are identical. They do not influence which characters are displayed following the time (AM versus PM), but only whether or not they are displayed. MATLAB software selects AM or PM based on the time entered.

Remarks

A vector of three or six numbers could represent either a single date vector, or a vector of individual serial date numbers. For example, the vector [2000 12 15 11 45 03] could represent either 11:45:03 on December 15, 2000 or a vector of date numbers 2000, 12, 15, and so

on. MATLAB uses the following general rule in interpreting vectors associated with dates:

- A 3- or 6-element vector having a first element within an approximate range of 500 greater than or less than the current year is considered by MATLAB to be a date vector. Otherwise, it is considered to be a vector of serial date numbers.

To specify dates outside of this range as a date vector, first convert the vector to a serial date number using the `datenum` function as shown here:

```
datestr(datenum([1400 12 15 11 45 03]), ...
        'mmm.dd,yyyy HH:MM:SS')
ans =
   Dec.15,1400 11:45:03
```

Examples

Return the current date and time in a string using the default format, `0`:

```
datestr(now)

ans =
   28-Mar-2005 15:36:23
```

Reformat the date and time, and also show milliseconds:

```
dt = datestr(now, 'mmmm dd, yyyy HH:MM:SS.FFF AM')
dt =
   March 28, 2005  3:37:07.952 PM
```

Format the same showing only the date and in the `mm/dd/yy` format. Note that you can specify this format either by number or by string.

```
datestr(now, 2)     -or-     datestr(now, 'mm/dd/yy')

ans =
   03/28/05
```

Display the returned date string using your own format made up of symbols shown in the Free-Form Date Format Specifiers on page 14-212 table above.

```
datestr(now, 'dd.mm.yyyy')

ans =
   28.03.2005
```

Convert a nonstandard date form into a standard MATLAB date form by first converting to a date number and then to a string:

```
datestr(datenum('28.03.2005', 'dd.mm.yyyy'), 2)

ans =
   03/28/05
```

See Also

dateaxis, datedisp, datenum, datevec, daysact, now, today

Purpose

Date components

Syntax

```
V = datevec(N)
V = datevec(S, F)
V = datevec(S, F, P)
V = datevec(S, P, F)
[Y, M, D, H, MN, S] = datevec(...)
V = datevec(S)
V = datevec(S, P)
```

Description

`datevec` is one of three conversion functions that enable you to express dates and times in any of three formats in MATLAB software: a string (or *date string*), a vector of date and time components (or *date vector*), or as a numeric offset from a known date in time (or *serial date number*). Here is an example of a date and time expressed in the three MATLAB formats:

```
Date String:           '24-Oct-2003 12:45:07'
Date Vector:           [2003  10  24  12  45  07]
Serial Date Number:    7.3188e+005
```

A serial date number represents the whole and fractional number of days from 1-Jan-0000 to a specific date. The year 0000 is merely a reference point and is not intended to be interpreted as a real year in time.

`V = datevec(N)` converts one or more date numbers `N` to date vectors `V`. Input argument `N` can be a scalar, vector, or multidimensional array of positive date numbers. `datevec` returns an `m`-by-`6` matrix containing `m` date vectors, where `m` is the total number of date numbers in `N`.

`V = datevec(S, F)` converts one or more date strings `S` to date vectors `V` using format string `F` to interpret the date strings in `S`. Input argument `S` can be a cell array of strings or a character array where each row corresponds to one date string. All of the date strings in `S` must have the same format which must be composed of date format symbols according to the table "Free-Form Date Format Specifiers" in the `datestr` help.

Formats with `'Q'` are not accepted by `datevec`. `datevec` returns an `m`-by-`6` matrix of date vectors, where `m` is the number of date strings in S.

Certain formats may not contain enough information to compute a date vector. In those cases, hours, minutes, and seconds default to 0, days default to 1, months default to January, and years default to the current year. Date strings with two character years are interpreted to be within the 100 years centered around the current year.

`V = datevec(S, F, P)` converts the date string `S` to a date vector `V` using date format `F` and pivot year `P`. The pivot year is the starting year of the 100-year range in which a two-character year resides. The default pivot year is the current year minus 50 years.

`V = datevec(S, P, F)` is the same as the syntax shown above, except the order of the last two arguments are switched.

`[Y, M, D, H, MN, S] = datevec(...)` takes any of the two syntaxes shown above and returns the components of the date vector as individual variables. `datevec` does not return milliseconds in a separate output, but as a fractional part of the seconds (`S`) output.

`V = datevec(S)` converts date string `S` to date vector `V`. Input argument `S` must be in one of the date formats 0, 1, 2, 6, 13, 14, 15, 16, or 23 as defined in the reference page for the `datestr` function. This calling syntax is provided for backward compatibility, and is significantly slower than the syntax which specifies the format string. If the format is known, the `V = datevec(S, F)` syntax is recommended.

`V = datevec(S, P)` converts the date string `S` using pivot year `P`. If the format is known, the `V = datevec(S, F, P)` or `V = datevec(S, P, F)` syntax should be used.

Note If more than one input argument is used, the first argument must be a date string or array of date strings.

When creating your own date vector, you need not make the components integers. Any components that lie outside their conventional ranges

affect the next higher component (so that, for instance, the anomalous June 31 becomes July 1). A zeroth month, with zero days, is allowed.

Note The vectorized calling syntax can offer significant performance improvement for large arrays.

Examples

Obtain a date vector using a string as input:

```
format short g

datevec('March 28, 2005  3:37:07.952 PM')
ans =
     2005       3       28       15       37       7.952
```

Obtain a date vector using a serial date number as input:

```
t = datenum('March 28, 2005  3:37:07.952 PM')
t =
     7.324e+005

datevec(t)
ans =
     2005       3       28       15       37       7.952
```

Assign elements of the returned date vector:

```
[y, m, d, h, mn, s] = datevec('March 28, 2005  3:37:07.952 PM');
sprintf('Date: %d/%d/%d   Time: %d:%d:%2.3f\n', m, d, y, h, mn, s)

ans =
   Date: 3/28/2005   Time: 15:37:7.952
```

Use free-form date format `'dd.mm.yyyy'` to indicate how you want a nonstandard date string interpreted:

```
datevec('28.03.2005', 'dd.mm.yyyy')

ans = 2005   3   28   0  0  0
```

See Also

`datenum`, `datestr`, `now`, `today`

datewrkdy

Purpose

Date of future or past workday

Syntax

```
EndDate = datewrkdy(StartDate, NumberWorkDays, NumberHolidays)
```

Arguments

`StartDate`	Start date vector. Enter as serial date numbers or date strings.
`NumberWorkDays`	Vector containing number of work or business days in future (positive) or past (negative), including the starting date.
`NumberHolidays`	Vector containing values for the number of holidays within `NumberWorkDays`. `NumberHolidays` and `NumberWorkDays` must have the same sign.

Any input can contain multiple values, but if so, all other inputs must contain the same number of values or a single value that applies to all. For example, if `StartDate` is an n-row character array of date strings, then `NumberWorkDays` must be an `n`-by-`1` vector of integers or a single integer. `EndDate` is then an `n`-by-`1` vector of date numbers.

Description

`EndDate = datewrkdy(StartDate, NumberWorkDays, NumberHolidays)` returns the serial number of the date a given number of workdays before or after the start date.

Use `datestr` to convert serial date numbers to formatted date strings.

Examples

```
Workday = datewrkdy('12-dec-2000', 16, 2);
datestr(Workday)
ans =
04-Jan-2001
NumDays = [16; 20; 44];
```

```
Workdays = datewrkdy('12-dec-2000', NumDays, 2);
datestr(Workdays)
ans =
4-Jan-2001
10-Jan-2001
13-Feb-2001
```

See Also

busdate, holidays, isbusday, wrkdydif

Purpose

Day of month

Syntax

```
DayMonth = day(Date)
```

Description

`DayMonth = day(Date)` returns the day of the month given a serial date number or date string.

Examples

```
DayMonth = day(730544)
```

or

```
DayMonth = day('2/28/00')
```

returns `DayMonth = 28`

See Also

`datevec`, `eomday`, `month`, `year`

Purpose

Days between dates based on 360-day year

Syntax

```
NumDays = days360(StartDate, EndDate)
```

Arguments

`StartDate`	Enter as serial date numbers or date strings.
`EndDate`	Enter as serial date numbers or date strings.

Either input can contain multiple values, but if so, the other must contain the same number of values or a single value that applies to all. For example, if `StartDate` is an n-row character array of date strings, then `EndDate` must be an `n`-by-`1` vector of integers or a single integer. `NumDays` is then an `n`-by-`1` vector of date numbers.

Description

`NumDays = days360(StartDate, EndDate)` returns the number of days between `StartDate` and `EndDate` based on a 360-day year (that is, all months contain 30 days). If `EndDate` is earlier than `StartDate`, `NumDays` is negative.

Examples

```
NumDays = days360('15-jan-2000', '15-mar-2000')

NumDays =

    60

MoreDays = ['15-mar-2000'; '15-apr-2000'; '15-jun-2000'];

NumDays = days360('15-jan-2000', MoreDays)

NumDays =

    60
    90
```

```
150
```

References

Addendum to Securities Industry Association, *Standard Securities Calculation Methods: Fixed Income Securities Formulas for Analytic Measures,* Vol. 2, Spring 1995.

See Also

`days365`, `daysact`, `daysdif`, `wrkdydif`, `yearfrac`

Purpose

Days between dates based on 360-day year (European)

Syntax

```
NumDays = days360e(StartDate, EndDate)
```

Arguments

`StartDate`	Row vector, column vector, or scalar value in serial date number or date string format.
`EndDate`	Row vector, column vector, or scalar value in serial date number or date string format.

Either input can contain multiple values, but if so, the other must contain the same number of values or a single value that applies to all.

Description

`NumDays = days360e(StartDate, EndDate)` returns a vector or scalar value representing the number of days between `StartDate` and `EndDate` based on a 360-day year (that is, all months contain 30 days). If `EndDate` is earlier than `StartDate`, `NumDays` is negative.

This day count convention is used primarily in Europe. Under this convention all months contain 30 days.

Examples

Example 1. Use this convention to find the number of days in the month of January.

```
StartDate = '1-Jan-2002';
EndDate = '1-Feb-2002';
NumDays = days360e(StartDate, EndDate)

NumDays =

    30
```

Example 2. Use this convention to find the number of days in February during a leap year.

```
StartDate = '1-Feb-2000';
EndDate = '1-Mar-2000';
NumDays = days360e(StartDate, EndDate)

NumDays =

    30
```

Example 3. Use this convention to find the number of days in February of a non-leap year.

```
StartDate = '1-Feb-2002';
EndDate = '1-Mar-2002';

NumDays = days360e(StartDate, EndDate)

NumDays =

    30
```

See Also

days360, days360isda, days360psa

Purpose

Days between dates based on 360-day year (International Swap Dealer Association (ISDA) compliant)

Syntax

```
NumDays = days360isda(StartDate, EndDate)
```

Arguments

`StartDate`	Row vector, column vector, or scalar value in serial date number or date string format.
`EndDate`	Row vector, column vector, or scalar value in serial date number or date string format.

Either input can contain multiple values, but if so, the other must contain the same number of values or a single value that applies to all.

Description

`NumDays = days360isda(StartDate, EndDate)` returns a vector or scalar value representing the number of days between `StartDate` and `EndDate` based on a 360-day year (that is, all months contain 30 days). If `EndDate` is earlier than `StartDate`, `NumDays` is negative.

Under this convention all months contain 30 days.

Examples

Example 1. Use this convention to find the number of days in the month of January.

```
StartDate = '1-Jan-2002';
EndDate = '1-Feb-2002';
NumDays = days360isda(StartDate, EndDate)

NumDays =

30
```

Example 2. Use this convention to find the number of days in February during a leap year.

```
StartDate = '1-Feb-2000';
EndDate = '1-Mar-2000';
NumDays = days360isda(StartDate, EndDate)

NumDays =

    30
```

Example 3. Use this convention to find the number of days in February of a non leap year.

```
StartDate = '1-Feb-2002';
EndDate = '1-Mar-2002';
NumDays = days360isda(StartDate, EndDate)

NumDays =

    30
```

See Also

days360, days360e, days360psa

Purpose

Days between dates based on 360-day year (Public Securities Association (PSA) compliant)

Syntax

```
NumDays = days360psa(StartDate, EndDate)
```

Arguments

`StartDate`	Row vector, column vector, or scalar value in serial date number or date string format.
`EndDate`	Row vector, column vector, or scalar value in serial date number or date string format.

Either input can contain multiple values, but if so, the other must contain the same number of values or a single value that applies to all.

Description

`NumDays = days360psa(StartDate, EndDate)` returns a vector or scalar value representing the number of days between `StartDate` and `EndDate` based on a 360-day year (that is, all months contain 30 days). If `EndDate` is earlier than `StartDate`, `NumDays` is negative.

Under this payment convention all months contain 30 days. In both leap and non-leap years, if the `StartDate` is the last day of February, this day is considered to be day 30 of the month.

Examples

Example 1. Use this convention to find the number of days in between the last day of February and the first day of March during a leap year.

```
StartDate = '29-Feb-2000';
EndDate = '1-Mar-2000';
NumDays = days360psa(StartDate, EndDate)

NumDays =

     1
```

Example 2. Use this convention to find the number of days in between the last day of February and the first day of March during a non-leap year.

```
StartDate = '28-Feb-2002';
EndDate = '1-Mar-2002';
NumDays = days360psa(StartDate, EndDate)

NumDays =

    1
```

As expected, the number of days in both cases is the same. The convention always assumes that the last day of February is the 30th day.

See Also

`days360`, `days360e`, `days360isda`

Purpose

Days between dates based on 365-day year

Syntax

```
NumDays = days365(StartDate, EndDate)
```

Arguments

`StartDate`	Enter as serial date numbers or date strings.
`EndDate`	Enter as serial date numbers or date strings.

Either input can contain multiple values, but if so, the other must contain the same number of values or a single value that applies to all. For example, if `StartDate` is an n-row character array of date strings, then `EndDate` must be an `n`-by-`1` vector of integers or a single integer. `NumDays` is then an `n`-by-`1` vector of date numbers.

Description

`NumDays = days365(StartDate, EndDate)` returns the number of days between dates `StartDate` and `EndDate` based on a 365-day year. (All months contain their actual number of days. February always contains 28 days.) If `EndDate` is earlier than `StartDate`, `NumDays` is negative. Enter dates as serial date numbers or date strings.

Examples

```
NumDays = days365('15-jan-2000', '15-mar-2000')

NumDays =

    59

MoreDays = ['15-mar-2000'; '15-apr-2000'; '15-jun-2000'];

NumDays = days365('15-jan-2000', MoreDays)

NumDays =

    59
```

```
                    90
                   151
```

See Also

days360, daysact, daysdif, wrkdydif, yearfrac

Purpose

Actual number of days between dates

Syntax

```
NumDays = daysact(StartDate, EndDate)
```

Arguments

`StartDate`	Enter as serial date numbers or date strings.
`EndDate`	(Optional) Enter as serial date numbers or date strings.

Either input can contain multiple values, but if so, the other must contain the same number of values or a single value that applies to all. For example, if `StartDate` is an *n*-row character array of date strings, then `EndDate` must be an *n*-row character array of date strings or a single date. `NumDays` is then an *n*-by-1 vector of numbers.

Description

`NumDays = daysact(StartDate, EndDate)` returns the actual number of days between two dates. Enter dates as serial date numbers or date strings. `NumDays` is negative if `EndDate` is earlier than `StartDate`.

`NumDays = daysact(StartDate)` returns the actual number of days between the MATLAB base date and `StartDate`. In MATLAB software, the base date 1 is 1-Jan-0000 A.D. See `datenum` for a similar function.

Examples

```
NumDays = daysact('7-sep-2002',  '25-dec-2002')
NumDays =
   109

NumDays = daysact('9/7/2002')
NumDays =
      731466

MoreDays = ['09/07/2002'; '10/22/2002'; '11/05/2002'];
NumDays = daysact(MoreDays, '12/25/2002')
```

```
NumDays =
   109
    64
    50
```

See Also

datenum, datevec, days360, days365, daysdif

Purpose

Date away from starting date for any day-count basis

Syntax

```
NumDays = daysadd(StartDate, NumDays, Basis)
```

Arguments

`StartDate`	Start date. Enter as serial date numbers or date strings.
`NumDays`	Integer number of days from start date. Enter a negative integer for dates before start date.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Note When using the 30/360 day-count basis, it is not always possible to find the exact date `NumDays` number of days away because of a known discontinuity in the method of counting days. A warning is displayed if this occurs.

Description

`NumDays = daysadd(StartDate, NumDays, Basis)` returns a date `NumDays` number of days away from `StartDate`, using the given day-count basis.

Examples

```
NewDate = daysadd('01-Feb-2004', 31)

NewDate =

      732009

datestr(NewDate)

ans =

03-Mar-2004

NewDate = daysadd('01-Feb-2004', 31, 1)

NewDate =

      732008

datestr(NewDate)

ans =

02-Mar-2004
```

References

Stigum, Marcia L. and Franklin Robinson, *Money Market and Bond Calculations*, Richard D. Irwin, 1996, ISBN 1-55623-476-7

See Also

`daysdif`

Purpose

Days between dates for any day-count basis

Syntax

```
NumDays = daysdif(StartDate, EndDate, Basis)
```

Arguments

`StartDate`	Enter as serial date numbers or date strings.
`EndDate`	Enter as serial date numbers or date strings.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Any input argument can contain multiple values, but if so, the other inputs must contain the same number of values or a single value that applies to all. For example, if `StartDate` is an n-row character array of

date strings, then EndDate must be an n-row character array of date strings or a single date. NumDays is then an n-by-1 vector of numbers.

Description

NumDays = daysdif(StartDate, EndDate, Basis) returns the number of days between dates StartDate and EndDate using the given day-count basis. Enter dates as serial date numbers or date strings. Enter dates as serial date numbers or date strings. The first date (StartDate) is not included when determining the number of days between first and last date.

This function is a helper function for the bond pricing and yield functions. It is designed to make the code more readable and to eliminate redundant calls within if statements.

Examples

```
NumDays = daysdif('3/1/99', '3/1/00', 1)
NumDays =
   360

MoreDays = ['3/1/2001'; '3/1/2002'; '3/1/2003'];
NumDays = daysdif('3/1/98', MoreDays)
NumDays =
         1096
         1461
         1826
```

References

Stigum, Marcia L. and Franklin Robinson, *Money Market and Bond Calculations*, Richard D. Irwin, 1996, ISBN 1-55623-476-7.

See Also

datenum, days360, days365, daysact, daysadd, wrkdydif, yearfrac

dec2thirtytwo

Purpose

Decimal to thirty-second quotation

Syntax

```
[OutNumber, Fractions] = dec2thirtytwo(InNumber, Accuracy)
```

Arguments

`InNumber`	Input number as a decimal fraction.
`Accuracy`	(Optional) Rounding. Default = 1, round down to nearest thirty second. Other values are 2 (nearest half), 4 (nearest quarter) and 10 (nearest decile).

Description

`[OutNumber, Fractions] = dec2thirtytwo(InNumber, Accuracy)` changes a decimal price quotation for a bond or bond future to a fraction with a denominator of 32.

`OutNumber` is `InNumber` rounded downward to the closest integer.

`Fractions` is the fractional part in units of thirty-second with accuracy as prescribed by the input `Accuracy`.

Examples

Two bonds are quoted with decimal prices of 101.78 and 102.96. Convert these prices to fractions with a denominator of 32.

```
InNumber  = [101.78; 102.96];

[OutNumber, Fractions] = dec2thirtytwo(InNumber)

OutNumber =

   101
   102

Fractions =

    25
```

```
31
```

See Also

`thirtytwo2dec`

depfixdb

Purpose

Fixed declining-balance depreciation schedule

Syntax

```
Depreciation = depfixdb(Cost, Salvage, Life, Period, Month)
```

Arguments

`Cost`	Scalar for the initial value of the asset.
`Salvage`	Scalar for the salvage value of the asset.
`Life`	Scalar value for the life of the asset in years.
`Period`	Scalar integer for the number of years to calculate.
`Month`	(Optional) Scalar value for the number of months in the first year of asset life. Default = 12.

Description

`Depreciation = depfixdb(Cost, Salvage, Life, Period, Month)` calculates the fixed declining-balance depreciation for each period.

Examples

A car is purchased for $11,000 with a salvage value of $1500 and a lifetime of eight years. To calculate the depreciation for the first five years

```
Depreciation = depfixdb(11000, 1500, 8, 5)
```

returns

```
Depreciation =
       2425.08     1890.44     1473.67     1148.78     895.52
```

See Also

`depgendb`, `deprdv`, `depsoyd`, `depstln`

Purpose

General declining-balance depreciation schedule

Syntax

```
Depreciation = depgendb(Cost, Salvage, Life, Factor)
```

Arguments

`Cost`	Cost of the asset.
`Salvage`	Estimated salvage value of the asset.
`Life`	Number of periods over which the asset is depreciated.
`Factor`	Depreciation factor. `Factor = 2` uses the double-declining-balance method.

Description

`Depreciation = depgendb(Cost, Salvage, Life, Factor)` calculates the declining-balance depreciation for each period.

Examples

A car is purchased for $11,000 and is to be depreciated over five years. The estimated salvage value is $1000. Using the double-declining-balance method, the function calculates the depreciation for each year and returns the remaining depreciable value at the end of the life of the car.

```
Depreciation = depgendb(11000, 1000, 5, 2)
```

returns

```
Depreciation =
       4400.00     2640.00     1584.00     950.40     425.60
```

See Also

`depfixdb`, `deprdv`, `depsoyd`, `depstln`

deprdv

Purpose

Remaining depreciable value

Syntax

```
Value = deprdv(Cost, Salvage, Accum)
```

Arguments

`Cost`	Cost of the asset.
`Salvage`	Salvage value of the asset.
`Accum`	Accumulated depreciation of the asset for prior periods.

Description

`Value = deprdv(Cost, Salvage, Accum)` returns the remaining depreciable value for an asset.

Examples

The cost of an asset is $13,000 with a life of 10 years. The salvage value is $1000. First find the accumulated depreciation with the straight-line depreciation function, `depstln`. Then find the remaining depreciable value after six years.

```
Accum = depstln(13000, 1000, 10) * 6

Accum =
       7200.00

Value = deprdv(13000, 1000, 7200)

Value =
       4800.00
```

See Also

`depfixdb`, `depgendb`, `depsoyd`, `depstln`

Purpose

Sum of years' digits depreciation

Syntax

```
Sum = depsoyd(Cost, Salvage, Life)
```

Arguments

`Cost`	Cost of the asset.
`Salvage`	Salvage value of the asset.
`Life`	Depreciable life of the asset in years.

Description

`Sum = depsoyd(Cost, Salvage, Life)` calculates the depreciation for an asset using the sum of years' digits method. `Sum` is a `1`-by-`Life` vector of depreciation values with each element corresponding to a year of the asset's life.

Examples

The cost of an asset is $13,000 with a life of 10 years. The salvage value of the asset is $1000.

```
Sum = depsoyd(13000, 1000, 10)'
```

returns

```
Sum =
       2181.82
       1963.64
       1745.45
       1527.27
       1309.09
       1090.91
        872.73
        654.55
        436.36
        218.18
```

See Also `depfixdb`, `depgendb`, `deprdv`, `depstln`

Purpose

Straight-line depreciation schedule

Syntax

```
Depreciation = depstln(Cost, Salvage, Life)
```

Arguments

`Cost`	Cost of the asset.
`Salvage`	Salvage value of the asset.
`Life`	Depreciable life of the asset in years.

Description

`Depreciation = depstln(Cost, Salvage, Life)` calculates straight-line depreciation for an asset.

Examples

The cost of an asset is $13,000 with a life of 10 years. The salvage value of the asset is $1000.

```
Depreciation = depstln(13000, 1000, 10)
```

returns

```
Depreciation =
                1200
```

See Also

`depfixdb`, `depgendb`, `deprdv`, `depsoyd`

diff

Purpose

Differencing

Syntax

```
newfts = diff(oldfts)
```

Description

`diff` computes the differences of the data series in a financial time series object. It returns another time series object containing the difference.

`newfts = diff(oldfts)` computes the difference of all the data in the data series of the object `oldfts` and returns the result in the object `newfts`. `newfts` is a financial time series object containing the same data series (names) as the input `oldfts`.

See Also

`diff` in the MATLAB documentation

Purpose

Zero curve given discount curve

Syntax

```
[ZeroRates, CurveDates] = disc2zero(DiscRates, CurveDates, Settle,
Compounding, Basis)
```

Arguments

`DiscRates`	Column vector of discount factors, as decimal fractions. In aggregate, the factors in `DiscRates` constitute a discount curve for the investment horizon represented by `CurveDates`.
`CurveDates`	Column vector of maturity dates (as serial date numbers) that correspond to the discount factors in `DiscRates`.
`Settle`	Serial date number that is the common settlement date for the discount rates in `DiscRates`.
`Compounding`	(Optional) Output compounding. A scalar that sets the compounding frequency per year for annualizing the output zero rates. Allowed values are:

1	Annual compounding
2	Semiannual compounding (default)
3	Compounding three times per year
4	Quarterly compounding
6	Bimonthly compounding
12	Monthly compounding
365	Daily compounding

	`-1` Continuous compounding
`Basis`	(Optional) Day-count basis for annualizing the output zero rates. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA) • 11 = 30/360E (ISMA) • 12 = actual/365 (ISDA)

Description

`[ZeroRates, CurveDates] = disc2zero(DiscRates, CurveDates, Settle, Compounding, Basis)` returns a zero curve given a discount curve and its maturity dates.

`ZeroRates`	Column vector of decimal fractions. In aggregate, the rates in `ZeroRates` constitute a zero curve for the investment horizon represented by `CurveDates`. The zero rates are the yields to maturity on theoretical zero-coupon bonds.
`CurveDates`	Column vector of maturity dates (as serial date numbers) that correspond to the zero rates. This vector is the same as the input vector `CurveDates`.

Examples

Given discount factors `DiscRates` over a set of maturity dates `CurveDates`, and a settlement date `Settle`

```
DiscRates = [0.9996
             0.9947
             0.9896
             0.9866
             0.9826
             0.9786
             0.9745
             0.9665
             0.9552
             0.9466];

CurveDates = [datenum('06-Nov-2000')
              datenum('11-Dec-2000')
              datenum('15-Jan-2001')
              datenum('05-Feb-2001')
              datenum('04-Mar-2001')
              datenum('02-Apr-2001')
              datenum('30-Apr-2001')
              datenum('25-Jun-2001')
              datenum('04-Sep-2001')
              datenum('12-Nov-2001')];

Settle = datenum('03-Nov-2000');
```

Set daily compounding for the output zero curve, on an actual/365 basis.

```
Compounding = 365;
Basis = 3;
```

Execute the function

```
[ZeroRates, CurveDates] = disc2zero(DiscRates, CurveDates,...
Settle, Compounding, Basis)
```

which returns the zero curve `ZeroRates` at the maturity dates `CurveDates`.

```
ZeroRates =
    0.0487
    0.0510
    0.0523
    0.0524
    0.0530
    0.0526
    0.0530
    0.0532
    0.0549
    0.0536

CurveDates =
      730796
      730831
      730866
      730887
      730914
      730943
      730971
      731027
      731098
      731167
```

For readability, `DiscRates` and `ZeroRates` are shown here only to the basis point. However, MATLAB software computed them at full precision. If you enter `DiscRates` as shown, `ZeroRates` may differ due to rounding.

See Also

`zero2disc` and other functions for "Term Structure of Interest Rates" on page 2-37

discrate

Purpose

Bank discount rate of money market security

Syntax

```
DiscRate = discrate(Settle, Maturity, Face, Price, Basis)
```

Arguments

`Settle`	Enter as serial date numbers or date strings. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Enter as serial date numbers or date strings.
`Face`	Redemption (par, face) value.
`Price`	Price of the security.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Description

`DiscRate = discrate(Settle, Maturity, Face, Price, Basis)` finds the bank discount rate of a security. The bank discount rate normalizes by the face value of the security (for example, U. S. Treasury Bills) and understates the true yield earned by investors.

Examples

```
DiscRate = discrate('12-jan-2000', '25-jun-2000', 100, 97.74, 0)
```

returns

```
DiscRate =

    0.0501
```

a discount rate of 5.01%.

References

Mayle, *Standard Securities Calculation Methods*, Volumes I-II, 3rd edition. Formula 1.

See Also

`acrudisc`, `fvdisc`, `prdisc`, `ylddisc`

ecmlsrmle

Purpose

Least-squares regression with missing data

Syntax

```
[Parameters, Covariance, Resid, Info] = ecmlsrmle(Data, Design,
MaxIterations, TolParam, TolObj, Param0, Covar0, CovarFormat)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. Missing values are represented as `NaN`s. Only samples that are entirely `NaN`s are ignored. (To ignore samples with at least one `NaN`, use `mvnrmle`.)
`Design`	A matrix or a cell array that handles two model structures: • If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series. • If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values. If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.

`MaxIterations` (Optional) Maximum number of iterations for the estimation algorithm. Default value is 100.

`TolParam` (Optional) Convergence tolerance for estimation algorithm based on changes in model parameter estimates. Default value is `sqrt(eps)` which is about 1.0e-8 for double precision. The convergence test for changes in model parameters is

$$\left\|\mathbf{P}\mathrm{aram}_k - \mathbf{P}\mathrm{aram}_{k-1}\right\| < \mathrm{TolParam} \times \left(1 + \left\|\mathrm{Param}_k\right|\right)$$

where `Param` represents the output `Parameters`, and iteration $k = 2, 3, \ldots$. Convergence is assumed when both the `TolParam` and `TolObj` conditions are satisfied. If both `TolParam` $\leq$ `0` and `TolObj` $\leq$ `0`, do the maximum number of iterations (`MaxIterations`), whatever the results of the convergence tests.

`TolObj` (Optional) Convergence tolerance for estimation algorithm based on changes in the objective function. Default value is $\mathrm{eps} \wedge 3/4$ which is about 1.0e-12 for double precision. The convergence test for changes in the objective function is

$$\left|\mathrm{Obj}_k - \mathrm{Obj}_{k-1}\right| < \mathrm{TolObj} \times \left(1 + \left|\mathrm{Obj}_k\right|\right)$$

for iteration $k = 2, 3, \ldots$. Convergence is assumed when both the `TolParam` and `TolObj` conditions are satisfied. If both `TolParam` $\leq$ `0` and `TolObj` $\leq$ `0`, do the maximum number of iterations (`MaxIterations`), whatever the results of the convergence tests.

`Param0`	(Optional) `NUMPARAMS`-by-`1` column vector that contains a user-supplied initial estimate for the parameters of the regression model. Default is a zero vector.
`Covar0`	(Optional) `NUMSERIES`-by-`NUMSERIES` matrix that contains a user-supplied initial or known estimate for the covariance matrix of the regression residuals. Default is an identity matrix. For covariance-weighted least-squares calculations, this matrix corresponds with weights for each series in the regression. The matrix also serves as an initial guess for the residual covariance in the expectation conditional maximization (ECM) algorithm.
`CovarFormat`	(Optional) String that specifies the format for the covariance matrix. The choices are: • `'full'` - Default method. Compute the full covariance matrix. • `'diagonal'` - Force the covariance matrix to be a diagonal matrix.

Description

`[Parameters, Covariance, Resid, Info] = ecmlsrmle(Data, Design, MaxIterations, TolParam, TolObj, Param0, Covar0, CovarFormat)` estimates a least-squares regression model with missing data. The model has the form

$$\text{Data}_k \sim N(\text{Design}_k \times \text{Parameters}, \text{Covariance})$$

for samples $k = 1, \ldots$, `NUMSAMPLES`.

`ecmlsrmle` estimates a `NUMPARAMS`-by-`1` column vector of model parameters called `Parameters`, and a `NUMSERIES`-by-`NUMSERIES` matrix of covariance parameters called `Covariance`.

`ecmlsrmle(Data, Design)` with no output arguments plots the log-likelihood function for each iteration of the algorithm.

To summarize the outputs of `ecmlsrmle`:

- `Parameters` is a `NUMPARAMS`-by-`1` column vector of estimates for the parameters of the regression model.
- `Covariance` is a `NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance of the regression model's residuals. For least-squares models, this estimate may not be a maximum likelihood estimate except under special circumstances.
- `Resid` is a `NUMSAMPLES`-by-`NUMSERIES` matrix of residuals from the regression.

Another output, `Info`, is a structure that contains additional information from the regression. The structure has these fields:

- `Info.Obj` – A variable-extent column vector, with no more than `MaxIterations` elements, that contains each value of the objective function at each iteration of the estimation algorithm. The last value in this vector, `Obj(end)`, is the terminal estimate of the objective function. If you do least-squares, the objective function is the least-squares objective function.
- `Info.PrevParameters` – `NUMPARAMS`-by-1 column vector of estimates for the model parameters from the iteration just prior to the terminal iteration.
- `Info.PrevCovariance` – `NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance parameters from the iteration just prior to the terminal iteration.

Notes

If doing covariance-weighted least-squares, `Covar0` should usually be a diagonal matrix. Series with greater influence should have smaller

diagonal elements in `CovarO` and series with lesser influence should have larger diagonal elements. Note that if doing CWLS, `CovarO` need not be a diagonal matrix even if `CovarFormat = 'diagonal'`.

You can configure `Design` as a matrix if `NUMSERIES = 1` or as a cell array if `NUMSERIES` $\geq$ `1`.

- If `Design` is a cell array and `NUMSERIES` = 1, each cell contains a `NUMPARAMS` row vector.
- If `Design` is a cell array and `NUMSERIES` > 1, each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix.

These points concern how `Design` handles missing data:

- Although `Design` should not have `NaN` values, ignored samples due to `NaN` values in `Data` are also ignored in the corresponding `Design` array.
- If `Design` is a `1`-by-`1` cell array, which has a single `Design` matrix for each sample, no `NaN` values are permitted in the array. A model with this structure must have `NUMSERIES` $\geq$ `NUMPARAMS` with `rank(Design{1}) = NUMPARAMS`.
- `ecmlsrmle` is more strict than `mvnrmle` about the presence of `NaN` values in the `Design` array.

Use the estimates in the optional output structure `Info` for diagnostic purposes.

Examples

See "Multivariate Normal Regression" on page 5-17, "Least-Squares Regression" on page 5-18, "Covariance-Weighted Least Squares" on page 5-19, "Feasible Generalized Least Squares" on page 5-20, and "Seemingly Unrelated Regression" on page 5-21.

References

Roderick J. A. Little and Donald B. Rubin, *Statistical Analysis with Missing Data*, 2nd ed., John Wiley & Sons, Inc., 2002.

Xiao-Li Meng and Donald B. Rubin, "Maximum Likelihood Estimation via the ECM Algorithm," *Biometrika*, Vol. 80, No. 2, 1993, pp. 267-278.

Joe Sexton and Anders Rygh Swensen, "ECM Algorithms that Converge at the Rate of EM," *Biometrika*, Vol. 87, No. 3, 2000, pp. 651-662.

A. P. Dempster, N.M. Laird, and D. B. Rubin, "Maximum Likelihood from Incomplete Data via the EM Algorithm," *Journal of the Royal Statistical Society*, Series B, Vol. 39, No. 1, 1977, pp. 1-37.

See Also

`ecmlsrobj`, `ecmmvnrmle`, `mvnrmle`

ecmlsrobj

Purpose

Log-likelihood function for least-squares regression with missing data

Syntax

```
Objective = ecmlsrobj(Data, Design, Parameters, Covariance)
```

Arguments

`Data`

`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. Missing values are represented as `NaN`s. Only samples that are entirely `NaN`s are ignored. (To ignore samples with at least one `NaN`, use `mvnrmle`.)

`Design`

A matrix or a cell array that handles two model structures:

- If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series.
- If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values.

  If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.

`Parameters`

`NUMPARAMS`-by-`1` column vector of estimates for the parameters of the regression model.

`Covariance`

(Optional) `NUMSERIES`-by-`NUMSERIES` matrix that contains a user-supplied estimate for the covariance matrix of the residuals of the regression. Default is an identity matrix.

Description

`Objective = ecmlsrobj(Data, Design, Parameters, Covariance)` computes a least-squares objective function based on current parameter estimates with missing data. `Objective` is a scalar that contains the least-squares objective function.

Notes

`ecmlsrobj` requires that `Covariance` be positive-definite.

Note that

```
ecmlsrobj(Data, Design, Parameters) = ecmmvnrobj(Data, ...
Design, Parameters, IdentityMatrix)
```

where `IdentityMatrix` is a `NUMSERIES`-by-`NUMSERIES` identity matrix.

You can configure `Design` as a matrix if `NUMSERIES = 1` or as a cell array if `NUMSERIES` $\geq$ `1`.

- If `Design` is a cell array and `NUMSERIES` = 1, each cell contains a `NUMPARAMS` row vector.
- If `Design` is a cell array and `NUMSERIES` > 1, each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix.

Examples

See “Multivariate Normal Regression” on page 5-17, “Least-Squares Regression” on page 5-18, “Covariance-Weighted Least Squares” on page 5-19, “Feasible Generalized Least Squares” on page 5-20, and “Seemingly Unrelated Regression” on page 5-21.

See Also

`ecmlsrmle`, `mvnrmle`, `mvnrobj`

ecmmvnrfish

Purpose

Fisher information matrix for multivariate normal regression model

Syntax

```
Fisher = ecmmvnrfish(Data, Design, Covariance, Method,
MatrixFormat, CovarFormat)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. Missing values are represented as `NaN`s. Only samples that are entirely `NaN`s are ignored. (To ignore samples with at least one `NaN`, use `mvnrfish`.)
`Design`	A matrix or a cell array that handles two model structures: • If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series. • If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values. If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.

`Covariance`

`NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance of the residuals of the regression.

`Method`

(Optional) String that identifies method of calculation for the information matrix:

- `hessian` - Default method. Use the expected Hessian matrix of the observed log-likelihood function. This method is recommended since the resultant standard errors incorporate the increased uncertainties due to missing data.
- `fisher` - Use the Fisher information matrix.

`MatrixFormat`

(Optional) String that identifies parameters to be included in the Fisher information matrix:

- `full` - Default format. Compute the full Fisher information matrix for both model and covariance parameter estimates.
- `paramonly` - Compute only components of the Fisher information matrix associated with the model parameter estimates.

`CovarFormat`

(Optional) String that specifies the format for the covariance matrix. The choices are:

- `'full'` - Default method. The covariance matrix is a full matrix.
- `'diagonal'` - The covariance matrix is a diagonal matrix.

Description

`Fisher = ecmmvnrfish(Data, Design, Covariance, Method, MatrixFormat, CovarFormat)` computes a Fisher information matrix based on current maximum likelihood or least-squares parameter estimates that account for missing data.

`Fisher` is a `NUMPARAMS`-by-`NUMPARAMS` Fisher information matrix or Hessian matrix. The size of `NUMPARAMS` depends on `MatrixFormat` and on current parameter estimates. If `MatrixFormat = 'full'`,

```
NUMPARAMS = NUMSERIES * (NUMSERIES + 3)/2
```

If `MatrixFormat = 'paramonly'`,

```
NUMPARAMS = NUMSERIES
```

Note `ecmmvnrfish` operates slowly if you calculate the full Fisher information matrix.

Examples

See “Multivariate Normal Regression” on page 5-17, “Least-Squares Regression” on page 5-18, “Covariance-Weighted Least Squares” on page 5-19, “Feasible Generalized Least Squares” on page 5-20, and “Seemingly Unrelated Regression” on page 5-21.

See Also

`ecmnmle` , `ecmnstd`

Purpose

Multivariate normal regression with missing data

Syntax

```
[Parameters, Covariance, Resid, Info] = ecmmvnrmle(Data, Design,
MaxIterations, TolParam, TolObj, Param0, Covar0, CovarFormat)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. Missing values are represented as `NaN`s. Only samples that are entirely `NaN`s are ignored. (To ignore samples with at least one `NaN`, use `mvnrmle`.)
`Design`	A matrix or a cell array that handles two model structures: • If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series. • If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values. If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.

`MaxIterations` (Optional) Maximum number of iterations for the estimation algorithm. Default value is 100.

`TolParam` (Optional) Convergence tolerance for estimation algorithm based on changes in model parameter estimates. Default value is `sqrt(eps)` which is about 1.0e-8 for double precision. The convergence test for changes in model parameters is

$$\left\|\mathbf{P}\mathrm{aram}_k - \mathbf{P}\mathrm{aram}_{k-1}\right\| < \mathbf{T}\mathrm{ol}\mathbf{P}\mathrm{aram} \times \left(1 + \left\|\mathbf{P}\mathrm{aram}_k\right|\right)$$

where `Param` represents the output `Parameters`, and iteration $k = 2, 3, \ldots$. Convergence is assumed when both the `TolParam` and `TolObj` conditions are satisfied. If both `TolParam` $\leq$ `0` and `TolObj` $\leq$ `0`, do the maximum number of iterations (`MaxIterations`), whatever the results of the convergence tests.

`TolObj` (Optional) Convergence tolerance for estimation algorithm based on changes in the objective function. Default value is $\mathrm{eps} \wedge 3/4$ which is about 1.0e-12 for double precision. The convergence test for changes in the objective function is

$$\left|\mathbf{O}\mathrm{bj}_k - \mathbf{O}\mathrm{bj}_{k-1}\right| < \mathbf{T}\mathrm{ol}\mathbf{O}\mathrm{bj} \times \left(1 + \left|\mathbf{O}\mathrm{bj}_k\right|\right)$$

for iteration $k = 2, 3, \ldots$. Convergence is assumed when both the `TolParam` and `TolObj` conditions are satisfied. If both `TolParam` $\leq$ `0` and `TolObj` $\leq$ `0`, do the maximum number of iterations (`MaxIterations`), whatever the results of the convergence tests.

`Param0`	(Optional) `NUMPARAMS`-by-`1` column vector that contains a user-supplied initial estimate for the parameters of the regression model.
`Covar0`	(Optional) `NUMSERIES`-by-`NUMSERIES` matrix that contains a user-supplied initial or known estimate for the covariance matrix of the regression residuals.
`CovarFormat`	(Optional) String that specifies the format for the covariance matrix. The choices are: • `'full'` - Default method. Compute the full covariance matrix. • `'diagonal'` - Force the covariance matrix to be a diagonal matrix.

Description

`[Parameters, Covariance, Resid, Info] = ecmmvnrmle(Data, Design, MaxIterations, TolParam, TolObj, Param0, Covar0, CovarFormat)` estimates a multivariate normal regression model with missing data. The model has the form

$$\mathrm{Data}_k \sim N(\mathrm{Design}_k \times \mathrm{Parameters}, \mathrm{Covariance})$$

for samples $k = 1, \ldots, \mathrm{NUMSAMPLES}$.

`ecmmvnrmle` estimates a `NUMPARAMS`-by-`1` column vector of model parameters called `Parameters`, and a `NUMSERIES`-by-`NUMSERIES` matrix of covariance parameters called `Covariance`.

`ecmmvnrmle(Data, Design)` with no output arguments plots the log-likelihood function for each iteration of the algorithm.

To summarize the outputs of `ecmmvnrmle`:

- `Parameters` is a `NUMPARAMS`-by-`1` column vector of estimates for the parameters of the regression model.

- `Covariance` is a `NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance of the regression model's residuals.
- `Resid` is a `NUMSAMPLES`-by-`NUMSERIES` matrix of residuals from the regression. For any missing values in `Data`, the corresponding residual is the difference between the conditionally imputed value for `Data` and the model, that is, the imputed residual.

Note The covariance estimate `Covariance` cannot be derived from the residuals.

Another output, `Info`, is a structure that contains additional information from the regression. The structure has these fields:

- `Info.Obj` – A variable-extent column vector, with no more than `MaxIterations` elements, that contains each value of the objective function at each iteration of the estimation algorithm. The last value in this vector, `Obj(end)`, is the terminal estimate of the objective function. If you do maximum likelihood estimation, the objective function is the log-likelihood function.
- `Info.PrevParameters` – `NUMPARAMS`-by-1 column vector of estimates for the model parameters from the iteration just prior to the terminal iteration.`nfo.PrevCovariance` – `NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance parameters from the iteration just prior to the terminal iteration.

Notes

`ecmmvnrmle` does not accept an initial parameter vector, since the parameters are estimated directly from the first iteration onward.

You can configure `Design` as a matrix if `NUMSERIES = 1` or as a cell array if `NUMSERIES` $\geq$ `1`.

- If `Design` is a cell array and `NUMSERIES` = 1, each cell contains a `NUMPARAMS` row vector.

- If `Design` is a cell array and `NUMSERIES` > 1, each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix.

These points concern how `Design` handles missing data:

- Although `Design` should not have `NaN` values, ignored samples due to `NaN` values in `Data` are also ignored in the corresponding `Design` array.
- If `Design` is a `1`-by-`1` cell array, which has a single `Design` matrix for each sample, no `NaN` values are permitted in the array. A model with this structure must have `NUMSERIES` ≥ `NUMPARAMS` with `rank(Design{1}) = NUMPARAMS`.
- `ecmmvnrmle` is more strict than `mvnrmle` about the presence of `NaN` values in the `Design` array.

Use the estimates in the optional output structure `Info` for diagnostic purposes.

References

Roderick J. A. Little and Donald B. Rubin, *Statistical Analysis with Missing Data*, 2nd ed., John Wiley & Sons, Inc., 2002.

Xiao-Li Meng and Donald B. Rubin, "Maximum Likelihood Estimation via the ECM Algorithm," *Biometrika*, Vol. 80, No. 2, 1993, pp. 267-278.

Joe Sexton and Anders Rygh Swensen, "ECM Algorithms that Converge at the Rate of EM," *Biometrika*, Vol. 87, No. 3, 2000, pp. 651-662.

A. P. Dempster, N.M. Laird, and D. B. Rubin, "Maximum Likelihood from Incomplete Data via the EM Algorithm," *Journal of the Royal Statistical Society*, Series B, Vol. 39, No. 1, 1977, pp. 1-37.

Examples

See "Multivariate Normal Regression" on page 5-17, "Least-Squares Regression" on page 5-18, "Covariance-Weighted Least Squares" on page 5-19, "Feasible Generalized Least Squares" on page 5-20, and "Seemingly Unrelated Regression" on page 5-21.

See Also

`ecmmvnrobj`, `mvnrmle`

ecmmvnrobj

Purpose

Log-likelihood function for multivariate normal regression with missing data

Syntax

```
Objective = ecmmvnrobj(Data, Design, Parameters, Covariance,
CovarFormat)
```

Arguments

`Data`

`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. Missing values are represented as `NaN`s. Only samples that are entirely `NaN`s are ignored. (To ignore samples with at least one `NaN`, use `mvnrmle`.)

`Design`

A matrix or a cell array that handles two model structures:

- If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series.
- If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values.

  If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.

`Parameters`

`NUMPARAMS`-by-`1` column vector of estimates for the parameters of the regression model.

`Covariance`	`NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance of the residuals of the regression.
`CovarFormat`	(Optional) String that specifies the format for the covariance matrix. The choices are: • `'full'` - Default method. The covariance matrix is a full matrix. • `'diagonal'` - The covariance matrix is a diagonal matrix.

Description

`Objective = ecmmvnrobj(Data, Design, Parameters, Covariance, CovarFormat)` computes a log-likelihood function based on current maximum likelihood parameter estimates with missing data. `Objective` is a scalar that contains the least-squares objective function.

Notes

You can configure `Design` as a matrix if `NUMSERIES = 1` or as a cell array if `NUMSERIES` $\geq$ `1`.

- If `Design` is a cell array and `NUMSERIES` = 1, each cell contains a `NUMPARAMS` row vector.
- If `Design` is a cell array and `NUMSERIES` > 1, each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix.

Examples

See “Multivariate Normal Regression” on page 5-17, “Least-Squares Regression” on page 5-18, “Covariance-Weighted Least Squares” on page 5-19, “Feasible Generalized Least Squares” on page 5-20, and “Seemingly Unrelated Regression” on page 5-21.

See Also

`ecmmvnrmle`, `mvnrmle`, `mvnrobj`

Purpose

Evaluate standard errors for multivariate normal regression model

Syntax

```
[StdParameters, StdCovariance] = ecmmvnrstd(Data, Design,
Covariance, Method, CovarFormat)
```

Arguments

`Data`

`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. Missing values are represented as `NaN`s. Only samples that are entirely `NaN`s are ignored. (To ignore samples with at least one `NaN`, use `mvnrstd`.)

`Design`

A matrix or a cell array that handles two model structures:

- If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series.
- If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values.

  If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.

`Covariance`

`NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance of the regression residuals.

`Method` (Optional) String that identifies method of calculation for the information matrix:

- `hessian` - Default method. Use the expected Hessian matrix of the observed log-likelihood function. This method is recommended since the resultant standard errors incorporate the increased uncertainties due to missing data.
- `fisher` - Use the Fisher information matrix.

`CovarFormat` (Optional) String that specifies the format for the covariance matrix. The choices are:

- `'full'` - Default method. The covariance matrix is a full matrix.
- `'diagonal'` - The covariance matrix is a diagonal matrix.

Description

`[StdParameters, StdCovariance] = ecmmvnrstd(Data, Design, Covariance, Method, CovarFormat)` evaluates standard errors for a multivariate normal regression model with missing data. The model has the form

$$\mathrm{Data}_k \sim N(\mathrm{Design}_k \times \mathrm{Parameters}, \mathrm{Covariance})$$

for samples k = 1, ... , `NUMSAMPLES`.

`ecmmvnrstd` computes two outputs:

- `StdParameters` is a `NUMPARAMS`-by-`1` column vector of standard errors for each element of `Parameters`, the vector of estimated model parameters.

- `StdCovariance` is a `NUMSERIES`-by-`NUMSERIES` matrix of standard errors for each element of `Covariance`, the matrix of estimated covariance parameters.

Note `ecmmvnrstd` operates slowly when you calculate the standard errors associated with the covariance matrix `Covariance`.

Notes

You can configure `Design` as a matrix if `NUMSERIES = 1` or as a cell array if `NUMSERIES` $\geq$ `1`.

- If `Design` is a cell array and `NUMSERIES` = 1, each cell contains a `NUMPARAMS` row vector.
- If `Design` is a cell array and `NUMSERIES` > 1, each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix.

References

Roderick J. A. Little and Donald B. Rubin, *Statistical Analysis with Missing Data*, 2nd ed., John Wiley & Sons, Inc., 2002.

Examples

See “Multivariate Normal Regression” on page 5-17, “Least-Squares Regression” on page 5-18, “Covariance-Weighted Least Squares” on page 5-19, “Feasible Generalized Least Squares” on page 5-20, and “Seemingly Unrelated Regression” on page 5-21.

See Also

`ecmmvnrmle`, `ecmmvnrstd`, `mvnrmle`

Purpose

Fisher information matrix

Syntax

```
Fisher = ecmnfish(Data, Covariance, InvCovariance, MatrixFormat)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix of observed multivariate normal data
`Covariance`	`NUMSERIES`-by-`NUMSERIES` matrix with covariance estimate of `Data`
`InvCovariance`	(Optional) Inverse of covariance matrix: `inv(Covariance)`
`MatrixFormat`	(Optional) String that identifies parameters included in the Fisher information matrix. If `MatrixFormat = []` or ' ', the default method `full` is used. The parameter choices are • `full` — (Default) Compute full Fisher information matrix. • `meanonly` — Compute only components of the Fisher information matrix associated with the mean.

Description

`Fisher = ecmnfish(Data, Covariance, InvCovariance, MatrixFormat)` computes a `NUMPARAMS`-by-`NUMPARAMS` Fisher information matrix based on current parameter estimates, where

```
NUMPARAMS = NUMSERIES*(NUMSERIES + 3)/2
```

if `MatrixFormat = 'full'` and

```
NUMPARAMS = NUMSERIES
```

if `MatrixFormat = 'meanonly'`.

This routine is very slow for `NUMSERIES > 10` or `NUMSAMPLES > 1000`.

The data matrix has `NaNs` for missing observations. The multivariate normal model has

```
NUMPARAMS = NUMSERIES + NUMSERIES*(NUMSERIES + 1)/2
```

distinct parameters. Therefore, the full Fisher information matrix is of size `NUMPARAMS`-by-`NUMPARAMS`. The first `NUMSERIES` parameters are estimates for the mean of the data in `Mean`, and the remaining `NUMSERIES*(NUMSERIES + 1)/2` parameters are estimates for the lower-triangular portion of the covariance of the data in `Covariance`, in row-major order.

If `MatrixFormat = 'meanonly'`, the number of parameters is reduced to `NUMPARAMS = NUMSERIES`, where the Fisher information matrix is computed for the mean parameters only. In this format, the routine executes fastest.

This routine expects the inverse of the covariance matrix as an input. If you do not pass in the inverse, the routine computes it. You can obtain an approximation for the lower-bound standard errors of estimation of the parameters from

```
Stderr = (1.0/sqrt(NumSamples)) .* sqrt(diag(inv(Fisher)));
```

Because of missing information, these standard errors may be smaller than the estimated standard errors derived from the expected Hessian matrix. To see the difference, compare to standard errors calculated with `ecmnhess`.

See Also

`ecmnhess`, `ecmnmle`

Purpose

Hessian of negative log-likelihood function

Syntax

```
Hessian = ecmnhess(Data, Covariance, InvCovariance, MatrixFormat)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix of observed multivariate normal data
`Covariance`	`NUMSERIES`-by-`NUMSERIES` matrix with covariance estimate of `Data`
`InvCovariance`	(Optional) Inverse of covariance matrix: `inv(Covariance)`
`MatrixFormat`	(Optional) String that identifies parameters included in the Hessian matrix. If `MatrixFormat = []` or ' ', the default method `full` is used. The parameter choices are • `full` — (Default) Compute full Hessian matrix. • `meanonly` — Compute only components of the Hessian matrix associated with the mean.

Description

`Hessian = ecmnhess(Data, Covariance, InvCovariance, MatrixFormat)` computes a `NUMPARAMS` -by-`NUMPARAMS` Hessian matrix of the observed negative log-likelihood function based upon current parameter estimates, where

```
NUMPARAMS = NUMSERIES*(NUMSERIES + 3)/2
```

if `MatrixFormat = 'full'` and

```
NUMPARAMS = NUMSERIES
```

if `MatrixFormat = 'meanonly'`.

This routine is very slow for `NUMSERIES > 10` or `NUMSAMPLES > 1000`.

The data matrix has `NaN`s for missing observations. The multivariate normal model has

```
NUMPARAMS = NUMSERIES + NUMSERIES*(NUMSERIES + 1)/2
```

distinct parameters. Therefore, the full Hessian is a `NUMPARAMS`-by-`NUMPARAMS` matrix.

The first `NUMSERIES` parameters are estimates for the mean of the data in `Mean` and the remaining `NUMSERIES*(NUMSERIES + 1)/2` parameters are estimates for the lower-triangular portion of the covariance of the data in `Covariance`, in row-major order.

If `MatrixFormat = 'meanonly'`, the number of parameters is reduced to `NUMPARAMS = NUMSERIES`, where the Hessian is computed for the mean parameters only. In this format, the routine executes fastest.

This routine expects the inverse of the covariance matrix as an input. If you do not pass in the inverse, the routine computes it.

The equation

```
Stderr = (1.0/sqrt(NumSamples)) .* sqrt(diag(inv(Hessian)));
```

provides an approximation for the observed standard errors of estimation of the parameters.

Because of the additional uncertainties introduced by missing information, these standard errors may be larger than the estimated standard errors derived from the Fisher information matrix. To see the difference, compare to standard errors calculated from `ecmnfish`.

See Also

`ecmnfish`, `ecmnmle`

Purpose

Initial mean and covariance

Syntax

```
[Mean, Covariance] = ecmninit(Data, InitMethod)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. Missing values are indicated by `NaN`s.
`InitMethod`	(Optional) String that identifies one of three defined initialization methods to compute initial estimates for the mean and covariance of the data. If `InitMethod` = `[]` or `''`, the default method `nanskip` is used. The initialization methods are • `nanskip` — (Default) Skip all records with `NaN`s. • `twostage` — Estimate mean. Fill `NaN`s with the mean. Then estimate the covariance. • `diagonal` — Form a diagonal covariance.

Description

`[Mean, Covariance] = ecmninit(Data, InitMethod)` creates initial mean and covariance estimates for the function `ecmnmle`. `Mean` is a `NUMSERIES`-by-`1` column vector estimate for the mean of `Data`. `Covariance` is a `NUMSERIES`-by-`NUMSERIES` matrix estimate for the covariance of `Data`.

Algorithm

Model

The general model is

$$Z \sim N(Mean, Covariance)$$

where each row of `Data` is an observation of Z.

Each observation of Z is assumed to be iid (independent, identically distributed) multivariate normal, and missing values are assumed to be missing at random (MAR).

Initialization Methods

This routine has three initialization methods that cover most cases, each with its advantages and disadvantages.

nanskip

The `nanskip` method works well with small problems (fewer than 10 series or with monotone missing data patterns). It skips over any records with `NaN`s and estimates initial values from complete-data records only. This initialization method tends to yield fastest convergence of the ECM algorithm. This routine switches to the `twostage` method if it determines that significant numbers of records contain `NaN`.

twostage

The `twostage` method is the best choice for large problems (more than 10 series). It estimates the mean for each series using all available data for each series. It then estimates the covariance matrix with missing values treated as equal to the mean rather than as `NaN`s. This initialization method is quite robust but tends to result in slower convergence of the ECM algorithm.

diagonal

The `diagonal` method is a worst-case approach that deals with problematic data, such as disjoint series and excessive missing data (more than 33% missing data). Of the three initialization methods, this method causes the slowest convergence of the ECM algorithm.

See Also

`ecmnmle`

Purpose

Mean and covariance of incomplete multivariate normal data

Syntax

```
[Mean, Covariance] = ecmnmle(Data, InitMethod, MaxIterations,
Tolerance, Mean0, Covar0)
```

Arguments

`Data`

`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. Missing values are indicated by `NaN`s. A sample is also called an *observation* or a *record*.

`InitMethod`

(Optional) String that identifies one of three defined initialization methods to compute initial estimates for the mean and covariance of the data. If `InitMethod` = `[]` or `''`, the default method `nanskip` is used. The initialization methods are:

- `nanskip` — (Default) Skip all records with `NaN`s.
- `twostage` — Estimate mean. Fill `NaN`s with mean. Then estimate covariance.
- `diagonal` — Form a diagonal covariance.

Note If you supply `Mean0` and `Covar0`, `InitMethod` is not executed.

`MaxIterations`

(Optional) Maximum number of iterations for the expectation conditional maximization (ECM) algorithm. Default = 50.

`Tolerance`	(Optional) Convergence tolerance for the ECM algorithm (Default = `1.0e-8`.) If `Tolerance` $\leq$ 0, perform maximum iterations specified by `MaxIterations` and do not evaluate the objective function at each step unless in display mode, as described below.
`Mean0`	(Optional) Initial `NUMSERIES`-by-`1` column vector estimate for the mean. If you leave `Mean0` unspecified (`[]`), the method specified by `InitMethod` is used. If you specify `Mean0`, you must also specify `Covar0`.
`Covar0`	(Optional) Initial `NUMSERIES`-by-`NUMSERIES` matrix estimate for the covariance, where the input matrix must be positive-definite. If you leave `Covar0` unspecified (`[]`), the method specified by `InitMethod` is used. If you specify `Covar0`, you must also specify `Mean0`.

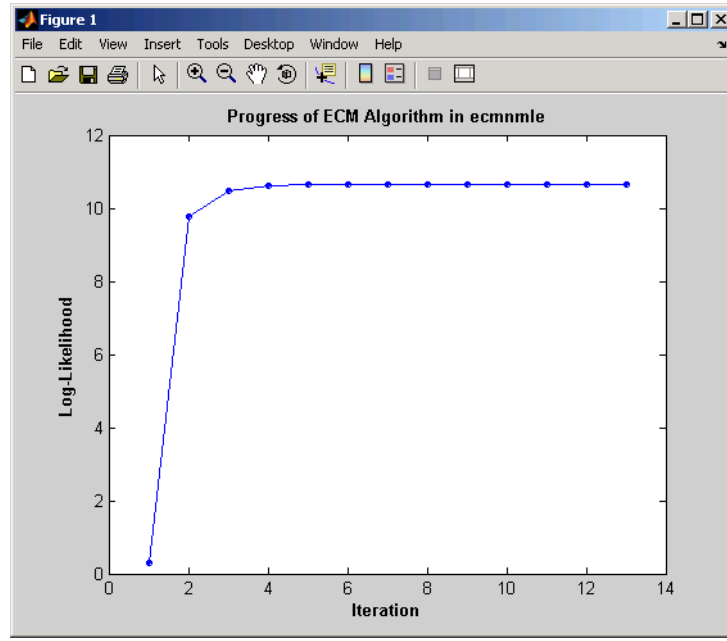
Description

`[Mean, Covariance] = ecmnmle(Data, InitMethod, MaxIterations, Tolerance, Mean0, Covar0)` estimates the mean and covariance of a data set. If the data set has missing values, this routine implements the ECM algorithm of Meng and Rubin [2] with enhancements by Sexton and Swensen [3]. ECM stands for *expectation conditional maximization*, a conditional maximization form of the EM algorithm of Dempster, Laird, and Rubin [4].

This routine has two operational modes.

Display Mode

With no output arguments, this mode displays the convergence of the ECM algorithm. It estimates and plots objective function values for each iteration of the ECM algorithm until termination, as shown in the following plot.



Display mode can determine `MaxIter` and `Tolerance` values or serve as a diagnostic tool. The objective function is the negative log-likelihood function of the observed data and convergence to a maximum likelihood estimate corresponds with minimization of the objective.

Estimation Mode

With output arguments, this mode estimates the mean and covariance via the ECM algorithm.

Examples

To see an example of how to use `ecmnmle`, run the demo program `ecmguidemo`.

Algorithm

Model

The general model is

$$Z \sim N(Mean, Covariance)$$

where each row of `Data` is an observation of Z.

Each observation of Z is assumed to be iid (independent, identically distributed) multivariate normal, and missing values are assumed to be missing at random (MAR). See Little and Rubin [1] for a precise definition of MAR.

This routine estimates the mean and covariance from given data. If data values are missing, the routine implements the ECM algorithm of Meng and Rubin [2] with enhancements by Sexton and Swensen [3].

If a record is empty (every value in a sample is `NaN`), this routine ignores the record because it contributes no information. If such records exist in the data, the number of nonempty samples used in the estimation is ≤ `NumSamples`.

The estimate for the covariance is a biased maximum likelihood estimate (MLE). To convert to an unbiased estimate, multiply the covariance by $Count/Count - 1)$, where *Count* is the number of nonempty samples used in the estimation.

Requirements

This routine requires consistent values for `NUMSAMPLES` and `NUMSERIES` with `NUMSAMPLES` > `NUMSERIES`. It must have enough nonmissing values to converge. Finally, it must have a positive-definite covariance matrix. Although the references provide some necessary and sufficient conditions, general conditions for existence and uniqueness of solutions in the missing-data case do not exist. The main failure mode is an ill-conditioned covariance matrix estimate. Nonetheless, this routine works for most cases that have less than 15% missing data (a typical upper bound for financial data).

Initialization Methods

This routine has three initialization methods that cover most cases, each with its advantages and disadvantages. The ECM algorithm always converges to a minimum of the observed negative log-likelihood

function. If you override the initialization methods, you must ensure that the initial estimate for the covariance matrix is positive-definite.

The following is a guide to the supported initialization methods.

nanskip

The `nanskip` method works well with small problems (fewer than 10 series or with monotone missing data patterns). It skips over any records with `NaN`s and estimates initial values from complete-data records only. This initialization method tends to yield fastest convergence of the ECM algorithm. This routine switches to the `twostage` method if it determines that significant numbers of records contain `NaN`.

twostage

The `twostage` method is the best choice for large problems (more than 10 series). It estimates the mean for each series using all available data for each series. It then estimates the covariance matrix with missing values treated as equal to the mean rather than as `NaN`s. This initialization method is quite robust but tends to result in slower convergence of the ECM algorithm.

diagonal

The `diagonal` method is a worst-case approach that deals with problematic data, such as disjoint series and excessive missing data (more than 33% of data missing). Of the three initialization methods, this method causes the slowest convergence of the ECM algorithm. If problems occur with this method, use display mode to examine convergence and modify either `MaxIterations` or `Tolerance`, or try alternative initial estimates with `Mean0` and `Covar0`. If all else fails, try

```
Mean0 = zeros(NumSeries);
Covar0 = eye(NumSeries,NumSeries);
```

Given estimates for mean and covariance from this routine, you can estimate standard errors with the companion routine `ecmnstd`.

Convergence

The ECM algorithm does not work for all patterns of missing values. Although it works in most cases, it can fail to converge if the covariance becomes singular. If this occurs, plots of the log-likelihood function tend to have a constant upward slope over many iterations as the log of the negative determinant of the covariance goes to zero. In some cases, the objective fails to converge due to machine precision errors. No general theory of missing data patterns exists to determine these cases. An example of a known failure occurs when two time series are proportional wherever both series contain nonmissing values.

References

[1] Little, Roderick J. A. and Donald B. Rubin, *Statistical Analysis with Missing Data*, 2nd ed., John Wiley & Sons, Inc., 2002.

[2] Meng, Xiao-Li and Donald B. Rubin, "Maximum Likelihood Estimation via the ECM Algorithm," *Biometrika*, Vol. 80, No. 2, 1993, pp. 267-278.

[3] Sexton, Joe and Anders Rygh Swensen, "ECM Algorithms that Converge at the Rate of EM," *Biometrika*, Vol. 87, No. 3, 2000, pp. 651-662.

[4] Dempster, A. P., N. M. Laird, and Donald B. Rubin, "Maximum Likelihood from Incomplete Data via the EM Algorithm," *Journal of the Royal Statistical Society*, Series B, Vol. 39, No. 1, 1977, pp. 1-37.

See Also

`ecmnfish`, `ecmnhess`, `ecmninit`, `ecmnobj`, `ecmnstd`

Purpose

Multivariate normal negative log-likelihood function

Syntax

```
Objective = ecmnobj(Data, Mean, Covariance, CholCovariance)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix of observed multivariate normal data
`Mean`	`NUMSERIES`-by-`1` column vector with mean estimate of `Data`
`Covariance`	`NUMSERIES`-by-`NUMSERIES` matrix with covariance estimate of `Data`
`CholCovariance`	(Optional) Cholesky decomposition of covariance matrix: `chol(Covariance)`

Description

`Objective = ecmnobj(Data, Mean, Covariance, CholCovariance)` computes the value of the observed negative log-likelihood function over the data given current estimates for the mean and covariance of the data.

The data matrix has `NaN`s for missing observations. The inputs `Mean` and `Covariance` are current estimates for model parameters.

This routine expects the Cholesky decomposition of the covariance matrix as an input. The routine computes the Cholesky decomposition if you do not explicitly specify it.

See Also

`chol`, `ecmnmle`

ecmnstd

Purpose

Standard errors for mean and covariance of incomplete data

Syntax

```
[StdMean, StdCovariance] = ecmnstd(Data, Mean, Covariance, Method)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. Missing values are indicated by `NaN`s.
`Mean`	`NUMSERIES`-by-`1` column vector of maximum-likelihood parameter estimates for the mean of `Data` using the expectation conditional maximization (ECM) algorithm
`Covariance`	`NUMSERIES`-by-`NUMSERIES` matrix of maximum-likelihood covariance estimates for the covariance of `Data` using the ECM algorithm
`Method`	(Optional) String indicating method of estimation for standard error calculations. The methods are: • `hessian` — (Default) Hessian of the observed negative log-likelihood function. • `fisher` — Fisher information matrix.

Description

`[StdMean, StdCovariance] = ecmnstd(Data, Mean, Covariance, Method)` computes standard errors for mean and covariance of incomplete data.

`StdMean` is a `NUMSERIES`-by-`1` column vector of standard errors of estimates for each element of the mean vector `Mean`.

`StdCovariance` is a `NUMSERIES`-by-`NUMSERIES` matrix of standard errors of estimates for each element of the covariance matrix `Covariance`.

Use this routine after estimating the mean and covariance of `Data` with `ecmnmle`. If the mean and distinct covariance elements are treated as the parameter θ in a complete-data maximum-likelihood estimation, then as the number of samples increases, θ attains asymptotic normality such that

$$\theta - E[\theta] \sim N(0, I^{-1}(\theta))$$

where $E[\theta]$ is the mean and $I(\theta)$ is the Fisher information matrix.

With missing data, the Hessian $H(\theta)$ is a good approximation for the Fisher information (which can only be approximated when data is missing).

It is usually advisable to use the default `Method` since the resultant standard errors incorporate the increased uncertainty due to missing data. In particular, standard errors calculated with the Hessian are generally larger than standard errors calculated with the Fisher information matrix.

Note This routine is very slow for `NUMSERIES > 10` or `NUMSAMPLES > 1000`.

See Also

`ecmnmle`

effrr

Purpose

Effective rate of return

Syntax

```
Return = effrr(Rate, NumPeriods)
```

Arguments

`Rate`	Annual percentage rate. Enter as a decimal fraction.
`NumPeriods`	Number of compounding periods per year, an integer.

Description

`Return = effrr(Rate, NumPeriods)` calculates the annual effective rate of return. Compounding continuously returns `Return` equivalent to `(e^Rate-1)`.

Examples

Find the effective annual rate of return based on an annual percentage rate of 9% compounded monthly.

```
Return = effrr(0.09, 12)
```

returns

```
Return =

          0.0938 or 9.38%
```

See Also

`nomrr`

Purpose

Compute expected lower partial moments for normal asset returns

Syntax

```
elpm(Mean, Sigma)
elpm(Mean, Sigma, MAR)
elpm(Mean, Sigma, MAR, Order)
Moment = elpm(Mean, Sigma, MAR, Order)
```

Arguments

`Mean`	`NUMSERIES` vector with mean returns for a collection of `NUMSERIES` assets.
`Sigma`	`NUMSERIES` vector with standard deviation of returns for a collection of `NUMSERIES` assets.
`MAR`	(Optional) Scalar minimum acceptable return (default `MAR` = 0). This is a cutoff level of return such that all returns above `MAR` contribute nothing to the lower partial moment.
`Order`	(Optional) Either a scalar or a `NUMORDERS` vector of nonnegative integer moment orders. If no order specified, default `Order` = 0, which is the shortfall probability. This function will not work for negative or noninteger orders.

Description

Given `NUMSERIES` asset returns with a vector of mean returns in a `NUMSERIES` vector `Mean`, a vector of standard deviations of returns in a `NUMSERIES` vector `Sigma`, a scalar minimum acceptable return `MAR`, and one or more nonnegative integer moment orders in a `NUMORDERS` vector `Order`, compute expected lower partial moments (`elpm`) relative to `MAR` for each asset in a `NUMORDERS`-by-`NUMSERIES`matrix `Moment`.

The output, `Moment`, is a `NUMORDERS`-by-`NUMSERIES` matrix of expected lower partial moments with `NUMORDERS` `Order`s and `NUMSERIES` series,

that is, each row contains expected lower partial moments for a given order.

Note To compute upper partial moments, just reverse the signs of both the input `Mean` and `MAR` (do not reverse the signs of either `Sigma` or the output). This function computes expected lower partial moments with the mean and standard deviation of normally distributed asset returns. To compute sample lower partial moments from asset returns which have no distributional assumptions, use `lpm`.

Example

See "Expected Lower Partial Moments Example" on page 4-14.

See Also

`lpm`

Purpose

Compute expected maximum drawdown for Brownian motion

Syntax

```
EDD = emaxdrawdown(Mu, Sigma, T)
```

Arguments

`Mu`	Scalar. Drift term of a Brownian motion with drift.
`Sigma`	Scalar. Diffusion term of a Brownian motion with drift.
`T`	A time period of interest or a vector of times.

Description

`EDD = emaxdrawdown(Mu, Sigma, T)` computes the expected maximum drawdown for a Brownian motion for each time period in `T` using the following equation:

$$dX(t) = \mu dt + \sigma dW(t)$$

If the Brownian motion is geometric with the stochastic differential equation

$$dS(t) = \mu_0 S(t) dt + \sigma_0 S(t) dW(t)$$

then use Ito's lemma with $X(t) = \log(S(t))$ such that

$$\mu = \mu_0 - 0.5\sigma_0^{\ 2}$$

$$\sigma = \sigma_0$$

converts it to the form used here.

The output argument `ExpDrawdown` is computed using an interpolation method. Values are accurate to a fraction of a basis point. Maximum drawdown is nonnegative since it is the change from a peak to a trough.

Note To compare the actual results from `maxdrawdown` with the expected results of `emaxdrawdown`, set the `Format` input argument of `maxdrawdown` to either of the nondefault values (`'arithmetic'` or `'geometric'`). These are the only two formats `emaxdrawdown` supports.

Example

See "Expected Maximum Drawdown Example" on page 4-18.

References

Malik Magdon-Ismail, Amir F. Atiya, Amrit Pratap, and Yaser S. Abu-Mostafa, "On the Maximum Drawdown of a Brownian Motion," *Journal of Applied Probability*, Volume 41, Number 1, March 2004, pp. 147-161.

See Also

`maxdrawdown`

Purpose

Last date entry

Syntax

```
end
```

Description

`end` returns the index to the last date entry in a financial time series object.

Examples

Consider a financial time series object called `fts`:

```
fts =

     desc:  DJI30MAR94.dat
     freq:  Daily (1)

     'dates:  (20)'    'Open:  (20)'
     '04-Mar-1994'     [        3830.9]
     '07-Mar-1994'     [        3851.7]
     '08-Mar-1994'     [        3858.5]
     '09-Mar-1994'     [          3854]
     '10-Mar-1994'     [        3852.6]
     '11-Mar-1994'     [        3832.6]
     '14-Mar-1994'     [        3870.3]
     '16-Mar-1994'     [          3851]
     '17-Mar-1994'     [        3853.6]
     '18-Mar-1994'     [        3865.4]
     '21-Mar-1994'     [        3878.4]
     '22-Mar-1994'     [        3865.7]
     '23-Mar-1994'     [        3868.9]
     '24-Mar-1994'     [        3849.9]
     '25-Mar-1994'     [        3827.1]
     '28-Mar-1994'     [        3776.5]
     '29-Mar-1994'     [        3757.2]
     '30-Mar-1994'     [        3688.4]
     '31-Mar-1994'     [        3639.7]
```

The command `fts(15:end)` returns

```
ans =

   desc:  DJI30MAR94.dat
   freq:  Daily (1)

   'dates:  (6)'     'Open:  (6)'
   '24-Mar-1994'     [        3849.9]
   '25-Mar-1994'     [        3827.1]
   '28-Mar-1994'     [        3776.5]
   '29-Mar-1994'     [        3757.2]
   '30-Mar-1994'     [        3688.4]
   '31-Mar-1994'     [        3639.7]
```

See Also

subsasgn, subsref

end in the MATLAB documentation

Purpose

Last date of month

Syntax

```
DayMonth = eomdate(Date)
DayMonth = eomdate(Year, Month)
```

Description

`DayMonth = eomdate(Date)` returns the serial date number of the last date of the month for the given `Date`. Enter `Date` as a four-digit integer or a date string.

`DayMonth = eomdate(Year, Month)` returns the serial date number of the last date of the month for the given year and month. Enter `Year` as a four-digit integer; enter `Month` as an integer from 1 through 12.

Either input argument can contain multiple values, but if so, the other input must contain the same number of values or a single value that applies to all. For example, if `Year` is a `1`-by-*n* vector of integers, then `Month` must be a `1`-by-*n* vector of integers or a single integer. `DayMonth` is then a `1`-by-*n* vector of date numbers.

Use the function `datestr` to convert serial date numbers to formatted date strings or `datenum` to convert date and time to serial date number.

Examples

```
DayMonth = eomdate(2001, 2)
DayMonth =
      730910
datestr(DayMonth)

ans =
28-Feb-2001

Year = [2002 2003 2004 2005];
DayMonth = eomdate(Year, 2)
DayMonth =
      731275      731640      732006      732371

datestr(DayMonth)
```

```
ans =
28-Feb-2002
28-Feb-2003
29-Feb-2004
28-Feb-2005
```

See Also

day, eomday, lbusdate, month, year

Purpose

Last day of month

Syntax

```
E = eomday(Y, M)
```

Description

`E = eomday(Y, M)` returns the last day of the year and month given by corresponding elements of arrays `Y` and `M`.

Examples

Because 1996 is a leap year, the statement `eomday(1996,2)` returns `29`.

To show all the leap years in this century, try:

```
y = 1900:1999;
E = eomday(y, 2);
y(find(E == 29))

ans =
  Columns 1 through 6
     1904     1908     1912     1916     1920     1924

  Columns 7 through 12
     1928     1932     1936     1940     1944     1948

  Columns 13 through 18
     1952     1956     1960     1964     1968     1972

  Columns 19 through 24
     1976     1980     1984     1988     1992     1996
```

See Also

`day`, `eomdate`, `month`

eq (fts)

Purpose

Multiple financial times series object equality

Syntax

```
tsobj_1 == tsobj_2
iseq = eq(tsobj_1, tsobj_2)
```

Arguments

`tsobj_1`	Financial time series object.
`tsobj_2`	Financial time series object.

Description

`tsobj_1 == tsobj_2` returns True (`1`) if both financial time series objects have the same dates, frequencies, data series names, and data values. Otherwise, `eq` returns False (`0`).

Note The data series names are case-sensitive, but do not have to be in the same order within each object.

Examples

Compare :

```
load disney
dis == dis
ans =
     1
```

See Also

`isequal`

Purpose

Expected return and covariance from return time series

Syntax

```
[ExpReturn, ExpCovariance, NumEffObs] = ewstats(RetSeries,
DecayFactor, WindowLength)
```

Arguments

`RetSeries`	Return Series: number of observations (`NUMOBS`) by number of assets (`NASSETS`) matrix of equally spaced incremental return observations. The first row is the oldest observation, and the last row is the most recent.
`DecayFactor`	(Optional) Controls how much less each observation is weighted than its successor. The *k*th observation back in time has weight `DecayFactor^k`. `DecayFactor` must lie in the range: `0 < DecayFactor <= 1`. Default = `1`, the equally weighted linear moving average model (BIS).
`WindowLength`	(Optional) Number of recent observations in the computation. Default = `NUMOBS`.

Description

`[ExpReturn, ExpCovariance, NumEffObs] = ewstats(RetSeries, DecayFactor, WindowLength)` computes estimated expected returns, estimated covariance matrix, and the number of effective observations.

`ExpReturn` is a `1`-by-`NASSETS` vector of estimated expected returns.

`ExpCovariance` is an `NASSETS`-by-`NASSETS` estimated covariance matrix. The standard deviations of the asset return processes are given by

```
STDVec = sqrt(diag(ExpCovariance))
```

The correlation matrix is

```
CorrMat = ExpCovariance./( STDVec*STDVec' )
```

`NumEffObs` is the number of effective observations = `(1-DecayFactor^WindowLength)/(1-DecayFactor)`.

A smaller `DecayFactor` or `WindowLength` emphasizes recent data more strongly but uses less of the available data set.

Examples

```
RetSeries = [ 0.24 0.08
              0.15 0.13
              0.27 0.06
              0.14 0.13 ];

DecayFactor = 0.98;

[ExpReturn, ExpCovariance] = ewstats(RetSeries, DecayFactor)

ExpReturn =

    0.1995    0.1002

ExpCovariance =

    0.0032   -0.0017
   -0.0017    0.0010
```

See Also

`cov`, `mean`

Purpose

Exponential values

Syntax

```
newfts = exp(tsobj)
```

Description

`newfts = exp(tsobj)` calculates the natural exponential (base e) of all the data in the data series of the financial time series object `tsobj` and returns the result in the object `newfts`.

See Also

`log`, `log2`, `log10`

extfield

Purpose

Data series extraction

Syntax

```
ftse = extfield(tsobj, fieldnames)
```

Arguments

`tsobj`	Financial time series object
`fieldnames`	Data series to be extracted. A cell array if a list of data series names (`fieldnames`) is supplied. A string if only one is wanted.

Description

`ftse = extfield(tsobj, fieldnames)` extracts from `tsobj` the dates and data series specified by `fieldnames` into a new financial time series object `ftse`. `ftse` has all the dates in `tsobj` but contains a smaller number of data series.

Examples

`extfield` is identical to referencing a field in the object. For example,

```
ftse = extfield(fts, 'Close')
```

is the same as

```
ftse = fts.Close
```

This function is the complement of the function `rmfield`.

See Also

`rmfield`

Purpose

First business date of month

Syntax

```
Date = fbusdate(Year, Month, Holiday, Weekend)
```

Arguments

`Year`	Enter as four-digit integer.
`Month`	Enter as integer from 1 to 12.
`Holiday`	(Optional) Vector of holidays and nontrading-day dates. All dates in `Holiday` must be the same format: either serial date numbers or date strings. (Using date numbers improves performance.) The `holidays` function supplies the default vector.
`Weekend`	(Optional) Vector of length 7, containing 0 and 1, the value 1 indicating weekend days. The first element of this vector corresponds to Sunday. Thus, when Saturday and Sunday form the weekend (default), then `Weekend = [1 0 0 0 0 0 1]`.

Description

`Date = fbusdate(Year, Month, Holiday, Weekend)` returns the serial date number for the first business date of the given year and month. `Holiday` specifies nontrading days.

`Year` and `Month` can contain multiple values. If one contains multiple values, the other must contain the same number of values or a single value that applies to all. For example, if `Year` is a `1`-by-`n` vector of integers, then `Month` must be a `1`-by-`n` vector of integers or a single integer. `Date` is then a `1`-by-`n` vector of date numbers.

Use the function `datestr` to convert serial date numbers to formatted date strings.

Examples

Example 1:

```
Date = fbusdate(2001, 11); datestr(Date)
ans =
01-Nov-2001

Year = [2002 2003 2004];
Date = fbusdate(Year, 11); datestr(Date)

ans =
01-Nov-2002
03-Nov-2003
01-Nov-2004
```

Example 2: You can indicate that Saturday is a business day by appropriately setting the `Weekend` argument.

```
Weekend = [1 0 0 0 0 0 0];
```

March 1, 2003, is a Saturday. Use `fbusdate` to check that this Saturday is actually the first business day of the month.

```
Date = datestr(fbusdate(2003, 3, [], Weekend))

Date =

01-Mar-2003
```

See Also

`busdate`, `eomdate`, `holidays`, `isbusday`, `lbusdate`

Purpose

Data from financial time series object

Syntax

```
newfts = fetch(oldfts, StartDate, StartTime, EndDate, EndTime,
delta, dmy_specifier, time_ref)
```

Arguments

`oldfts`	Existing financial time series object.
`StartDate`	First date in the range from which data is to be extracted.
`StartTime`	Beginning time on each day. If you do not require specific times or `oldfts` does not contain time information, use `[]`. If you specify `StartTime`, you must also specify `EndTime`.
`EndDate`	Last date in the range from which data is to be extracted.
`EndTime`	Ending time on each day. If you do not require specific times or `oldfts` does not contain time information, use `[]`. If you specify `EndTime`, you must also specify `StartTime`.
`delta`	Skip interval. Can be any positive integer. Units for the skip interval specified by `dmy_specifier`.
`dmy_specifier`	Specifies the units for `delta`. Can be • `D, d` (Days) • `M, m` (Months) • `Y, y` (Years)
`time_ref`	Time reference intervals or specific times. Valid time reference intervals are 1, 5, 15, or 60 minutes. Enter specific times as `'hh:mm'`.

Description

`newfts = fetch(oldfts, StartDate, StartTime, EndDate, EndTime, delta, dmy_specifier, time_ref)` requests data from a financial time series object beginning from the start date and/or start time to the end date and/or end time, skipping a specified number of days, months, or years.

Note If time information is present in `oldfts`, using `[]` for start or end times results in `fetch` returning all instances of a specific date.

Examples

Example 1. Create a financial time series object containing both dates and times:

```
dates = ['01-Jan-2001';'01-Jan-2001'; '02-Jan-2001'; ...
 '02-Jan-2001'; '03-Jan-2001';'03-Jan-2001'];
times = ['11:00';'12:00';'11:00';'12:00';'11:00';'12:00'];
dates_times = cellstr([dates, repmat(' ',size(dates,1),1),...
times]);
myFts = fints(dates_times,(1:6)',{'Data1'},1,'My first FINTS')

myFts =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [          4]
    '03-Jan-2001'    '11:00'          [          5]
    '     "     '    '12:00'          [          6]
```

To fetch all dates and times from this financial time series, enter

```
fetch(myFts,'01-Jan-2001',[],'03-Jan-2001',[],1,'d')
```

or

```
fetch(myFts,'01-Jan-2001','11:00','03-Jan-2001','12:00',1,'d')
```

These commands reproduce the entire time series shown above.

To fetch every other day's data, enter

```
fetch(myFts,'01-Jan-2001',[],'03-Jan-2001',[],2,'d')
```

This produces

```
ans =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (4)'    'times:  (4)'    'Data1:  (4)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
    '03-Jan-2001'    '11:00'          [          5]
    '     "     '    '12:00'          [          6]
```

Example 2. Create a financial time series object with time intervals of less than 1 hour:

```
dates2 = ['01-Jan-2001';'01-Jan-2001'; '01-Jan-2001';...
'02-Jan-2001'; '02-Jan-2001';'02-Jan-2001'];
times2 = ['11:00';'11:05';'11:06';'12:00';'12:05';'12:06'];
dates_times2 = cellstr([dates2, repmat(' ',size(dates2,1),1),...
times2]);
myFts2 = fints(dates_times2,(1:6)',{'Data1'},1,'My second
FINTS')

myFts2 =
```

```
desc:  My second FINTS
freq:  Daily (1)

'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
'01-Jan-2001'    '11:00'          [          1]
'     "     '    '11:05'          [          2]
'     "     '    '11:06'          [          3]
'02-Jan-2001'    '12:00'          [          4]
'     "     '    '12:05'          [          5]
'     "     '    '12:06'          [          6]
```

Use `fetch` to extract data from this time series object at 5-minute intervals for each day starting at 11:00 o'clock on January 1, 2001.

```
fetch(myFts2,'01-Jan-2001',[],'02-Jan-2001',[],1,'d',5)

    desc:  My second FINTS
    freq:  Daily (1)

    'dates:  (4)'    'times:  (4)'    'Data1:  (4)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '11:05'          [          2]
    '02-Jan-2001'    '12:00'          [          4]
    '     "     '    '12:05'          [          5]
```

You can use this version of `fetch` to extract data at specific times. For example, to fetch data only at 11:06 and 12:06 from `myFts2`, enter

```
fetch(myFts2,'01-Jan-2001',[],'02-Jan-2001',[],1,'d',...
{'11:06';'12:06'})

ans =

    desc:  My second FINTS
    freq:  Daily (1)

    'dates:  (2)'    'times:  (2)'    'Data1:  (2)'
```

```
    '01-Jan-2001'    '11:06'          [           3]
    '02-Jan-2001'    '12:06'          [           6]
```

See Also

extfield, ftsbound, getfield, subsref

fieldnames

Purpose

Get names of fields

Syntax

```
fnames = fieldnames(tsobj)
fnames = fieldnames(tsobj, srsnameonly)
```

Arguments

`tsobj`	Financial time series object
`srsnameonly`	Field names returned:
	0 = All field names (default).
	1 = Data series names only.

Description

`fieldnames` gets field names in a financial time series object.

`fnames = fieldnames(tsobj)` returns the field names associated with the financial time series object `tsobj` as a cell array of strings, including the common fields: `desc`, `freq`, `dates` (and `times` if present).

`fnames = fieldnames(tsobj, srsnameonly)` returns field names depending upon the setting of `srsnameonly`. If `srsnameonly` is 0, the function returns all field names, including the common fields: `desc`, `freq`, `dates`, and `times`. If `srsnameonly` is set to 1, `fieldnames` returns only the data series in `fnames`.

See Also

`chfield`, `getfield`, `isfield`, `rmfield`, `setfield`

Purpose

Fill missing values in time series

Syntax

```
newfts = fillts(oldfts, fill_method)
newfts = fillts(oldfts, fill_method, newdates)
newfts = fillts(oldfts, fill_method, newdates, {'T1','T2',...})
newfts = fillts(oldfts, fill_method, newdates, 'SPAN', {'TS','TE'},
delta)
newfts = fillts(... sortmode)
```

Arguments

`oldfts`	Financial time series object.
`fill_method`	(Optional) Replaces missing values (`NaN`) in `oldfts` using an interpolation process, a constant, or a zero-order hold. Valid fill methods (interpolation methods) are: • linear - `'linear '` - `'l'` (default) • linear with extrapolation - `'linearExtrap'` - `'le'` • `cubic` - `'cubic'` - `'c'` • cubic with extrapolation - `'cubicExtrap'` - `'ce'` • `spline` - `'spline'` - `'s'` • spline with extrapolation - `'splineExtrap'` -`'se'` • `nearest` - `'nearest'` - `'n'` • nearest with extrapolation - `'nearestExtrap'` -`'ne'` • `pchip` - `'pchip'` - `'p'`

	• `pchip` with extrapolation - `'pchipExtrap'` -`'pe'` (See `interp1` for a discussion of extrapolation.) To fill with a constant, enter that constant. A zero-order hold (`'zero'`) fills a missing value with the value immediately preceding it. If the first value in the time series is missing, it remains a `NaN`.
`newdates`	(Optional) Column vector of serial dates, a date string, or a column cell array of date strings. If `oldfts` contains time of day information, `newdates` must be accompanied by a time vector (`newtimes`). Otherwise, `newdates` is assumed to have times of `'00:00'`.
`T1, T2, TS, TE`	First time, second time, start time, end time
`delta`	Time interval in minutes to span between the start time and end time
`sortmode`	(Optional) Default = 0 (unsorted). 1 = sorted.

Description

`newfts = fillts(oldfts, fill_method)` replaces missing values (represented by `NaN`) in the financial time series object `oldfts` with real values, using either a constant or the interpolation process indicated by *`fill_method`*.

`newfts = fillts(oldfts, fill_method, newdates)` replaces all the missing values on the specified dates `newdates` added to the financial time series `oldfts` with new values. The values can be a single constant or values obtained through the interpolation process designated by `fill_method`. If any of the dates in `newdates` exists in `oldfts`, the existing one has precedence.

`newfts = fillts(oldfts, fill_method, newdates, {'T1','T2',...})` additionally allows the designation of specific times of day for addition or replacement of data.

`newfts = fillts(oldfts, fill_method, newdates, 'SPAN', {'TS','TE'}, delta)` is similar to the previous format except that you designate only a start time and an end time. You follow these times with a spanning time interval, `delta`.

If you specify only one date for `newdates`, specifying a start and end time generates only times for that specific date.

`newfts = fillts(... sortmode)` additionally denotes whether you want the order of the dates in the output object to stay the same as in the input object or to be sorted chronologically.

`sortmode = 0` (unsorted) appends any new dates to the end. The interpolation and zero-order processes that calculate the values for the new dates work on a sorted object. Upon completion, the existing dates are reordered as they were originally, and the new dates are appended to the end.

`sortmode = 1` sorts the output. After interpolation, no reordering of the date sequence occurs.

Examples

Example 1. Create a financial time series object with missing data in the fourth and fifth rows.

```
dates = ['01-Jan-2001';'01-Jan-2001'; '02-Jan-2001';...
         '02-Jan-2001'; '03-Jan-2001';'03-Jan-2001'];
times = ['11:00';'12:00';'11:00';'12:00';'11:00';'12:00'];
dates_times = cellstr([dates, repmat(' ',size(dates,1),1),...
                       times]);
OpenFts = fints(dates_times,[(1:3)'; nan; nan; 6],{'Data1'},1,...
'Open Financial Time Series');
```

`OpenFts` looks like this:

```
OpenFts =
```

```
    desc:  Open Financial Time Series
    freq:  Daily (1)

    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [        NaN]
    '03-Jan-2001'    '11:00'          [        NaN]
    '     "     '    '12:00'          [          6]
```

Example 2. Fill the missing data in `OpenFts` using cubic interpolation.

```
FilledFts = fillts(OpenFts,'cubic')

FilledFts =

       desc:  Filled Open Financial Time Series
       freq:  Unknown (0)

       'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
       '01-Jan-2001'    '11:00'          [          1]
       '     "     '    '12:00'          [          2]
       '02-Jan-2001'    '11:00'          [          3]
       '     "     '    '12:00'          [     3.0663]
       '03-Jan-2001'    '11:00'          [     5.8411]
       '     "     '    '12:00'          [     6.0000]
```

Example 3. Fill the missing data in `OpenFts` with a constant value.

```
FilledFts = fillts(OpenFts,0.3)

FilledFts =

    desc:  Filled Open Financial Time Series
    freq:  Unknown (0)
```

```
    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [     0.3000]
    '03-Jan-2001'    '11:00'          [     0.3000]
    '     "     '    '12:00'          [          6]
```

Example 4. You can use `fillts` to identify a specific time on a specific day for the replacement of missing data. This example shows how to replace missing data at 12:00 on January 2 and 11:00 on January 3.

```
FilltimeFts = fillts(OpenFts,'c',...
{'02-Jan-2001';'03-Jan-2001'}, {'12:00';'11:00'},0)

FilltimeFts =

       desc:  Filled Open Financial Time Series
       freq:  Unknown (0)

       'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
       '01-Jan-2001'    '11:00'          [          1]
       '     "     '    '12:00'          [          2]
       '02-Jan-2001'    '11:00'          [          3]
       '     "     '    '12:00'          [     3.0663]
       '03-Jan-2001'    '11:00'          [     5.8411]
       '     "     '    '12:00'          [     6.0000]
```

Example 5. Use a spanning time interval to add an additional day to `OpenFts`.

```
SpanFts = fillts(OpenFts,'c','04-Jan-2001','span',...
               {'11:00';'12:00'},60,0)

SpanFts =

       desc:  Filled Open Financial Time Series
```

```
freq:  Unknown (0)

'dates:  (8)'    'times:  (8)'    'Data1:  (8)'
'01-Jan-2001'    '11:00'          [          1]
'     "     '    '12:00'          [          2]
'02-Jan-2001'    '11:00'          [          3]
'     "     '    '12:00'          [     3.0663]
'03-Jan-2001'    '11:00'          [     5.8411]
'     "     '    '12:00'          [     6.0000]
'04-Jan-2001'    '11:00'          [     9.8404]
'     "     '    '12:00'          [     9.9994]
```

See Also

`interp1` in the MATLAB documentation

Purpose

Linear filtering

Syntax

```
newfts = filter(B, A, oldfts)
```

Description

`filter` filters an entire financial time series object with certain filter specifications. The filter is specified in a transfer function expression.

`newfts = filter(B, A, oldfts)` filters the data in the financial time series object `oldfts` with the filter described by vectors `A` and `B` to create the new financial time series object `newfts`. The filter is a "Direct Form II Transposed" implementation of the standard difference equation. `newfts` is a financial time series object containing the same data series (names) as the input `oldfts`.

See Also

`filter`, `filter2` in the MATLAB documentation

fints

Purpose

Construct financial time series object

Syntax

```
tsobj = fints(dates_and_data)
tsobj = fints(dates, data)
tsobj = fints(dates, data, datanames)
tsobj = fints(dates, data, datanames, freq)
tsobj = fints(dates, data, datanames, freq, desc)
```

Arguments

`dates_and_data`

Column-oriented matrix containing one column of dates and a single column for each series of data. In this format, dates must be entered in serial date number format. If the input serial date numbers encode time-of-day information, the output object contains a column labeled `'dates'` containing the date information and another labeled `'times'` containing the time information.

You can use the function `today` to enter date information or the function `now` to enter date with time information.

`dates`

Column vector of dates. Dates can be date strings or serial date numbers and can include time of day information. When entering time-of-day information as serial date numbers, the entry must be a column-oriented matrix when multiple entries are present. If the time-of-day information is in string format, the entry must be a column-oriented cell array of dates and times when multiple entries are present.

Valid date and time string formats are:

- `'ddmmmyy hh:mm'` or `'ddmmmyyyy hh:mm'`
- `'mm/dd/yy hh:mm'` or `'mm/dd/yyyy hh:mm'`
- `'dd-mmm-yy hh:mm'` or `'dd-mmm-yyyy hh:mm'`
- `'mmm.dd,yy hh:mm'` or `'mmm.dd,yyyy hh:mm'`

Dates and times can initially be separate column-oriented vectors, but they must be concatenated into a single column-oriented matrix before being passed to `fints`. You can use the MATLAB functions `today` and `now` to assist in entering date and time information.

`data`

Column-oriented matrix containing a column for each series of data. The number of values in each data series must match the number of dates. If a mismatch occurs, MATLAB does not generate the financial time series object, and you receive an error message.

`datanames`

Cell array of data series names. Overrides the default data series names. Default data series names are `series1`, `series2`, ...

`freq`	Frequency indicator. Allowed values are:
	`UNKNOWN`, `Unknown`, `unknown`, `U`, `u`,`0`
	`DAILY`, `Daily`, `daily`, `D`, `d`,`1`
	`WEEKLY`, `Weekly`, `weekly`, `W`, `w`,`2`
	`MONTHLY`, `Monthly`, `monthly`, `M`, `m`, `3`
	`QUARTERLY`, `Quarterly`, `quarterly`, `Q`, `q`,`4`
	`SEMIANNUAL`, `Semiannual`, `semiannual`, `S`, `s`,`5`
	`ANNUAL`, `Annual`, `annual`, `A`, `a`, `6`
	Default = `Unknown`.

`desc`	String providing descriptive name for financial time series object. Default = `''`.

Note The toolbox supports only hourly and minute time series. Seconds are disregarded when the object is created (for example, 01-jan-2001 12:00:01 is considered to be 01-jan-2001 12:00). If there are duplicate dates and times, `fints` sorts the dates and times and chooses the first instance of the duplicate dates and times. The other duplicate dates and times are removed from the object along with their corresponding data.

Description

`fints` constructs a financial time series object. A financial time series object is a MATLAB object that contains a series of dates and one or more series of data. Before you perform an operation on the data, you must set the frequency indicator (`freq`). You can optionally provide a description (`desc`) for the time series.

`tsobj = fints(dates_and_data)` creates a financial time series object containing the dates and data from the matrix `dates_and_data`. If the dates contain time-of-day information, the object contains an additional series of times. The date series and each data series must

each be a column in the input matrix. The names of the data series default to `series1, ..., seriesn`. The `desc` and `freq` fields are set to their defaults.

`tsobj = fints(dates, data)` generates a financial time series object containing dates from the `dates` column vector of dates and data from the matrix `data`. If the dates contain time-of-day information, the object contains an additional series of times. The data matrix must be column-oriented, that is, each column in the matrix is a data series. The names of the series default to `series1, ..., seriesn`, where `n` is the total number of columns in `data`. The `desc` and `freq` fields are set to their defaults.

`tsobj = fints(dates, data, datanames)` additionally allows you to rename the data series. The names are specified in the `datanames` cell array. The number of strings in `datanames` must correspond to the number of columns in `data`. The `desc` and `freq` fields are set to their defaults.

`tsobj = fints(dates, data, datanames, freq)` additionally sets the frequency when you create the object. The `desc` field is set to its default `''`.

`tsobj = fints(dates, data, datanames, freq, desc)` provides a description string for the financial time series object.

Examples

Example 1. Create a financial time series containing days and data only.

```
data = [1:6]'

data =

     1
     2
     3
     4
     5
     6
```

```
dates = [today:today+5]'

dates =

      731132
      731133
      731134
      731135
      731136
      731137

tsobjkt = fints(dates, data)

tsobjkt =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (6)'    'series1:  (6)'
    '08-Oct-2001'    [            1]
    '09-Oct-2001'    [            2]
    '10-Oct-2001'    [            3]
    '11-Oct-2001'    [            4]
    '12-Oct-2001'    [            5]
    '13-Oct-2001'    [            6]
```

Example 2. Expand Example 1 to include time-of-day information:

```
dates = [now:now+5]';

tsobjkt = fints(dates, data)

tsobjkt =

    desc:  (none)
    freq:  Unknown (0)
```

```
    'dates:  (6)'    'times:  (6)'    'series1:  (6)'
    '08-Oct-2001'    '14:51'          [            1]
    '09-Oct-2001'    '14:51'          [            2]
    '10-Oct-2001'    '14:51'          [            3]
    '11-Oct-2001'    '14:51'          [            4]
    '12-Oct-2001'    '14:51'          [            5]
    '13-Oct-2001'    '14:51'          [            6]
```

Example 3. Create a financial time series object when dates and times are located in separate vectors.

Step 1. Create a column vector of times in date number format:

```
times = datenum(datestr(now:1/24+1/24/60:now+6/24+1/24/60,15))

times =

   0.43750000000000
   0.47986111111111
   0.52222222222222
   0.56458333333333
   0.60694444444444
   0.64930555555556
```

Step 2. Create a column vector of dates:

```
dates = [today:today+5]'

dates =

      731133
      731134
      731135
      731136
      731137
      731138
```

Step 3. Concatenate dates and times into a single matrix:

```
dates_times = [dates, times]

dates_times =

  1.0e+005 *

   7.31133000000000   0.00000437500000
   7.31134000000000   0.00000479861111
   7.31135000000000   0.00000522222222
   7.31136000000000   0.00000564583333
   7.31137000000000   0.00000606944444
   7.31138000000000   0.00000649305556
```

Step 4. Create column vector of data:

```
data = [1:6]'
```

Step 5. Create the financial time series object:

```
tsobj = fints(dates_times, data)

tsobj =

    desc:  (none)
    freq:  Unknown (0)

    'dates:  (6)'    'times:  (6)'    'series1:  (6)'
    '09-Oct-2001'    '10:30'          [            1]
    '10-Oct-2001'    '11:31'          [            2]
    '11-Oct-2001'    '12:32'          [            3]
    '12-Oct-2001'    '13:33'          [            4]
    '13-Oct-2001'    '14:34'          [            5]
    '14-Oct-2001'    '15:35'          [            6]
```

See Also

datenum, datestr

Purpose

Fast stochastics

Syntax

```
[pctk, pctd] = fpctkd(highp, lowp, closep)
[pctk, pctd] = fpctkd([highp lowp closep])
[pctk, pctd] = fpctkd(highp, lowp, closep, kperiods, dperiods,
dmamethod)
[pctk, pctd] = fpctkd([highp lowp closep], kperiods, dperiods,
dmamethod)
pkdts = fpctkd(tsobj, kperiods, dperiods, dmamethod)
pkdts = fpctkd(tsobj, kperiods, dperiods, dmamethod, ParameterName,
ParameterValue, ...)
```

Arguments

`highp`	High price (vector).
`lowp`	Low price (vector).
`closep`	Closing price (vector).
`kperiods`	(Optional) %K periods. Default = 10.
`dperiods`	(Optional) %D periods. Default = 3.
`damethod`	(Optional) %D moving average method. Default = `'e'` (exponential).
`tsobj`	Financial time series object.
`ParameterName`	Valid parameter names are: • `HighName`: high prices series name • `LowName`: low prices series name • `CloseName`: closing prices series name
`ParameterValue`	Parameter values are the strings that represent the valid parameter names.

Description

`fpctkd` calculates the stochastic oscillator.

`[pctk, pctd] = fpctkd(highp, lowp, closep)` calculates the fast stochastics F%K and F%D from the stock price data `highp` (high prices), `lowp` (low prices), and `closep` (closing prices).

`[pctk, pctd] = fpctkd([highp lowp closep])` accepts a three-column matrix of high (`highp`), low (`lowp`), and closing prices (`closep`), in that order.

`[pctk, pctd] = fpctkd(highp, lowp, closep, kperiods, dperiods, dmamethod)` calculates the fast stochastics F%K and F%D from the stock price data `highp` (high prices), `lowp` (low prices), and `closep` (closing prices). `kperiods` sets the %K period. `dperiods` sets the %D period.

`damethod` specifies the %D moving average method. Valid moving average methods for %D are Exponential (`'e'`) and Triangular (`'t'`). See `tsmovavg` for explanations of these methods.

`[pctk, pctd]= fpctkd([highp lowp closep], kperiods, dperiods, dmamethod)` accepts a three-column matrix of high (`highp`), low (`lowp`), and closing prices (`closep`), in that order.

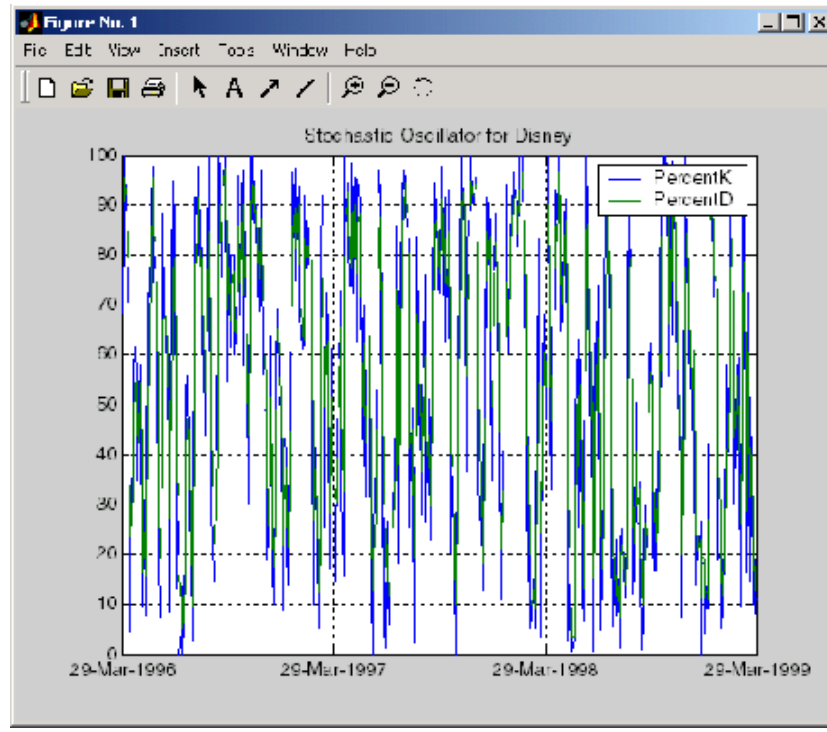
`pkdts = fpctkd(tsobj, kperiods, dperiods, dmamethod)` calculates the fast stochastics F%K and F%D from the stock price data in the financial time series object `tsobj`. `tsobj` must minimally contain the series `High` (high prices), `Low` (low prices), and `Close` (closing prices). `pkdts` is a financial time series object with similar dates to `tsobj` and two data series named `PercentK` and `PercentD`.

`pkdts = fpctkd(tsobj, kperiods, dperiods, dmamethod, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Parameter values are the strings that represent the valid parameter names.

Examples

Compute the stochastic oscillator for Disney stock and plot the results:

```
load disney.mat
dis_FastStoc = fpctkd(dis)
plot(dis_FastStoc)
title('Stochastic Oscillator for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second Edition, McGraw-Hill, 1995, pp. 268–271.

See Also

`spctkd`, `stochosc`, `tsmovavg`

frac2cur

Purpose

Fractional currency value to decimal value

Syntax

```
Decimal = frac2cur(Fraction, Denominator)
```

Description

`Decimal = frac2cur(Fraction, Denominator)` converts a fractional currency value to a decimal value. `Fraction` is the fractional currency value input as a string, and `Denominator` is the denominator of the fraction.

Examples

```
Decimal = frac2cur('12.1', 8)
```

returns

```
Decimal =
          12.1250
```

See Also

`cur2frac`, `cur2str`

Purpose

Convert string frequency indicator to numeric frequency indicator

Syntax

```
nfreq = freqnum(sfreq)
```

Arguments

sfreq	UNKNOWN, Unknown, unknown, U, u
	DAILY, Daily, daily, D, d
	WEEKLY, Weekly, weekly, W, w
	MONTHLY, Monthly, monthly, M, m
	QUARTERLY, Quarterly, quarterly, Q, q
	SEMIANNUAL, Semiannual, semiannual, S, s
	ANNUAL, Annual, annual, A, a

Description

`nfreq = freqnum(sfreq)` converts a string frequency indicator into a numeric value.

String Frequency Indicator	Numeric Representation
UNKNOWN, Unknown, unknown, U, u	0
DAILY, Daily, daily, D, d	1
WEEKLY, Weekly, weekly, W, w	2
MONTHLY, Monthly, monthly, M, m	3
QUARTERLY, Quarterly, quarterly, Q, q	4
SEMIANNUAL, Semiannual, semiannual, S, s	5
ANNUAL, Annual, annual, A, a	6

See Also `freqstr`

Purpose

Convert numeric frequency indicator to string representation

Syntax

```
sfreq = freqstr(nfreq)
```

Arguments

nfreq	0
	1
	2
	3
	4
	5
	6

Description

`sfreq = freqstr(nfreq)` converts a numeric frequency indicator into a string representation.

Numeric Frequency Indicator	String Representation
0	Unknown
1	Daily
2	Weekly
3	Monthly
4	Quarterly
5	Semiannual
6	Annual

See Also `freqnum`

Purpose

Mean-variance efficient frontier

Syntax

```
[PortRisk, PortReturn, PortWts] = frontcon(ExpReturn,
ExpCovariance, NumPorts, PortReturn, AssetBounds, Groups,
GroupBounds, varargin)
```

Arguments

`ExpReturn`	1 by number of assets (`NASSETS`) vector specifying the expected (mean) return of each asset.
`ExpCovariance`	`NASSETS`-by-`NASSETS` matrix specifying the covariance of asset returns.
`NumPorts`	(Optional) Number of portfolios generated along the efficient frontier. Returns are equally spaced between the maximum possible return and the minimum risk point. If `NumPorts` is empty (entered as `[]`, `frontcon` computes 10 equally spaced points. When entering a target rate of return (`PortReturn`), enter `NumPorts` as an empty matrix `[]`.
`PortReturn`	(Optional) Vector of length equal to the number of portfolios (`NPORTS`) containing the target return values on the frontier. If `PortReturn` is not entered or `[]`, `NumPorts` equally spaced returns between the minimum and maximum possible values are used.
`AssetBounds`	(Optional) `2`-by-`NASSETS` matrix containing the lower and upper bounds on the weight allocated to each asset in the portfolio. Default lower bound = all 0s (no short-selling). Default upper bound = all 1s (any asset may constitute the entire portfolio).

`Groups`	(Optional) Number of groups (`NGROUPS`)-by-`NASSETS` matrix specifying `NGROUPS` asset groups or classes. Each row specifies a group. `Groups(i,j) = 1` (*j*th asset belongs in the *i*th group). `Groups(i,j) = 0` (*j*th asset not a member of the *i*th group).
`GroupBounds`	(Optional) `NGROUPS`-by-`2` matrix specifying, for each group, the lower and upper bounds of the total weights of all assets in that group. Default lower bound = all 0s. Default upper bound = all 1s.

`varargin`	(Optional) `varargin` supports the following parameter-value pairs:
	• `'algorithm'` – Defines which algorithm to use with `frontcon`. Use either a value of `'lcprog'` or `'quadprog'` to indicate the algorithm to use. The default is `'lcprog'`.
	• `'maxiter'` – Maximum number of iterations before termination of algorithm. The default is 100000.
	• `'tiebreak'` – Method to break ties for pivot selection. This value pair applies only to `'lcprog'` algorithm. The default is `'first'`. Options are:
	  ▪ `'first'` – Selects pivot with lowest index.
	  ▪ `'last'` – Selects pivot with highest index.
	  ▪ `'random'` – Selects pivot at random.
	• `'tolcon'` – Tolerance for constraint violations. This value pair applies only to `'lcprog'` algorithm. The default is 1.0e-6.

- `'tolpiv'` – Pivot value below which a number is considered to be zero. This value pair applies only to `'lcprog'` algorithm. The default is 1.0e-9.

Description

`[PortRisk, PortReturn, PortWts] = frontcon(ExpReturn, ExpCovariance, NumPorts, PortReturn, AssetBounds, Groups, GroupBounds, varargin)` returns the mean-variance efficient frontier with user-specified asset constraints, covariance, and returns. For a collection of `NASSETS` risky assets, computes a portfolio of asset investment weights that minimize the risk for given values of the expected return. The portfolio risk is minimized subject to constraints on the asset weights or on groups of asset weights.

`PortRisk` is an `NPORTS`-by-`1` vector of the standard deviation of each portfolio.

`PortReturn` is a `NPORTS`-by-`1` vector of the expected return of each portfolio.

`PortWts` is an `NPORTS`-by-`NASSETS` matrix of weights allocated to each asset. Each row represents a portfolio. The total of all weights in a portfolio is 1.

`frontcon` generates a plot of the efficient frontier if you invoke it without output arguments.

The asset returns are assumed to be jointly normal, with expected mean returns of `ExpReturn` and return covariance `ExpCovariance`. The variance of a portfolio with `1`-by-`NASSETS` weights `PortWts` is given by `PortVar = PortWts*ExpCovariance*PortWts'`. The portfolio expected return is `PortReturn = dot(ExpReturn, PortWts)`.

Examples

Given three assets with expected returns of

```
ExpReturn = [0.1 0.2 0.15];
```

and expected covariance of

```
ExpCovariance = [ 0.0100   -0.0061    0.0042
                 -0.0061    0.0400   -0.0252
                  0.0042   -0.0252    0.0225];
```

compute the mean-variance efficient frontier for four points.

```
NumPorts = 4;
[PortRisk, PortReturn, PortWts] = frontcon(ExpReturn,...
ExpCovariance, NumPorts)

PortRisk =

    0.0426
    0.0483
    0.1089
    0.2000

PortReturn =

    0.1569
    0.1713
    0.1856
    0.2000

PortWts =

    0.2134    0.3518    0.4348
    0.0096    0.4352    0.5552
         0    0.7128    0.2872
         0    1.0000         0
```

See Also

ewstats, frontier, portopt, portstats

Purpose

Rolling efficient frontier

Syntax

```
[PortWts, AllMean, AllCovariance] = frontier(Universe, Window,
Offset, NumPorts, ActiveMap, ConSet, NumNonNan)
```

Arguments

`Universe`	Number of observations (`NUMOBS`) by number of assets plus one (`NASSETS + 1`) time series array containing total return data for a group of securities. Each row represents an observation. Column 1 contains MATLAB serial date numbers. The remaining columns contain the total return data for each security.
`Window`	Number of data periods used to calculate each frontier.
`Offset`	Increment in number of periods between each frontier.
`NumPorts`	Number of portfolios to calculate on each frontier.
`ActiveMap`	(Optional) Number of observations (`NUMOBS`) by number of assets (`NASSETS`) matrix with Boolean elements corresponding to the `Universe`. Each element indicates if the asset is part of the `Universe` on the corresponding date. Default = `NUMOBS`-by-`NASSETS` matrix of `1`'s (all assets active on all dates).

`Conset`	(Optional) Constraint matrix for a portfolio of asset investments, created using `portcons` with the `'Default'` constraint type. This single constraint matrix is applied to each frontier.
`NumNonNan`	(Optional) Minimum number of non`NaN` points for each active asset in each window of data needed to perform the optimization. The default value is `Window - NASSETS`.

Description

`[PortWts, AllMean, AllCovariance] = frontier(Universe, Window, Offset, NumPorts, ActiveMap, ConSet, NumNonNan)` generates a surface of efficient frontiers showing how asset allocation influences risk and return over time.

`PortWts` is a number of curves (`NCURVES`)-by-`1` cell array, where each element is a `NPORTS`-by-`NASSETS` matrix of weights allocated to each asset.

`AllMean` is a `NCURVES`-by-`1` cell array, where each element is a `1`-by-`NASSETS` vector of the expected asset returns used to generate each curve on the surface.

`AllCovariance` is a `NCURVES`-by-`1` cell array, where each element is a `NASSETS`-by-`NASSETS` vector of the covariance matrix used to generate each curve on the surface.

See Also

`portcons`, `portopt`

Purpose

Write elements of time-series data into ASCII file

Syntax

```
stat = fts2ascii(filename, tsobj, exttext)
stat = fts2ascii(filename, dates, data, colheads, desc, exttext)
```

Arguments

`filename`	Name of an ASCII file
`tsobj`	Financial time series object
`exttext`	(Optional) Extra text. A string written after the description line (line 2 in the file).
`dates`	Column vector containing dates. Dates must be in serial date number format and can specify time of day.
`data`	Column-oriented matrix. Each column is a series.
`colheads`	(Optional) Cell array of column headers (names); first cell must always be the one for the dates column. `colheads` will be written to the file just before the data.
`desc`	(Optional) Description string, which will be the first line in the file.

Description

`stat = fts2ascii(filename, tsobj, exttext)` writes the financial time series object `tsobj` into an ASCII file `filename`. The data in the file is tab delimited.

`stat = fts2ascii(filename, dates, data, colheads, desc, exttext)` writes into an ASCII file `filename` the dates, times, and data contained in the column vector dates and the column-oriented matrix `data`. The first column in `filename` contains the dates, followed by `times` (if specified). Subsequent columns contain the `data`. The data in the file is tab delimited.

`stat` indicates whether file creation is successful (1) or not (0).

See Also

`ascii2fts`

Purpose

Convert to matrix

Syntax

```
tsmat = fts2mat(tsobj)
tsmat = fts2mat(tsobj, datesflag)
tsmat = fts2mat(tsobj, seriesnames)
tsmat = fts2mat(tsobj, datesflag, seriesnames)
```

Arguments

`tsobj`	Financial time series object
`datesflag`	(Optional) Specifies inclusion of dates vector:
	`datesflag = 0` (default) excludes dates.
	`datesflag = 1` includes dates vector.
`seriesnames`	(Optional) Specifies the data series to be included in the matrix. Can be a cell array of strings.

Description

`tsmat = fts2mat(tsobj)` takes the data series in the financial time series object `tsobj` and puts them into the matrix `tsmat` as columns. The order of the columns is the same as the order of the data series in the object `tsobj`.

`tsmat = fts2mat(tsobj, datesflag)` specifies whether or not you want the dates vector included. The dates vector will be the first column. The dates are represented as serial date numbers. Dates can include time-of-day information.

`tsmat = fts2mat(tsobj, seriesnames)` extracts the data series named in `seriesnames` and puts its values into `tsmat`. The seriesnames argument can be a cell array of strings.

`tsmat = fts2mat(tsobj, datesflag, seriesnames)` puts into `tsmat` the specific data series named in `seriesnames`. The `datesflag` argument must be specified. If `datesflag` is set to `1`, the dates vector

is included. If you specify an empty matrix (`[]`) for `datesflag`, the default behavior is adopted.

See Also

`subsref`

Purpose

Start and end dates

Syntax

```
datesbound = ftsbound(tsobj)
datesbound = ftsbound(tsobj, dateform)
```

Arguments

`tsobj`	Financial time series object
`dateform`	`dateform` is an integer representing the format of a date string. See `datestr` for a description of these formats.

Description

`ftsbound` returns the start and end dates of a financial time series object. If the object contains time-of-day data, `ftsbound` additionally returns the starting time on the first date and the ending time on the last date.

`datesbound = ftsbound(tsobj)` returns the start and end dates contained in `tsobj` as serial dates in the column matrix `datesbound`. The first row in `datesbound` corresponds to the start date, and the second corresponds to the end date.

`datesbound = ftsbound(tsobj, dateform)` returns the starting and ending dates contained in the object, `tsobj`, as date strings in the column matrix, `datesbound`. The first row in `datesbound` corresponds to the start date, and the second corresponds to the end date. The `dateform` argument controls the format of the output dates.

See Also

`datestr`

Purpose

Financial time series GUI

Syntax

```
ftsgui
```

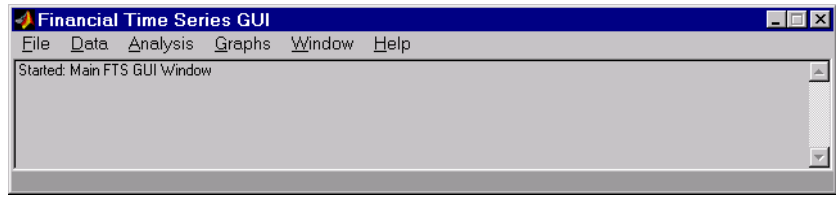
Description

`ftsgui` displays the financial time series graphical user interface (GUI) main window.

The use of the financial time series GUI is described in Chapter 10, “Financial Time Series Graphical User Interface”.

Examples

```
ftsgui
```



See Also

`ftstool`

Purpose

Financial time series object information

Syntax

```
ftsinfo(tsobj)
infofts = ftsinfo(tsobj)
```

Arguments

`tsobj`	Financial time series object.

Description

`ftsinfo(tsobj)` displays information about the financial time series object `tsobj`.

`infofts = ftsinfo(tsobj)` stores information about the financial time series object `tsobj` in the structure `infofts`.

`infofts` has these fields.

Field	Contents
`version`	Financial time series object version.
`desc`	Description of the time series object (`tsobj.desc`).
`freq`	Numeric representation of the time series data frequency (`tsobj.freq`). See `freqstr` for list of numeric frequencies and what they represent.
`startdate`	Earliest date in the time series.
`enddate`	Latest date in the time series.
`seriesnames`	Cell array containing the time series data column names.
`ndata`	Number of data points in the time series.
`nseries`	Number of columns of time series data.

Examples

Convert the supplied file `disney.dat` into a financial time series object named `dis`:

```
dis = ascii2fts('disney.dat', 1, 3);
```

Now use `ftsinfo` to obtain information about `dis`:

```
ftsinfo(dis)

 FINTS version:   2.0
   Description:  Walt Disney Company (DIS)
     Frequency:  Unknown
    Start date:  29-Mar-1996
      End date:  29-Mar-1999
  Series names:  OPEN
                 HIGH
                 LOW
                 CLOSE
                 VOLUME
     # of data:  782
   # of series:  5
```

Then, executing

```
infodis = ftsinfo(dis)
```

creates the structure `infodis` containing the values

```
infodis =

            ver: '2.0'
           desc: 'Walt Disney Company (DIS)'
           freq: 0
      startdate: '29-Mar-1996'
        enddate: '29-Mar-1999'
    seriesnames: {5x1 cell}
          ndata: 782
        nseries: 5
```

See Also

`fints`, `freqnum`, `freqstr`, `ftsbound`

ftstool

Purpose

Financial time series tool

Syntax

```
ftstool
```

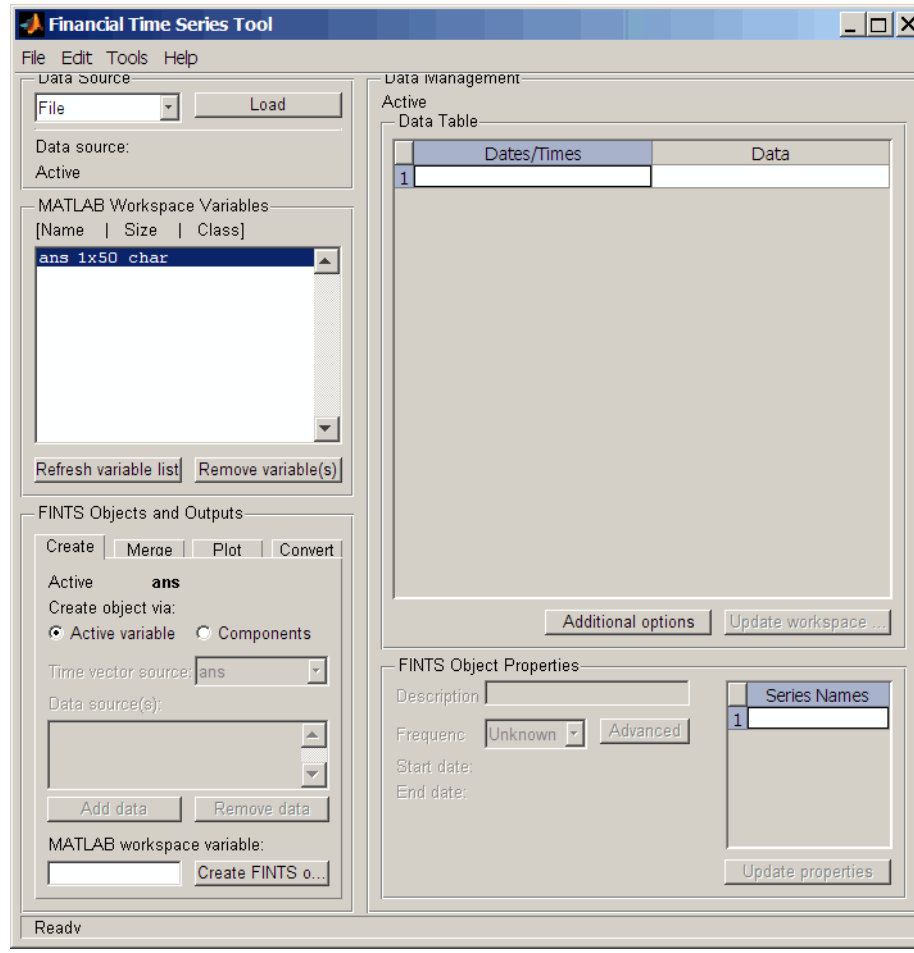
Description

`ftstool` creates and manages Financial Time Series objects. `ftstool` allows the creation and management of Financial Time Series objects via a graphical user interface. `ftstool` can interface with `ftsgui`, meaning Line Plots generated with `ftstool` can be analyzed with `ftsgui`FTSGUI. However, `ftsgui` must be running prior to the generation of any Line Plots.

The use of the financial time series tool is described in Chapter 9, “Financial Time Series Tool (FTSTool)”.

Examples

```
ftstool
```



See Also

`ftsgui`

ftsuniq

Purpose

Determine uniqueness

Syntax

```
uniq = ftsuniq(dates_and_times)
[uniq, dup] = ftsuniq(dates_and_times)
```

Arguments

`dates_and_times`	A single column vector of serial date numbers. The serial date numbers can include time-of-day information.

Description

`uniq = ftsuniq(dates_and_times)` returns `1` if the dates and times within the financial time series object are unique and `0` if duplicates exist.

`[uniq, dup] = ftsuniq(dates_and_times)` additionally returns a structure `dup`. In the structure

- `dup.dt` contains the strings of the duplicate dates and times and their locations in the object.
- `dup.intidx` contains the integer indices of duplicate dates and times in the object.

See Also

`fints`

Purpose

Future value of discounted security

Syntax

```
FutureVal = fvdisc(Settle, Maturity, Price, Discount, Basis)
```

Arguments

`Settle`	Settlement date. Enter as serial date number or date string. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. Enter as serial date number or date string.
`Price`	Price (present value) of the security.
`Discount`	Bank discount rate of the security. Enter as decimal fraction.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA)

- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Description

`FutureVal = fvdisc(Settle, Maturity, Price, Discount, Basis)` finds the amount received at maturity for a fully vested security.

Examples

Using this data

```
Settle = '02/15/2001';
Maturity = '05/15/2001';
Price = 100;
Discount = 0.0575;
Basis = 2;

FutureVal = fvdisc(Settle, Maturity, Price, Discount, Basis)
```

returns

```
FutureVal =
            101.44
```

References

Mayle, *Standard Securities Calculation Methods*, Volumes I-II, 3rd edition.

See Also

`acrudisc`, `discrate`, `prdisc`, `ylddisc`

Purpose

Future value with fixed periodic payments

Syntax

```
FutureVal = fvfix(Rate, NumPeriods, Payment, PresentVal, Due)
```

Arguments

`Rate`	Periodic interest rate, as a decimal fraction.
`NumPeriods`	Number of periods.
`Payment`	Periodic payment.
`PresentVal`	(Optional) Initial value. Default = 0.
`Due`	(Optional) When payments are due or made: 0 = end of period (default), or 1 = beginning of period.

Description

`FutureVal = fvfix(Rate, NumPeriods, Payment, PresentVal, Due)` returns the future value of a series of equal payments.

Examples

A savings account has a starting balance of $1500. $200 is added at the end of each month for 10 years and the account pays 9% interest compounded monthly. Using this data

```
FutureVal = fvfix(0.09/12, 12*10, 200, 1500, 0)
```

returns

```
FutureVal =
            42379.89
```

See Also

`fvvar`, `pvfix`, `pvvar`

fvvar

Purpose

Future value of varying cash flow

Syntax

```
FutureVal = fvvar(CashFlow, Rate, IrrCFDates)
```

Arguments

`CashFlow`	A vector of varying cash flows. Include the initial investment as the initial cash flow value (a negative number).
`Rate`	Periodic interest rate. Enter as a decimal fraction.
`IrrCFDates`	(Optional) For irregular (nonperiodic) cash flows, a vector of dates on which the cash flows occur. Enter dates as serial date numbers or date strings. Default assumes `CashFlow` contains regular (periodic) cash flows.

Description

`FutureVal = fvvar(CashFlow, Rate, IrrCFDates)` returns the future value of a varying cash flow.

Examples

This cash flow represents the yearly income from an initial investment of $10,000. The annual interest rate is 8%.

Year 1	$2000
Year 2	$1500
Year 3	$3000
Year 4	$3800
Year 5	$5000

For the future value of this regular (periodic) cash flow

```
FutureVal = fvvar([-10000 2000 1500 3000 3800 5000], 0.08)
```

returns

```
FutureVal =

             2520.47
```

An investment of $10,000 returns this irregular cash flow. The original investment and its date are included. The periodic interest rate is 9%.

Cash Flow	Dates
($10000)	January 12, 2000
$2500	February 14, 2001
$2000	March 3, 2001
$3000	June 14, 2001
$4000	December 1, 2001

To calculate the future value of this irregular (nonperiodic) cash flow

```
CashFlow = [-10000, 2500, 2000, 3000, 4000];

IrrCFDates = ['01/12/2000'
              '02/14/2001'
              '03/03/2001'
              '06/14/2001'
              '12/01/2001'];

FutureVal = fvvar(CashFlow, 0.09, IrrCFDates)
```

returns

```
FutureVal =
```

```
170.66
```

See Also

fvfix, irr, payuni, pvfix, pvvar

Purpose

Zero curve given forward curve

Syntax

```
[ZeroRates, CurveDates] = fwd2zero(ForwardRates, CurveDates,
Settle, Compounding, Basis)
```

Arguments

`ForwardRates` A number of bonds (`NUMBONDS`)-by-`1` vector of annualized implied forward rates, as decimal fractions. In aggregate, the rates in `ForwardRates` constitute an implied forward curve for the investment horizon represented by `CurveDates`. The first element pertains to forward rates from the settlement date to the first curve date.

`CurveDates` A `NUMBONDS`-by-`1` vector of maturity dates (as serial date numbers) that correspond to the forward rates.

`Settle` A serial date number that is the common settlement date for the forward rates.

`Compounding` (Optional) Output compounding. A scalar that sets the compounding frequency per year for annualizing the output zero rates. Allowed values are:

`1`	Annual compounding
`2`	Semiannual compounding (default)
`3`	Compounding three times per year
`4`	Quarterly compounding
`6`	Bimonthly compounding
`12`	Monthly compounding
`365`	Daily compounding

	`-1` Continuous compounding
`Basis`	(Optional) Output day-count basis for annualizing the output zero rates. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA) • 11 = 30/360E (ISMA) • 12 = actual/365 (ISDA)

Description

`[ZeroRates, CurveDates] = fwd2zero(ForwardRates, CurveDates, Settle, Compounding, Basis)` returns a zero curve given an implied forward rate curve and its maturity dates.

`ZeroRates`	A `NUMBONDS`-by-`1` vector of decimal fractions. In aggregate, the rates in `ZeroRates` constitute a zero curve for the investment horizon represented by `CurveDates`.
`CurveDates`	A `NUMBONDS`-by-`1` vector of maturity dates (as serial date numbers) that correspond to the zero rates in `ZeroRates`. This vector is the same as the input vector `CurveDates`.

Examples

Given an implied forward rate curve over a set of maturity dates, a settlement date, and a compounding rate, compute the zero curve.

```
ForwardRates = [0.0469
                0.0519
                0.0549
                0.0535
                0.0558
                0.0508
                0.0560
                0.0545
                0.0615
                0.0486];

CurveDates = [datenum('06-Nov-2000')
              datenum('11-Dec-2000')
              datenum('15-Jan-2001')
              datenum('05-Feb-2001')
              datenum('04-Mar-2001')
              datenum('02-Apr-2001')
              datenum('30-Apr-2001')
              datenum('25-Jun-2001')
              datenum('04-Sep-2001')
              datenum('12-Nov-2001')];

Settle = datenum('03-Nov-2000');
```

```
Compounding = 1;
```

Execute the function

```
[ZeroRates, CurveDates] = fwd2zero(ForwardRates, CurveDates,...
Settle, Compounding)
```

which returns the zero curve `ZeroRates` at the maturity dates `CurveDates`.

```
ZeroRates =

    0.0469
    0.0515
    0.0531
    0.0532
    0.0538
    0.0532
    0.0536
    0.0539
    0.0556
    0.0543

CurveDates =

      730796
      730831
      730866
      730887
      730914
      730943
      730971
      731027
      731098
      731167
```

For readability, `ForwardRates` and `ZeroRates` are shown here only to the basis point. However, MATLAB software computed them at full precision. If you enter `ForwardRates` as shown, `ZeroRates` may differ due to rounding.

See Also

`zero2fwd` and other functions for "Term Structure of Interest Rates" on page 2-37

geom2arith

Purpose

Geometric to arithmetic moments of asset returns

Syntax

```
[ma, Ca] = geom2arith(mg, Cg);
[ma, Ca] = geom2arith(mg, Cg, t);
```

Arguments

`mg`	Continuously-compounded or "geometric" mean of asset returns (positive n-vector).
`Cg`	Continuously-compounded or "geometric" covariance of asset returns (n-by-n symmetric, positive-semidefinite matrix).
`t`	(Optional) Target period of arithmetic moments in terms of periodicity of geometric moments with default value 1 (positive scalar).

Description

`geom2arith` transforms moments associated with a continuously-compounded geometric Brownian motion into equivalent moments associated with a simple Brownian motion with a possible change in periodicity.

`[ma, Ca] = geom2arith(mg, Cg, t)` returns `ma`, arithmetic mean of asset returns over the target period (n-vector), and`Ca`, which is an arithmetic covariance of asset returns over the target period (n-by-n matrix).

Geometric returns over period t_G are modeled as multivariate lognormal random variables

$$\mathbf{Y} \sim LN(1 + \mathbf{m}_G, \mathbf{C}_G)$$

with moments

$$E[\mathbf{Y}] = 1 + \mathbf{m}_G$$

and

$$\mathrm{cov}(\mathbf{Y}) = \mathbf{C}_G$$

Arithmetic returns over period t_A are modeled as multivariate normal random variables

$$\mathbf{X} \sim N(\mathbf{m}_A, \mathbf{C}_A)$$

with moments

$$E[\mathbf{X}] = \mathbf{m}_A$$

$$\mathrm{cov}(\mathbf{X}) = \mathbf{C}_A$$

Given $t = t_A / t_G$, the transformation from geometric to arithmetic moments is

$$\mathbf{C}_{A_{ij}} = t \log\left(1 + \frac{\mathbf{C}_{G_{ij}}}{(1+\mathbf{m}_{G_i})(1+\mathbf{m}_{G_j})}\right)$$

$$\mathbf{m}_{A_i} = t \log(1+\mathbf{m}_{G_i}) - \frac{1}{2}\mathbf{C}_{A_{ii}}$$

For $i,j = 1,\ldots, n$.

Note If $t = 1$, then $\mathbf{X} = \log(\mathbf{Y})$.

This function requires that the input mean must satisfy `1 + mg > 0` and that the input covariance `Cg` must be a symmetric, positive, semidefinite matrix.

The functions `geom2arith` and `arith2geom` are complementary so that, given `m`, `C`, and `t`, the sequence

```
[ma, Ca] = geom2arith(m, C, t);
[mg, Cg] = arith2geom(ma, Ca, 1/t);
```

yields mg = m and Cg = C.

Examples

Example 1. Given geometric mean m and covariance C of monthly total returns, obtain annual arithmetic mean ma and covariance Ca. In this case, the output period (1 year) is 12 times the input period (1 month) so that t = 12 with

```
[ma, Ca] = geom2arith(m, C, 12);
```

Example 2. Given annual geometric mean m and covariance C of asset returns, obtain monthly arithmetic mean ma and covariance Ca. In this case, the output period (1 month) is 1/12 times the input period (1 year) so that t = 1/12 with

```
[ma, Ca] = geom2arith(m, C, 1/12);
```

Example 3. Given geometric means m and standard deviations s of daily total returns (derived from 260 business days per year), obtain annualized arithmetic mean ma and standard deviations sa with

```
[ma, Ca] = geom2arith(m, diag(s .^2), 260);
sa = sqrt(diag(Ca));
```

Example 4. Given geometric mean m and covariance C of monthly total returns, obtain quarterly arithmetic return moments. In this case, the output is 3 of the input periods so that t = 3 with

```
[ma, Ca] = geom2arith(m, C, 3);
```

Example 5. Given geometric mean m and covariance C of 1254 observations of daily total returns over a 5-year period, obtain annualized arithmetic return moments. Since the periodicity of the geometric data is based on 1254 observations for a 5-year period, a 1-year period for arithmetic returns implies a target period of t = 1254/5 so that

```
[ma, Ca] = geom2arith(m, C, 1254/5);
```

See Also

arith2geom

getfield

Purpose

Content of specific field

Syntax

```
fieldval = getfield(tsobj, field)
fieldval = getfield(tsobj, field, {dates})
```

Arguments

`tsobj`	Financial time series object.
`field`	Field name within `tsobj`.
`dates`	Date range. Dates can be expanded to include time-of-day information.

Description

`getfield` treats the contents of a financial times series object `tsobj` as fields in a structure.

`fieldval = getfield(tsobj, field)` returns the contents of the specified field. This is equivalent to the syntax `fieldval = tsobj field`.

`fieldval = getfield(tsobj, field, {dates})` returns the contents of the specified field for the specified dates. `dates` can be individual cells of date strings or a cell of a date string range using the `::` operator, such as `'03/01/99::03/31/99'`.

Examples

Create a financial time series object containing both date and time-of-day information:

```
dates = ['01-Jan-2001';'01-Jan-2001'; '02-Jan-2001'; ...
         '02-Jan-2001'; '03-Jan-2001';'03-Jan-2001'];
times = ['11:00';'12:00';'11:00';'12:00';'11:00';'12:00'];
dates_times = cellstr([dates, repmat(' ',size(dates,1),1),...
times]);
AnFts = fints(dates_times,[(1:4)'; nan; 6],{'Data1'},1,...
              'Yet Another Financial Time Series')
```

```
AnFts =

    desc:  Yet Another Financial Time Series
    freq:  Daily (1)

    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [          4]
    '03-Jan-2001'    '11:00'          [        NaN]
    '     "     '    '12:00'          [          6]
```

Example 1. Get the contents of the `times` field in `AnFts`:

```
F = datestr(getfield(AnFts, 'times'))

F =

11:00 AM
12:00 PM
11:00 AM
12:00 PM
11:00 AM
12:00 PM
```

Example 2. Extract the contents of specific data fields within `AnFts`:

```
FF = getfield(AnFts,'Data1',...
              '01-Jan-2001 12:00::02-Jan-2001 12:00')

FF =

     2
     3
     4
```

See Also `chfield`, `fieldnames`, `isfield`, `rmfield`, `setfield`

Purpose

Find name in list

Syntax

```
nameidx = getnameidx(list, name)
```

Arguments

`list`	Cell array of name strings.
`name`	String or cell array of name strings.

Description

`nameidx = getnameidx(list, name)` finds the occurrence of a name or set of names in a list. It returns an index (order number) indicating where the specified names are located within the list. If `name` is not found, `nameidx` returns `0`.

If `name` is a cell array of names, `getnameidx` returns a vector containing the indices (order number) of the `name` strings within `list`. If none of the names in the `name` cell array is in `list`, it returns zero. If some of the names in `name` are not found, the indices for these names will be zeros.

`getnameidx` finds only the first occurrence of the name in the list of names. This function is meant to be used on a list of unique names (strings) only. It does not find multiple occurrences of a name or a list of names within `list`.

Examples

Given

```
poultry = {'duck', 'chicken'}
animals = {'duck', 'cow', 'sheep', 'horse', 'chicken'}
nameidx = getnameidx(animals, poultry)
ans =
    1   5
```

Given

```
poultry = {'duck', 'goose', 'chicken'}
```

```
animals = {'duck', 'cow', 'sheep', 'horse', 'chicken'}
nameidx = getnameidx(animals, poultry)
ans =
    1   0   5
```

See Also

findstr, strcmp, strfind

Purpose

Highest high

Syntax

```
hhv = hhigh(data)
hhv = hhigh(data, nperiods, dim)
hhvts = hhigh(tsobj, nperiods)
hhvts = hhigh(tsobj, nperiods, ParameterName, ParameterValue)
```

Arguments

`data`	Data series matrix.
`nperiods`	(Optional) Number of periods. Default = 14.
`dim`	(Optional) Dimension.
`tsobj`	Financial time series object.
`ParameterName`	The valid parameter name is: • `HighName`: high prices series name
`ParameterValue`	The parameter value is a string that represents the valid parameter name.

Description

`hhv = hhigh(data)` generates a vector of highest high values the past 14 periods from the matrix `data`.

`hhv = hhigh(data, nperiods, dim)` generates a vector of highest high values the past `nperiods` periods. `dim` indicates the direction in which the highest high is to be searched. If you input `[]` for `nperiods`, the default is 14.

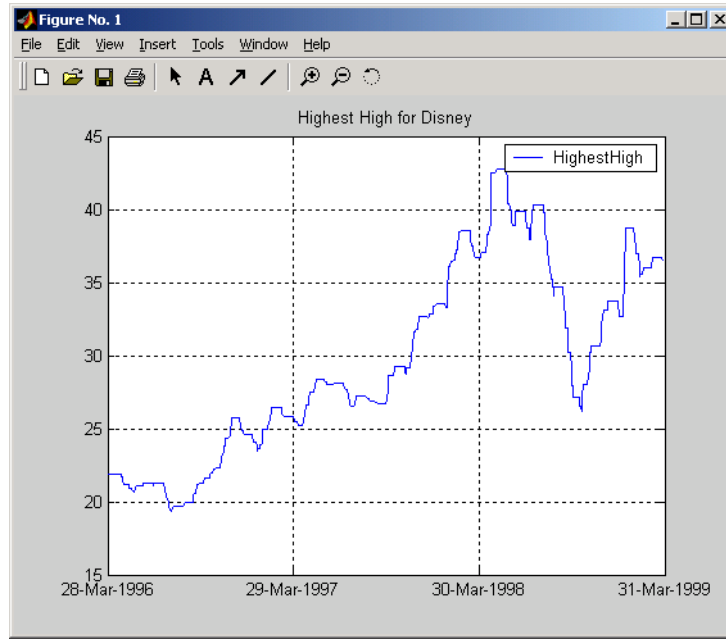
`hhvts = hhigh(tsobj, nperiods)` generates a vector of highest high values from `tsobj`, a financial time series object. `tsobj` must include at least the series `High`. The output `hhvts` is a financial time series object with the same dates as `tsobj` and data series named `HighestHigh`. If `nperiods` is specified, `hhigh` generates a financial time series object of highest high values for the past `nperiods` periods.

`hhvts = hhigh(tsobj, nperiods, ParameterName, ParameterValue)` specifies the name for the required data series when it is different from the default name. The valid parameter name is`HighName`. The parameter value is a string that represents the valid parameter name.

Example

Compute the highest high prices for Disney stock and plot the results:

```
load disney.mat
dis_HHigh = hhigh(dis)
plot(dis_HHigh)
title('Highest High for Disney')
```



See Also

`llow`

Purpose

Time series High-Low plot

Syntax

```
highlow(tsobj)
highlow(tsobj, color)
highlow(tsobj, color, dateform)
highlow(tsobj, color, dateform, ParameterName, ParameterValue, ...)
hhll = highlow(tsobj, color, dateform, ParameterName,
ParameterValue, ...)
```

Arguments

`tsobj`	Financial time series object.
`color`	(Optional) A three-element row vector representing RGB or a color identifier. (See `plot` in the MATLAB documentation.)
`dateform`	(Optional) Date string format used as the *x*-axis tick labels. (See `datetick` in the MATLAB documentation.) You can specify a `dateform` only when `tsobj` does not contain time-of-day data. If `tsobj` contains time-of-day data, `dateform` is restricted to `'dd-mmm-yyyy HH:MM'`.
`ParameterName`	`ParameterName` can be: • `HighName`: high prices series name • `LowName`: low prices series name • `OpenName`: open prices series name • `CloseName`: closing prices series name
`ParameterValue`	The parameter value is a string that represents the valid parameter name.

Description

`highlow(tsobj)` generates a High-Low plot of the data in the financial time series object `tsobj`. `tsobj` must contain at least four data series representing the high, low, open, and closing prices. These series must have the names `High`, `Low`, `Open`, and `Close` (case-insensitive).

`highlow(tsobj, color)` additionally specifies the color of the plot.

`highlow(tsobj, color, dateform)` additionally specifies the date string format used as the *x*-axis tick labels. See `datestr` for a list of date string formats.

`highlow(tsobj, color, dateform, ParameterName, ParameterValue,...)` indicates the actual name(s) of the required data series if the data series do not have the default names.

You can specify open prices as optional by providing the parameter name `'OpenName'` and the parameter value `''` (empty string).

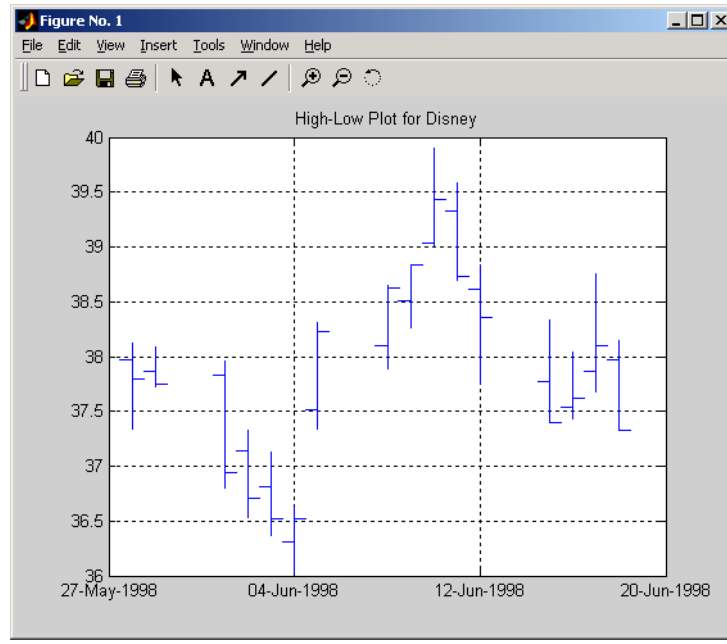
```
highlow(tsobj, color, dateform, 'OpenName', '')
```

`hhll = highlow(tsobj, color, dateform, ParameterName, ParameterValue, ...)` returns the handle to the line object that makes up the High-Low plot.

Examples

Generate a High-Low plot for Disney stock for the dates from May 28 to June 18, 1998:

```
load disney.mat
highlow(dis('28-May-1998::18-Jun-1998'))
title('High-Low Plot for Disney')
```



See Also

`candle`

highlow

Purpose

High, low, open, close chart

Syntax

```
highlow(High, Low, Close, Open, Color)
Handles = highlow(High, Low, Close, Open, Color)
```

Arguments

`High`	High prices for a security. A column vector.
`Low`	Low prices for a security. A column vector.
`Close`	Closing prices for a security. A column vector.
`Open`	(Optional) Opening prices for a security. A column vector. To specify `Color` when `Open` is unknown, enter `Open` as an empty matrix `[]`.
`Color`	(Optional) Vertical line color. A string. MATLAB software supplies a default color if none is specified. The default color differs depending on the background color of the figure window. See `ColorSpec` in the MATLAB documentation for `color` names.

Description

`highlow(High, Low, Close, Open, Color)` plots the high, low, opening, and closing prices of an asset. Plots are vertical lines whose top is the high, bottom is the low, open is a short horizontal tick to the left, and close is a short horizontal tick to the right.

`Handles = highlow(High, Low, Close, Open, Color)` plots the figure and returns the handles of the lines.

Examples

The high, low, and closing prices for an asset are stored in equal-length vectors `AssetHi`, `AssetLo`, and `AssetCl` respectively.

```
highlow(AssetHi, AssetLo, AssetCl, [], 'cyan')
```

plots the price data using cyan lines.

See Also

`bolling`, `candle`, `dateaxis`, `highlow`, `movavg`, `pointfig`

hist

Purpose

Histogram

Syntax

```
hist(tsobj, numbins)
ftshist = hist(tsobj, numbins)
[ftshist, binpos] = hist(tsobj, numbins)
```

Arguments

`tsobj`	Financial time series object.
`numbins`	(Optional) Number of histogram bins. Default = 10.

Description

`hist(tsobj, numbins)` calculates and displays the histogram of the data series contained in the financial time series object `tsobj`.

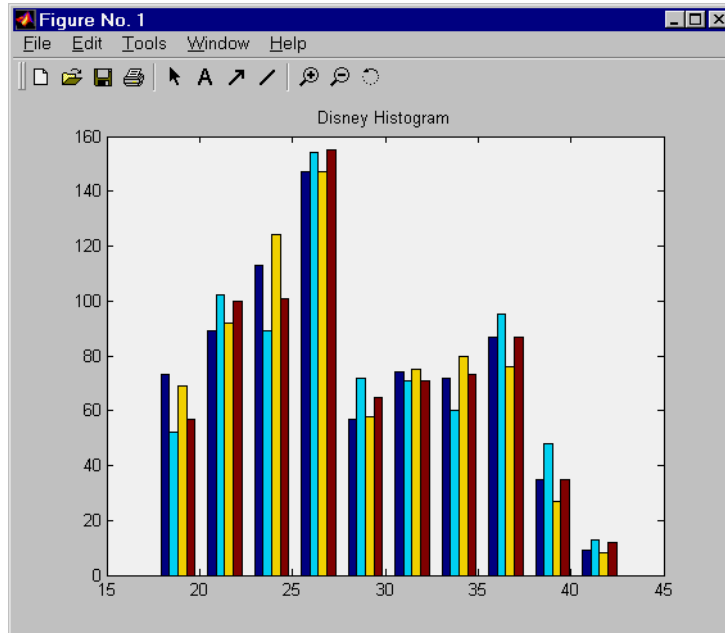
`ftshist = hist(tsobj, numbins)` calculates, but does not display, the histogram of the data series contained in the financial time series object `tsobj`. The output `ftshist` is a structure with field names similar to the data series names of `tsobj`.

`[ftshist, binpos] = hist(tsobj, numbins)` additionally returns the bin positions `binpos`. The positions are the centers of each bin. `binpos` is a column vector.

Example

Create a histogram of Disney open, high, low, and close prices:

```
load disney.mat
dis = rmfield(dis,'VOLUME') % Remove VOLUME field
hist(dis)
title('Disney Histogram')
```



See Also

`mean`, `std`

`hist` in the MATLAB documentation

holdings2weights

Purpose

Portfolio holdings into weights

Syntax

```
Weights = holdings2weights(Holdings, Prices, Budget)
```

Arguments

`Holdings`	Number of portfolios (`NPORTS`) by number of assets (`NASSETS`) matrix with the holdings of `NPORTS` portfolios containing `NASSETS` assets.
`Prices`	`NASSETS` vector of asset prices.
`Budget`	(Optional) Scalar or `NPORTS` vector of nonzero budget constraints. Default = `1`.

Description

`Weights = holdings2weights(Holdings, Prices, Budget)` converts portfolio holdings into portfolio weights. The weights must satisfy a budget constraint such that the weights sum to `Budget` for each portfolio.

Weights is a `NPORTS` by `NASSETS` matrix containing the normalized weights of `NPORTS` portfolios containing `NASSETS` assets.

Notes

- `Holdings` may be negative to indicate a short position, but the overall portfolio weights must satisfy a nonzero budget constraint.
- The weights in each portfolio sum to the `Budget` value (which is 1 if `Budget` is unspecified.)

See Also

`weights2holdings`

Purpose

Holidays and nontrading days

Syntax

```
H = holidays(StartDate, EndDate)
```

Arguments

`StartDate`	Start date vector. Enter as serial date numbers or date strings.
`EndDate`	End date vector. Enter as serial date numbers or date strings.

Description

`H = holidays(StartDate, EndDate)` returns a vector of serial date numbers corresponding to the holidays and nontrading days between `StartDate` and `EndDate`, inclusive.

`H = holidays` returns a vector of serial date numbers corresponding to all holidays and nontrading days.

As shipped, this function contains all holidays and special nontrading days for the New York Stock Exchange between 1950 and 2050. You can edit the `holidays.m` file to contain your own holidays and nontrading days. By definition, holidays and nontrading days are those that occur on weekdays.

Examples

```
H = holidays('jan 1 2001', 'jun 23 2001')
returns
H =

      730852
      730901
      730954
      730999
```

which are the serial date numbers for

```
01-Jan-2001 (New Year's Day)
19-Feb-2001 (President's Day)
13-Apr-2001 (Good Friday)
28-May-2001 (Memorial Day)
```

See Also

busdate, createholidays, fbusdate, isbusday, lbusdate

Purpose

Concatenate financial time series objects horizontally

Description

`horzcat` implements horizontal concatenation of financial time series objects. `horzcat` essentially merges the data columns of the financial time series objects. The time series objects must contain the exact same dates and times.

When multiple instances of a data series name occur, concatenation adds a suffix to the current names of the data series. The suffix has the format `_objectname<n>`, where `n` is a number indicating the position of the time series, from left to right, in the concatenation command. The `n` part of the suffix appears only when there is more than one instance of a particular data series name.

The description fields are concatenated as well. They are separated by two forward slashes (//).

Examples

Construct three financial time series, each containing a data series named `DataSeries`:

```
firstfts  = fints((today:today+4)', (1:5)','DataSeries','d');
secondfts = fints((today:today+4)', (11:15)','DataSeries','d');
thirdfts  = fints((today:today+4)', (21:25)','DataSeries','d');
```

Concatenate the time series horizontally into a new financial time series `newfts`:

```
newfts  = [firstfts secondfts thirdfts secondfts];
```

The resulting object `newfts` has data series names `DataSeries_firstfts`, `DataSeries_secondfts2`, `DataSeries_thirdfts`, and `DataSeries_secondfts4`.

Verify this with the command

```
fieldnames(newfts)

ans =
```

```
'desc'
'freq'
'dates'
'DataSeries_firstfts'
'DataSeries_secondfts2'
'DataSeries_thirdfts'
'DataSeries_secondfts4'
'times'
```

Use `chfield` to change the data series names.

Note If all input objects have the same frequency, the new object has that frequency as well. However, if one of the objects concatenated has a different frequency from the others, the frequency indicator of the resulting object is set to `Unknown (0)`.

See Also

`vertcat`

Purpose

Hour of date or time

Syntax

```
Hour = hour(Date)
```

Description

`Hour = hour(Date)` returns the hour of the day given a serial date number or a date string.

Examples

```
Hour = hour(730473.5584278936)
```

or

```
Hour = hour('19-dec-1999, 13:24:08.17')
```

returns

```
Hour =
       13
```

See Also

`datevec`, `minute`, `second`

inforatio

Purpose

Calculate information ratio for one or more assets

Syntax

```
inforatio(Asset, Benchmark)
  Ratio = inforatio(Asset, Benchmark)
  [Ratio, TE] = inforatio(Asset, Benchmark)
```

Arguments

`Asset`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` observations of asset returns for `NUMSERIES` asset return series.
`Benchmark`	`NUMSAMPLES` vector of returns for a benchmark asset. The periodicity must be the same as the periodicity of `Asset`. For example, if `Asset` is monthly data, then `Benchmark` must be monthly returns.

Description

Given `NUMSERIES` assets with `NUMSAMPLES` returns for each asset in a `NUMSAMPLES x NUMSERIES` matrix `Asset` and given a `NUMSAMPLES` vector of benchmark returns in `Benchmark`, `inforatio` computes the information ratio and tracking error for each asset relative to the `Benchmark`.

To summarize the outputs of `inforatio`:

- `Ratio` is a `1 x NUMSERIES` row vector of information ratios for each series in `Asset`. Any series in `Asset` with a tracking error of 0 will have a `NaN` value for its information ratio.
- `TE` is a `1 x NUMSERIES` row vector of tracking errors, that is, the standard deviation of `Asset` relative to `Benchmark` returns, for each series.

Note `NaN` values in the data are ignored. If the `Asset` and `Benchmark` series are identical, the information ratio will be `NaN` since the tracking error is 0. The information ratio and the Sharpe ratio of an `Asset` versus a riskless `Benchmark` (a `Benchmark` with standard deviation of returns equal to 0) are equivalent. This equivalence is not necessarily true if the `Benchmark` is risky.

Examples

See “Information Ratio Example” on page 4-8.

References

Richard C. Grinold and Ronald N. Kahn, *Active Portfolio Management*, 2nd. ed., McGraw-Hill, 2000.

Jack Treynor and Fischer Black, "How to Use Security Analysis to Improve Portfolio Selection," *Journal of Business*, Vol. 46, No. 1, January 1973, pp. 66-86.

See Also

`portalpha`, `sharpe`

Purpose

Internal rate of return

Syntax

```
Return = irr(CashFlow)
```

Description

`Return = irr(CashFlow)` calculates the internal rate of return for a series of periodic cash flows. `CashFlow` is the cash flow vector. The first entry in `CashFlow` is the initial investment. If the initial investment is negative, `irr` generates a unique result only if all subsequent cash flows are positive. If some future cash flows are negative, `irr` generates nonunique solutions (multiple solutions that are each valid).

If the cash flow payments are monthly, multiply the resulting rate of return by 12 for the annual rate of return. This function calculates only positive rates of return; for nonpositive rates of return, `Return = NaN`.

Examples

This cash flow represents the yearly income from an initial investment of $100,000:

Year 1	$10,000
Year 2	$20,000
Year 3	$30,000
Year 4	$40,000
Year 5	$50,000

To calculate the internal rate of return on the investment

```
Return = irr([-100000  10000  20000  30000  40000  50000])
```

returns

```
Return =

          0.1201 (12.01%)
```

References

Brealey and Myers, *Principles of Corporate Finance*, Chapter 5

See Also

`effrr`, `mirr`, `nomrr`, `taxedrr`, `xirr`

isbusday

Purpose

True for dates that are business days

Syntax

```
Busday = isbusday(Date, Holiday, Weekend)
```

Arguments

`Date`	Date(s) being checked. Enter as a serial date number or date string. `Date` can contain multiple dates, but they must all be in the same format.
`Holiday`	(Optional) Vector of holidays and nontrading-day dates. All dates in `Holiday` must be the same format: either serial date numbers or date strings. (Using date numbers improves performance.) The `holidays` function supplies the default vector.
`Weekend`	(Optional) Vector of length 7, containing 0 and 1, the value 1 indicating weekend days. The first element of this vector corresponds to Sunday. Thus, when Saturday and Sunday form the weekend (default), then `Weekend = [1 0 0 0 0 0 1]`.

Description

`Busday = isbusday(Date, Holiday, Weekend)` returns logical true (`1`) if `Date` is a business day and logical false (`0`) otherwise.

Examples

Example 1:

```
Busday = isbusday('16 jun 2001')

Busday =

          0

Date = ['15 feb 2001'; '16 feb 2001'; '17 feb 2001'];
```

```
Busday = isbusday(Date)

Busday =

         1
         1
         0
```

Example 2: Set June 21, 2003 (a Saturday) as a business day.

```
Weekend = [1 0 0 0 0 0 0];

isbusday('June 21, 2003', [], Weekend)

ans =

     1
```

See Also

`busdate`, `fbusdate`, `holidays`, `lbusdate`

iscompatible

Purpose

Structural equality

Syntax

```
iscomp = iscompatible(tsobj_1, tsobj_2)
```

Arguments

`tsobj_1, tsobj_2`	A pair of financial time series objects.

Description

`iscomp = iscompatible(tsobj_1, tsobj_2)` returns `1` if both financial time series objects `tsobj_1` and `tsobj_2` have the same dates and data series names. It returns `0` if any component is different.

`iscomp = 1` indicates that the two objects contain the same number of data points and equal number of data series. However, the values contained in the data series can be different.

Note Data series names are case-sensitive.

See Also

`isequal`

Purpose

Multiple object equality

Syntax

```
iseq = isequal(tsobj_1, tsobj_2, ...)
```

Arguments

`tsobj_1 ...`	A list of financial time series objects.

Description

`iseq = isequal(tsobj_1, tsobj_2, ...)` returns `1` if all listed financial time series objects have the same dates, data series names, and values contained in the data series. It returns `0` if any of those components is different.

Note Data series names are case-sensitive.

`iseq = 1` implies that each object contains the same number of dates and the same data. Only the descriptions can differ.

See Also

`eq`, `iscompatible`

isempty

Purpose

True for empty financial time series objects

Syntax

```
tf = isempty(fts)
```

Arguments

`fts`	Financial time series object.

Description

`isempty` for financial times series objects is based on the MATLAB `isempty` function. See `isempty` in the MATLAB documentation.

`tf = isempty(fts)` returns true (`1`) if `fts` is an empty financial time series object and false (`0`) otherwise. An empty financial times series object has no elements, that is, `length(fts) = 0`.

See Also

`nanmax`, `nanmean`, `nanmedian`, `nanmin`, `nanstd`, `nanvar`

Purpose

Check whether string is field name

Syntax

```
F = isfield(tsobj, name)
```

Description

`F = isfield(tsobj, name)` returns true (1) if `name` is the name of a data series in `tsobj`. Otherwise, `isfield` returns false (0).

See Also

`fieldnames`, `getfield`, `setfield`

issorted

Purpose

Check whether dates and times are monotonically increasing

Syntax

```
monod = issorted(tsobj)
```

Arguments

`tsobj`	Financial time series object

Description

`monod = issorted(tsobj)` returns `1` if the dates and times in `tsobj` are monotonically increasing or `0` if they are not.

See Also

`sortfts`

Purpose

Kagi chart

Syntax

```
kagi(X)
```

Arguments

X	M-by-2 matrix where the first column contains date numbers and the second column is the asset price.

Description

`kagi(X)` plots asset price with respect to dates.

Examples

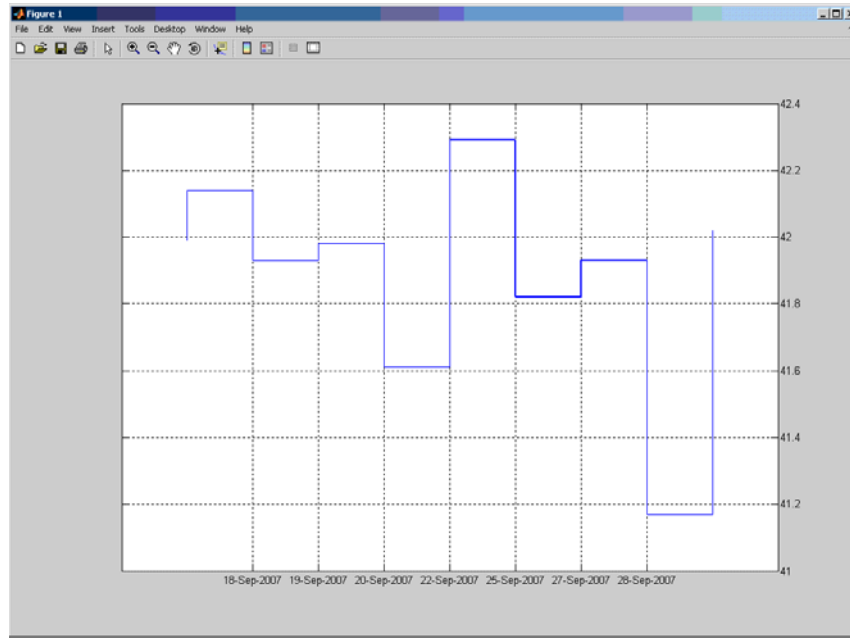
If asset `X` is an `M`-by-`2` matrix of date numbers and asset price:

```
X = [...

733299.00          41.99;...
733300.00          42.14;...
733303.00          41.93;...
733304.00          41.98;...
733305.00          41.75;...
733306.00          41.61;...
733307.00          42.29;...
733310.00          42.19;...
733311.00          41.82;...
733312.00          41.93;...
733313.00          41.81;...
733314.00          41.37;...
733317.00          41.17;...
733318.00          42.02]
```

then the Kagi chart is

```
kagi(X)
```

which plots the asset prices with respect to dates as follows.



See Also

bolling, candle, highlow, linebreak, movavg, pointfig, priceandvol, renko, volarea

Purpose

Lag time series object

Syntax

```
newfts = lagts(oldfts)
newfts = lagts(oldfts, lagperiod)
newfts = lagts(oldfts, lagperiod, padmode)
```

Arguments

`oldfts`	Financial time series object
`lagperiod`	Number of lag periods expressed in the frequency of the time series object
`padmode`	Data padding value

Description

`lagts` delays a financial time series object by a specified time step.

`newfts = lagts(oldfts)` delays the data series in `oldfts` by one time series date entry and returns the result in the object `newfts`. The end will be padded with zeros, by default.

`newfts = lagts(oldfts, lagperiod)` shifts time series values to the right on an increasing time scale. `lagts` delays the data series to happen at a later time. `lagperiod` is the number of lag periods expressed in the frequency of the time series object `oldfts`. For example, if `oldfts` is a daily time series, `lagperiod` is specified in days. `lagts` pads the data with zeros (default).

`newfts = lagts(oldfts, lagperiod, padmode)` lets you pad the data with an arbitrary value, `NaN`, or `Inf` rather than zeros by setting `padmode` to the desired value.

See Also

`leadts`

lbusdate

Purpose

Last business date of month

Syntax

```
Date = lbusdate(Year, Month, Holiday, Weekend)
```

Arguments

`Year`	Enter as four-digit integer.
`Month`	Enter as integer from 1 through 12.
`Holiday`	(Optional) Vector of holidays and nontrading-day dates. All dates in `Holiday` must be the same format: either serial date numbers or date strings. (Using date numbers improves performance.) The `holidays` function supplies the default vector.
`Weekend`	(Optional) Vector of length 7, containing 0 and 1, the value 1 indicating weekend days. The first element of this vector corresponds to Sunday. Thus, when Saturday and Sunday form the weekend (default), then `Weekend = [1 0 0 0 0 0 1]`.

Description

`Date = lbusdate(Year, Month, Holiday, Weekend)` returns the serial date number for the last business date of the given year and month. `Holiday` specifies nontrading days.

`Year` and `Month` can contain multiple values. If one contains multiple values, the other must contain the same number of values or a single value that applies to all. For example, if `Year` is a `1`-by-`n` vector of integers, then `Month` must be a 1-by-n vector of integers or a single integer. `Date` is then a `1`-by-`n` vector of date numbers.

Use the function `datestr` to convert serial date numbers to formatted date strings.

Examples

Example 1.

```
Date = lbusdate(2001, 5)

Date =

      731002

datestr(Date)

ans =

31-May-2001

c
ans =

31-May-2001
31-May-2002
30-May-2003
```

Example 2. You can indicate that Saturday is a business day by appropriately setting the `Weekend` argument.

```
Weekend = [1 0 0 0 0 0 0];
```

May 31, 2003, is a Saturday. Use `lbusdate` to check that this Saturday is actually the last business day of the month.

```
Date = datestr(lbusdate(2003, 5, [], Weekend))

Date =

31-May-2003
```

See Also

`busdate`, `eomdate`, `fbusdate`, `holidays`, `isbusday`

leadts

Purpose

Lead time series object

Syntax

```
newfts = leadts(oldfts)
newfts = leadts(oldfts, leadperiod)
newfts = leadts(oldfts, leadperiod, padmode)
```

Arguments

`oldfts`	Financial time series object.
`leadperiod`	Number of lead periods expressed in the frequency of the time series object.
`padmode`	Data padding value.

Description

`leadts` advances a financial time series object by a specified time step.

`newfts = leadts(oldfts)` advances the data series in `oldfts` by one time series date entry and returns the result in the object `newfts`. The end will be padded with zeros, by default.

`newfts = leadts(oldfts, leadperiod)` shifts time series values to the left on an increasing time scale. `leadts` advances the data series to happen at an earlier time. `leadperiod` is the number of lead periods expressed in the frequency of the time series object `oldfts`. For example, if `oldfts` is a daily time series, `leadperiod` is specified in days. `leadts` pads the data with zeros (default).

`newfts = leadts(oldfts, leadperiod, padmode)` lets you pad the data with an arbitrary value, `NaN`, or `Inf` rather than zeros by setting `padmode` to the desired value.

See Also

`lagts`

Purpose

Get number of dates (rows)

Syntax

```
lenfts = length(tsobj)
```

Description

`lenfts = length(tsobj)` returns the number of dates (rows) in the financial time series object `tsobj`. This is the same as issuing `lenfts = size(tsobj, 1)`.

See Also

`size`

`length` in the MATLAB documentation

linebreak

Purpose

Line break chart

Syntax

```
linebreak(X)
```

Arguments

X	M -by-2 matrix where the first column contains date numbers and the second column is the asset price.

Description

`linebreak(X)` plots asset price with respect to dates.

Examples

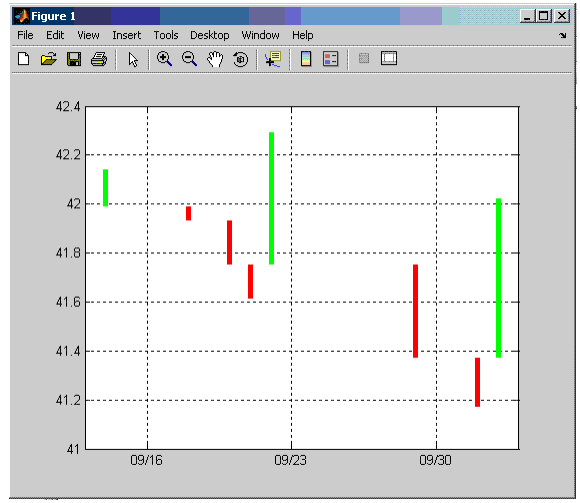
If asset X is an M-by-2 matrix of date numbers and asset price:

```
X = [...

733299.00         41.99;...
733300.00         42.14;...
733303.00         41.93;...
733304.00         41.98;...
733305.00         41.75;...
733306.00         41.61;...
733307.00         42.29;...
733310.00         42.19;...
733311.00         41.82;...
733312.00         41.93;...
733313.00         41.81;...
733314.00         41.37;...
733317.00         41.17;...
733318.00         42.02]
```

then the Line break chart is

```
linebreak(X)
```

which plots the asset prices with respect to dates as follows.



See Also

`bolling`, `candle`, `highlow`, `kagi`, `movavg`, `pointfig`, `priceandvol`, `renko`, `volarea`

llow

Purpose

Lowest low

Syntax

```
llv = llow(data)
llv = llow(data, nperiods, dim)
llvts = llow(tsobj, nperiods)
llvts = llow(tsobj, nperiods, ParameterName, ParameterValue)
```

Arguments

`data`	Data series matrix.
`nperiods`	(Optional) Number of periods. Default = 14.
`dim`	Dimension.
`tsobj`	Financial time series object.
`ParameterName`	The valid parameter name is: • `LowName`: low prices series name
`ParameterValue`	The parameter value is a string that represents the valid parameter name.

Description

`llv = llow(data)` generates a vector of lowest low values for the past 14 periods from the matrix `data`.

`llv = llow(data, nperiods, dim)` generates a vector of lowest low values for the past `nperiods` periods. `dim` indicates the direction in which the lowest low is to be searched. If you input `[]` for `nperiods`, the default is 14.

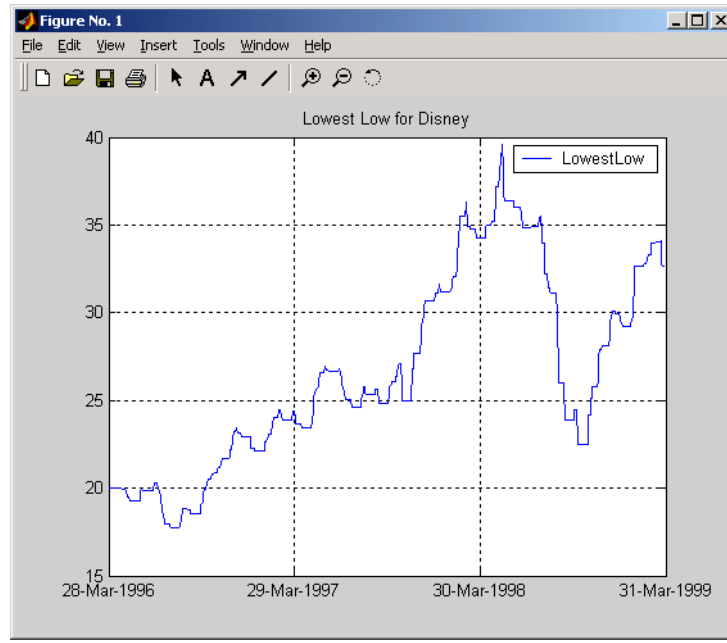
`llvts = llow(tsobj, nperiods)` generates a vector of lowest low values from `tsobj`, a financial time series object. `tsobj` must include at least the series `Low`. The output `llvts` is a financial time series object with the same dates as `tsobj` and data series named `LowestLow`. If `nperiods` is specified, `llow` generates a financial time series object of lowest low values for the past `nperiods` periods.

`llvts = llow(tsobj, nperiods, ParameterName, ParameterValue)` specifies the name for the required data series when it is different from the default name. The parameter value is a string that represents the valid parameter name.

Examples

Compute the lowest low prices for Disney stock and plot the results.

```
load disney.mat
dis_LLow = llow(dis)
plot(dis_LLow)
title('Lowest Low for Disney')
```



See Also

`hhigh`

log

Purpose

Natural logarithm

Syntax

```
newfts = log(tsobj)
```

Description

`newfts = log(tsobj)` calculates the natural logarithm (log base e) of the data series in a financial time series object `tsobj`. It returns another time series object newfts containing the natural logarithms.

See Also

`exp`, `log2`, `log10`

Purpose

Common logarithm

Syntax

```
newfts = log10(tsobj)
```

Description

`newfts = log10(tsobj)` calculates the common logarithm (base 10) of all the data in the data series of the financial time series object `tsobj` and returns the result in the object `newfts`.

See Also

`exp`, `log`, `log2`

log2

Purpose

Base 2 logarithm

Syntax

```
newfts = log2(tsobj)
```

Description

`newfts = log2(tsobj)` calculates the base 2 logarithm of the data series in a financial time series object `tsobj`. It returns another time series object `newfts` containing the logarithms.

See Also

`exp`, `log`, `log10`

Purpose

Compute sample lower partial moments of data

Syntax

```
lpm(Data)
   lpm(Data, MAR)
   lpm(Data, MAR, Order)
   Moment = lpm(Data, MAR, Order)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` observations of `NUMSERIES` asset returns.
`MAR`	(Optional) Scalar minimum acceptable return (default `MAR` = 0). This is a cutoff level of return such that all returns above `MAR` contribute nothing to the lower partial moment.
`Order`	(Optional) Either a scalar or a `NUMORDERS`-vector of nonnegative integer moment orders. If no order specified, default `Order` = 0, which is the shortfall probability. Although this function will work for noninteger orders and, in some cases, for negative orders, this falls outside customary usage.

Description

Given `NUMSERIES` assets with `NUMSAMPLES` returns in a `NUMSAMPLES`-by-`NUMSERIES` matrix `Data`, a scalar minimum acceptable return `MAR`, and one or more nonnegative moment orders in a `NUMORDERS` vector `Order`, `lpm` computes lower partial moments relative to `MAR` for each asset in a `NUMORDERS x NUMSERIES` matrix `Moment`.

The output `Moment` is a `NUMORDERS x NUMSERIES` matrix of lower partial moments with `NUMORDERS` `Orders` and `NUMSERIES` series, that is, each row contains lower partial moments for a given order.

Note To compute upper partial moments, just reverse the signs of both `Data` and `MAR` (do not reverse the sign of the output). This function computes sample lower partial moments from data. To compute expected lower partial moments for multivariate normal asset returns with a specified mean and covariance, use `elpm`. With `lpm`, you can compute various investment ratios such as Omega ratio, Sortino ratio, and Upside Potential ratio, where:

- `Omega = lpm(-Data, -MAR, 1) / lpm(Data, MAR, 1)`
- `Sortino = (mean(Data) - MAR) / sqrt(lpm(Data, MAR, 2))`
- `Upside = lpm(-Data, -MAR, 1) / sqrt(lpm(Data, MAR, 2))`

Example

See “Sample Lower Partial Moments Example” on page 4-13.

References

Vijay S. Bawa, "Safety-First, Stochastic Dominance, and Optimal Portfolio Choice," *Journal of Financial and Quantitative Analysis*, Vol. 13, No. 2, June 1978, pp. 255-271.

W. V. Harlow, "Asset Allocation in a Downside-Risk Framework," *Financial Analysts Journal*, Vol. 47, No. 5, September/October 1991, pp. 28-40.

W. V. Harlow and K. S. Rao, "Asset Pricing in a Generalized Mean-Lower Partial Moment Framework: Theory and Evidence," *Journal of Financial and Quantitative Analysis*, Vol. 24, No. 3, September 1989, pp. 285-311.

Frank A. Sortino and Robert van der Meer, "Downside Risk," *Journal of Portfolio Management*, Vol. 17, No. 5, Spring 1991, pp. 27-31.

See Also

`elpm`

Purpose

Date of last occurrence of weekday in month

Syntax

```
LastDate = lweekdate(Weekday, Year, Month, NextDay)
```

Arguments

`Weekday`	Weekday whose date you seek. Enter as an integer from 1 through 7: `1` Sunday `2` Monday `3` Tuesday `4` Wednesday `5` Thursday `6` Friday `7` Saturday
`Year`	Year. Enter as a four-digit integer.
`Month`	Month. Enter as an integer from 1 through 12.
`NextDay`	(Optional) Weekday that must occur after `Weekday` in the same week. Enter as an integer from 0 through 7, where 0 = ignore (default) and 1 through 7 are the same as for `Weekday`.

Any input can contain multiple values, but if so, all other inputs must contain the same number of values or a single value that applies to all. For example, if `Year` is a 1-by-n vector of integers, then `Month` must be a 1-by-n vector of integers or a single integer. `LastDate` is then a 1-by-n vector of date numbers.

Description

`LastDate = lweekdate(Weekday, Year, Month, NextDay)` returns the serial date number for the last occurrence of `Weekday` in the given year and month and in a week that also contains `NextDay`.

Use the function `datestr` to convert serial date numbers to formatted date strings.

Examples

Example 1. To find the last Monday in June 2001

```
LastDate = lweekdate(2, 2001, 6); datestr(LastDate)

ans =

25-Jun-2001
```

Example 2. To find the last Monday in a week that also contains a Friday in June 2001

```
LastDate = lweekdate(2, 2001, 6, 6); datestr(LastDate)

ans =

25-Jun-2001
```

Example 3. To find the last Monday in May for 2001, 2002, and 2003

```
Year = [2001:2003];

LastDate = lweekdate(2, Year, 5)

LastDate =

           730999      731363      731727
datestr(LastDate)

ans =

28-May-2001
```

```
27-May-2002
26-May-2003
```

See Also

eomdate, lbusdate, nweekdate

Purpose

MATLAB serial date number to Excel serial date number

Syntax

```
DateNum = m2xdate(MATLABDateNumber, Convention)
```

Arguments

`MATLABDateNumber`	A vector or scalar of MATLAB serial date numbers.
`Convention`	(Optional) Excel date system. A vector or scalar. When `Convention = 0` (default), the Excel 1900 date system is in effect. When `Convention = 1`, the Excel 1904 date system in used. In the Excel 1900 date system, the Excel serial date number 1 corresponds to January 1, 1900 A.D. In the Excel 1904 date system, date number 0 is January 1, 1904 A.D. Due to a software limitation in Excel software, the year 1900 is considered a leap year. As a result, all DATEVALUE's reported by Excel software between Jan. 1, 1900 and Feb. 28, 1900 (inclusive) differs from the values reported by 1. For example: • In Excel software, Jan. 1, 1900 = 1 • In MATLAB, Jan. 1, 1900 = 2

Vector arguments must have consistent dimensions.

Description

`DateNum = m2xdate(MATLABDateNumber, Convention)` converts MATLAB serial date numbers to Excel serial date numbers. MATLAB date numbers start with 1 = January 1, 0000 A.D., hence there is a

difference of 693960 relative to the 1900 date system, or 695422 relative to the 1904 date system. This function is useful with Spreadsheet Link™ EX software.

Examples

Given MATLAB date numbers for Christmas 2001 through 2004

```
DateNum = datenum(2001:2004, 12, 25)

DateNum =

      731210      731575      731940      732306
```

convert them to Excel date numbers in the 1904 system

```
ExDate = m2xdate(DateNum, 1)

ExDate =

       35788       36153       36518       36884
```

or the 1900 system

```
ExDate = m2xdate(DateNum)

ExDate =

       37250       37615       37980       38346
```

See Also

`datenum`, `datestr`, `x2mdate`

Purpose

Moving Average Convergence/Divergence (MACD)

Syntax

```
[macdvec, nineperma] = macd(data)
[macdvec, nineperma] = macd(data, dim)
macdts = macd(tsobj, series_name)
```

Arguments

`data`	Data matrix
`dim`	Dimension. Default = 1 (column orientation).
`tsobj`	Financial time series object
`series_name`	Data series name

Description

`[macdvec, nineperma] = macd(data)` calculates the Moving Average Convergence/Divergence (MACD) line, `macdvec`, from the data matrix, data, as well as the nine-period exponential moving average, `nineperma`, from the MACD line.

When the two lines are plotted, they can give you an indication of whether to buy or sell a stock, when an overbought or oversold condition is occurring, and when the end of a trend might occur.

The MACD is calculated by subtracting the 26-period (7.5%) exponential moving average from the 12-period (15%) moving average. The 9-day (20%) exponential moving average of the MACD line is used as the *signal* line. For example, when the MACD and the 20% moving average line have just crossed and the MACD line falls below the other line, it is time to sell.

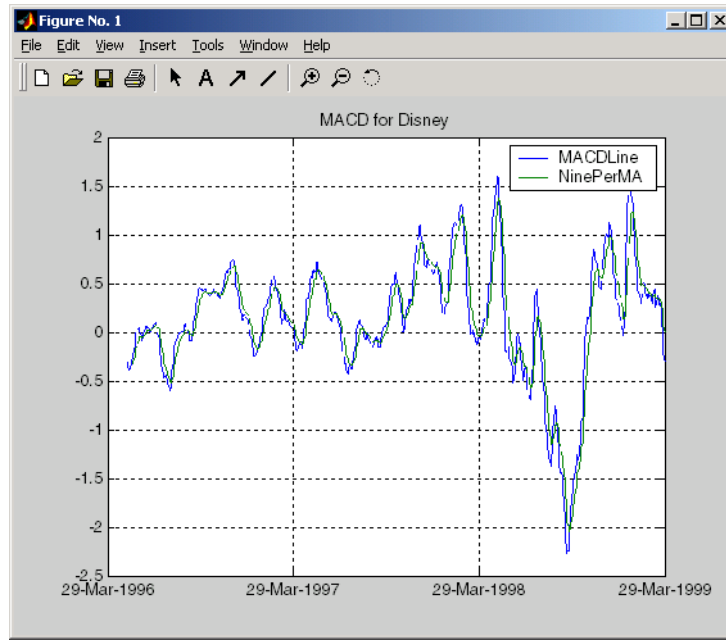
`[macdvec, nineperma] = macd(data, dim)` lets you specify the orientation direction for the input. If the input data is a matrix, you need to indicate whether each row is a set of observations (`dim = 2`) or each column is a set of observations (`dim = 1`, the default).

`macdts = macd(tsobj, series_name)` calculates the MACD line from the financial time series `tsobj`, as well as the nine-period exponential moving average from the MACD line. The MACD is calculated for the closing price series in tsobj, presumed to have been named `Close`. The result is stored in the financial time series object macdts. The macdts object has the same dates as the input object `tsobj` and contains only two series, named `MACDLine` and `NinePerMA`. The first series contains the values representing the MACD line and the second is the nine-period exponential moving average of the MACD line.

Examples

Compute the MACD for Disney stock and plot the results:

```
load disney.mat
dis_CloseMACD = macd(dis);
dis_OpenMACD = macd(dis, 'OPEN');
plot(dis_CloseMACD);
plot(dis_OpenMACD);
title('MACD for Disney')
```



See Also

`adline`, `willad`

Purpose

Maximum value

Syntax

```
tsmax = max(tsobj)
```

Description

`tsmax = max(tsobj)` finds the maximum value in each data series in the financial time series object tsobj and returns it in a structure `tsmax`. The `tsmax` structure contains field name(s) identical to the data series name(s).

Note `tsmax` returns only the values and does not return the dates associated with the values. The maximum values are not necessarily from the same date.

See Also

`min`

maxdrawdown

Purpose

Compute maximum drawdown for one or more price series

Syntax

```
MaxDD = maxdrawdown(Data)
MaxDD = maxdrawdown(Data, Format)
[MaxDD, MaxDDIndex] = maxdrawdown(Data, Format)
```

Arguments

`Data`	`T`-by-`N` matrix with `T` samples of `N` total return price series (also known as total equity).
`Format`	(Optional) MATLAB string indicating format of data. Possible values are: `'return'` (default): Maximum drawdown in terms of maximum percentage drop from a peak. `'arithmetic'`: Maximum drawdown of an arithmetic Brownian motion with drift (differences of data from peak to trough) using the equation $$dX(t) = \mu dt + \sigma dW(t)$$ `'geometric'`: Maximum drawdown of a geometric Brownian motion with drift (differences of log of data from peak to trough) using the equation $$dS(t) = \mu_0 S(t)dt + \sigma_0 S(t)dW(t)$$

Description

`MaxDD = maxdrawdown(Data, Format)` computes maximum drawdown for each series in an `N`-vector `MaxDD` and identifies start and end indexes of maximum drawdown periods for each series in a `2 x N` matrix `MaxDDIndex`.

To summarize the outputs of `maxdrawdown`:

- `MaxDD` is a `1`-by-`N` vector with maximum drawdown for each of `N` time series.

- `MaxDDIndex` is a `2`-by-`N` vector of start and end indexes for each maximum drawdown period for each total equity time series, where the first row contains the start indexes and the second row contains the end indexes of each maximum drawdown period.

Notes

- Drawdown is the percentage drop in total returns from the start to the end of a period. If the total equity time series is increasing over an entire period, drawdown is 0. Otherwise, it is a negative number. Maximum drawdown is an ex-ante proxy for downside risk that computes the largest drawdown over all intervals of time that can be formed within a specified interval of time.
- Maximum drawdown is sensitive to quantization error.

Example

See “Maximum Drawdown Example” on page 4-16.

References

Christian S. Pederson and Ted Rudholm-Alfvin, "Selecting a Risk-Adjusted Shareholder Performance Measure," *Journal of Asset Management*, Vol. 4, No. 3, 2003, pp. 152-172.

See Also

`emaxdrawdown`

Purpose Arithmetic average

Syntax

```
tsmean = mean(tsobj)
```

Description `tsmean = mean(tsobj)` computes the arithmetic mean of all data in all series in tsobj and returns it in a structure `tsmean`. The `tsmean` structure contains field name(s) identical to the data series name(s).

See Also `peravg`, `tsmovavg`

Purpose

Median price

Syntax

```
mprc = medprice(highp, lowp)
mprc = medprice([highp lowp])
mprcts = medprice(tsobj)
mprcts = medprice(tsobj, ParameterName, ParameterValue, ...)
```

Arguments

`highp`	High price (vector)
`lowp`	Low price (vector)
`tsobj`	Financial time series object
`ParameterName`	Valid parameter names are: • `HighName`: high prices series name • `LowName`: low prices series name
`ParameterValue`	Parameter values are the strings that represent the valid parameter names.

Description

`mprc = medprice(highp, lowp)` calculates the median prices `mprc` from the high (`highp`) and low (`lowp`) prices. The median price is the average of the high and low price for each period.

`mprc = medprice([highp lowp])` accepts a two-column matrix as the input rather than two individual vectors. The columns of the matrix represent the high and low prices, in that order.

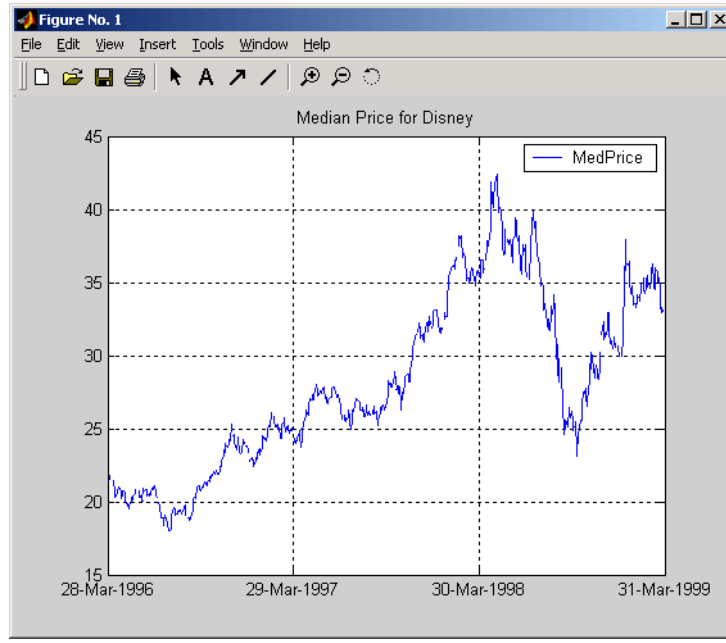
`mprcts = medprice(tsobj)` calculates the median prices of a financial time series object `tsobj`. The object must minimally contain the series `High` and `Low`. The median price is the average of the high and low price each period. `mprcts` is a financial time series object with the same dates as `tsobj` and the data series `MedPrice`.

`mprcts = medprice(tsobj, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Parameter values are the strings that represent the valid parameter names.

Examples

Compute the median price for Disney stock and plot the results:

```
load disney.mat
dis_MedPrice = medprice(dis)
plot(dis_MedPrice)
title('Median Price for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 177 -178.

Purpose

Merge multiple financial time series objects

Syntax

```
newfts = merge(fts1, fts2)
newfts = merge(fts1, fts2, ..., ftsx)
newfts = merge(fts1, fts2, ..., ftsx, 'PARAM1', VALUE1, 'PARAM2',
VALUE2, ...)
```

Arguments

`fts1, fts2, ...`	Comma-separated list of financial time series objects to merge.

Note Multiple Financial Time Series objects can be merged at once. The merged objects must appear in a comma separated list before the optional inputs. The order of the inputs is significant.

`'DateSetMethod'`	(Optional) Merge *`method`*. Valid merge values are: `'union'` or `'u'`: (Default) Returns the combined values of all merged objects. `'intersection'` or `'i'`: Returns the values common to all merged objects. `RefObf`: Maps all values to a reference time contained in a Financial Time Series object (`RefObj`) or vector of date numbers.

`'DataSetMethod'`	(Optional) Merge *`method`*. Valid merge values are: `'closest'`: (Default) Returns data based on the order of the inputs. However, the first missing data point (`NaN` value) of a date will be replaced by the closest non-`NaN` data point that appears on the same date of subsequent merged objects. `'order'`: Returns data based strictly on the order of the inputs.
`'SortColumns'`	(Optional) Sorts columns. Valid merge values are: `True/1`: Sorts the columns based on the headers (series names). The headers are sorted in alphabetical order. `False/0`: Columns are not sorted.

Description

`newfts = merge(fts1, fts2, ..., ftsx, 'PARAM1', VALUE1, 'PARAM2', VALUE2', ...)` merges multiple financial time series objects. The optional parameter and value pair argument specifies the values contained in the output financial time series object `ftsout`.

Examples

Example 1. Create three financial time series objects and merge them into a single object.

```
dates = {'jan-01-2001'; 'jan-02-2001'; 'jan-03-2001'; ...
         'jan-04-2001'; 'jan-06-2001'};
data = [1; 1; 1; 1; 1];
t1 = fints(dates, data);

dates = {'jan-02-2001'; 'jan-03-2001'; 'jan-04-2001';
         'jan-05-2001'};
data = [2; 2; 2; 2];
t2 = fints(dates, data);

dates = {'jan-03-2001'; 'jan-04-2001'; 'jan-05-2001';
         'jan-06-2001'};
```

```
data = [3; 3; 3; 3];
t3 = fints(dates, data);

t123 = merge(t1, t2, t3)

ans =

    desc:   ||  ||
    freq:  Unknown (0)

    'dates:  (6)'    'series1:  (6)'
    '01-Jan-2001'    [            1]
    '02-Jan-2001'    [            1]
    '03-Jan-2001'    [            1]
    '04-Jan-2001'    [            1]
    '05-Jan-2001'    [            2]
    '06-Jan-2001'    [            1]
```

If you change the order of input time series, the output may contain different data when duplicate dates exist. Here, for example, is the result of using the same three time series defined above but with the order changed.

```
merge(t3, t2, t1)

ans =

    desc:   ||  ||
    freq:  Unknown (0)

    'dates:  (6)'    'series1:  (6)'
    '01-Jan-2001'    [            1]
    '02-Jan-2001'    [            2]
    '03-Jan-2001'    [            3]
    '04-Jan-2001'    [            3]
    '05-Jan-2001'    [            3]
    '06-Jan-2001'    [            3]%
```

Note `t123` contains all 1s except on `'05-Jan-2001'` because `t1` appears first in the list of inputs and takes precedence. The same logic can be applied to`t321`.

By changing the order of inputs, you can overwrite old financial time series data with new data by placing the new time series ahead of the old one in the list of inputs to the `merge` function.

Example 2. Merging time series objects with different headers (series names).

```
dates = {'jan-01-2001'; 'jan-02-2001'; 'jan-03-2001'; ...
'jan-04-2001'; 'jan-06-2001'};
data = [1; 1; 1; 1; 1];
t4 = fints(dates, data, 'ts4');

dates = {'jan-02-2001'; 'jan-03-2001'; 'jan-04-2001'; 'jan-05-2001'};
data = [2; 2; 2; 2];
t5 = fints(dates, data, 'ts5');

t45 = merge(t4, t5)
t45 =
desc: ||
freq: Unknown (0)

'dates: (6)' 'ts4: (6)' 'ts5: (6)'
'01-Jan-2001' [ 1] [ NaN]
'02-Jan-2001' [ 1] [ 2]
'03-Jan-2001' [ 1] [ 2]
'04-Jan-2001' [ 1] [ 2]
'05-Jan-2001' [ NaN] [ 2]
'06-Jan-2001' [ 1]  [ NaN]
```

See Also

`horzcat`, `vertcat`

Purpose

Minimum value

Syntax

```
tsmin = min(tsobj)
```

Description

`tsmin = min(tsobj)` finds the minimum value in each data series in the financial time series object `tsobj` and returns it in the structure `tsmin`. The `tsmin` structure contains field name(s) identical to the data series name(s).

Note `tsmin` returns only the values and does not return the dates associated with the values. The minimum values are not necessarily from the same date.

See Also

`max`

minus

Purpose

Financial time series subtraction

Syntax

```
newfts = tsobj_1 - tsobj_2
newfts = tsobj - array
newfts = array - tsobj
```

Arguments

`tsobj_1, tsobj_2`	A pair of financial time series objects .
`array`	A scalar value or array with the number of rows equal to the number of dates in `tsobj` and the number of columns equal to the number of data series in `tsobj`.

Description

`minus` is an element-by-element subtraction of the components.

`newfts = tsobj_1 - tsobj_2` subtracts financial time series objects. If an object is to be subtracted from another object, both objects must have the same dates and data series names, although the order need not be the same. The order of the data series, when one financial time series object is subtracted from another, follows the order of the first object.

`newfts = tsobj - array` subtracts an array element by element from a financial time series object.

`newfts = array - tsobj` subtracts a financial time series object element by element from an array.

See Also

`rdivide`, `plus`, `times`

Purpose

Minute of date or time

Syntax

```
Minute = minute(Date)
```

Description

`Minute = minute(Date)` returns the minute given a serial date number or a date string.

Examples

```
Minute = minute(731204.5591223380)
```

or

```
Minute = minute('19-dec-2001, 13:25:08.17')
```

returns

```
Minute =

    25
```

See Also

`datevec`, `hour`, `second`

Purpose

Modified internal rate of return

Syntax

```
Return = mirr(CashFlow, FinRate, Reinvest)
```

Arguments

`CashFlow`	Vector of cash flows. The first entry is the initial investment.
`FinRate`	Finance rate for negative cash flow values. Enter as a decimal fraction.
`Reinvest`	Reinvestment rate for positive cash flow values, as a decimal fraction.

Description

`Return = mirr(CashFlow, FinRate, Reinvest)` calculates the modified internal rate of return for a series of periodic cash flows. This function calculates only positive rates of return; for nonpositive rates of return, `Return = 0`.

Examples

This cash flow represents the yearly income from an initial investment of $100,000. The finance rate is 9% and the reinvestment rate is 12%.

Year 1	$20,000
Year 2	($10,000)
Year 3	$30,000
Year 4	$38,000
Year 5	$50,000

To calculate the modified internal rate of return on the investment

```
Return = mirr([-100000 20000 -10000 30000 38000 50000], 0.09,...
0.12)
```

returns

```
Return =
         0.0832 (8.32%)
```

References

Brealey and Myers, *Principles of Corporate Finance*, Chapter 5

See Also

`annurate`, `effrr`, `irr`, `nomrr`, `pvvar`, `xirr`

month

Purpose

Month of date

Syntax

```
[MonthNum, MonthString] = month(Date)
```

Description

`[MonthNum, MonthString] = month(Date)` returns the month in numeric and string form given a serial date number or a date string.

Examples

```
[MonthNum, MonthString] = month(730368)
```

or

```
[MonthNum, MonthString] = month('05-Sep-1999')
```

returns

```
MonthNum =

      9

MonthString =

Sep
```

See Also

`datevec`, `day`, `year`

Purpose

Number of whole months between dates

Syntax

```
MyMonths = months(StartDate, EndDate, EndMonthFlag)
```

Arguments

`StartDate`	Enter as serial date numbers or date strings.
`EndDate`	Enter as serial date numbers or date strings.
`EndMonthFlag`	(Optional) end-of-month flag. If `StartDate` and `EndDate` are end-of-month dates and `EndDate` has fewer days than `StartDate`, `EndMonthFlag = 1` (default) treats `EndDate` as the end of a whole month, while `EndMonthFlag = 0` does not.

Description

`MyMonths = months(StartDate, EndDate, EndMonthFlag)` returns the number of whole months between `StartDate` and `EndDate`. If `EndDate` is earlier than `StartDate`, `MyMonths` is negative. Enter dates as serial date numbers or date strings.

Any input argument can contain multiple values, but if so, all other inputs must contain the same number of values or a single value that applies to all. For example, if `StartDate` is an *n*-row character array of date strings, then `EndDate` must be an *n*-row character array of date strings or a single date. `MyMonths` is then an *n*-by-1 vector of numbers.

Examples

```
MyMonths = months('may 31 2000', 'jun 30 2000', 1)
MyMonths =
         1

MyMonths = months('may 31 2000','jun 30 2000', 0)
MyMonths =
         0
```

```
Dates = ['mar 31 2002'; 'apr 30 2002'; 'may 31 2002'];
MyMonths = months(Dates, 'jun 30 2002')
MyMonths =
         3
         2
         1
```

See Also

yearfrac

Purpose

Leading and lagging moving averages chart

Syntax

```
movavg(Asset, Lead, Lag, Alpha)
[Short, Long] = movavg(Asset, Lead, Lag, Alpha)
```

Arguments

`Asset`	Security data, a vector of time-series prices.
`Lead`	Number of samples to use in leading average calculation. A positive integer. `Lead` must be less than or equal to `Lag`.
`Lag`	Number of samples to use in the lagging average calculation. A positive integer.
`Alpha`	(Optional) Control parameter that determines the type of moving averages. 0 = simple moving average (default), 0.5 = square root weighted moving average, 1 = linear moving average, 2 = square weighted moving average, and so on. To calculate the exponential moving average, set `Alpha ='e'`.

Description

`movavg(Asset, Lead, lag, Alpha)` plots leading and lagging moving averages.

`[Short, Long] = movavg(Asset, Lead, lag, Alpha)` returns the leading `Short` and lagging `Long` moving average data without plotting it.

Examples

If asset `A` is a vector of stock price data from `01/01/2006` to `02/01/2006`

```
>> A(:,2)

ans =

    8.6500
```

```
    9.0000
    8.8500
    9.3500
    9.5000
    9.3500
    9.2500
    9.7000
    9.9500
   10.5000
   10.1000
    9.9000
   10.0000
    9.9000
    9.6000
    9.7000
    9.8000
    9.7000
    9.9500
   10.1500
    9.8500
    9.9000
   10.2000
   10.0000
    9.9500
    9.8500
    9.9500
   10.0000
   10.0000
   10.5400
   10.5900
   11.1900
   11.0400
   11.0900
   10.7400
   10.3500
   10.2500
   10.4500
```

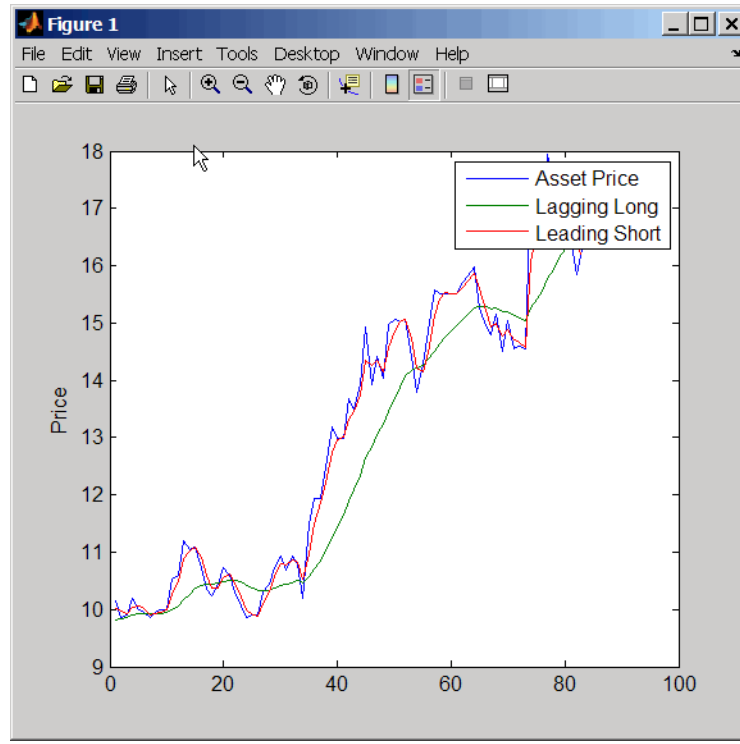
```
10.7400
10.5900
10.3000
10.0500
 9.8500
 9.9000
 9.9000
10.3000
10.4500
10.7400
10.9400
10.6900
10.9400
10.7900
10.2000
11.4900
11.9400
11.9400
12.4800
13.1800
12.9800
12.9800
13.6800
13.4800
13.9300
14.9200
13.9300
14.4200
14.0300
14.9700
15.0700
15.0200
15.0700
14.4200
13.7800
14.2800
14.8700
```

```
15.5700
15.5200
15.5200
15.5200
15.5200
15.7200
15.8200
15.9700
15.2700
14.9500
14.8000
15.1500
14.5000
15.0500
14.5500
14.6000
14.5500
17.5500
16.7000
16.8000
17.9500
17.3000
17.6000
17.5500
16.5000
15.8500
16.3000
```

then the moving average is

```
[Short,Long]= movavg(A(:,2),3,20,1);
movavg(A(:,2),3,20,1);
ylabel('Price')
legend('Asset Price','Lagging Long','Leading Short')
```

this plots linear three-sample leading and 20-sample lagging moving averages



See Also

`bolling`, `candle`, `dateaxis`, `highlow`, `pointfig`

mrdivide

Purpose

Financial time series matrix division

Syntax

```
newfts = tsobj_1 / tsobj_2
newfts = tsobj / array
newfts = array / tsobj
```

Arguments

`tsobj_1, tsobj_2`	A pair of financial time series objects.
`array`	A scalar value or array with number of rows equal to the number of dates in `tsobj` and number of columns equal to the number of data series in `tsobj`.

Description

The `mrdivide` method divides element by element the components of one financial time series object by the components of the other. You can also divide the whole object by an array or divide a financial time series object into an array.

If an object is to be divided by another object, both objects must have the same dates and data series names, although the order need not be the same. The order of the data series, when an object is divided by another object, follows the order of the first object.

`newfts = tsobj_1 / tsobj_2` divides financial time series objects element by element.

`newfts = tsobj / array` divides a financial time series object element by element by an array.

`newfts = array / tsobj` divides an array element by element by a financial time series object.

For financial time series objects, the `mrdivide` operation is identical to the `rdivide` operation.

See Also

`minus`, `plus`, `rdivide`, `times`

mtimes

Purpose

Financial time series matrix multiplication

Syntax

```
newfts = tsobj_1 * tsobj_2
newfts = tsobj * array
newfts = array * tsobj
```

Arguments

`tsobj_1, tsobj_2`	A pair of financial time series objects.
`array`	A scalar value or array with number of rows equal to the number of dates in `tsobj` and number of columns equal to the number of data series in `tsobj`.

Description

The `mtimes` method multiplies element by element the components of one financial time series object by the components of the other. You can also multiply the entire object by an array.

If an object is to be multiplied by another object, both objects must have the same dates and data series names, although the order need not be the same. The order of the data series, when an object is multiplied by another object, follows the order of the first object.

`newfts = tsobj_1 * tsobj_2` multiplies financial time series objects element by element.

`newfts = tsobj * array` multiplies a financial time series object element by element by an array.

`newfts = array * tsobj` `newfts = array / tsobj` multiplies an array element by element by a financial time series object.

For financial time series objects, the `mtimes` operation is identical to the `times` operation.

See Also

`minus`, `mrdivide`, `plus`, `times`

Purpose

Fisher information matrix for multivariate normal or least-squares regression

Syntax

```
Fisher = mvnrfish(Data, Design, Covariance, MatrixFormat,
CovarFormat)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. If a data sample has missing values, represented as `NaN`s, the sample is ignored.
`Design`	A matrix or a cell array that handles two model structures: • If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series. • If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values. If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.

`Covariance`	`NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance of the residuals of the regression.
`MatrixFormat`	(Optional) String that identifies parameters to be included in the Fisher information matrix: • `full` - Default format. Compute the full Fisher information matrix for both model and covariance parameter estimates. • `paramonly` - Compute only components of the Fisher information matrix associated with the model parameter estimates.
`CovarFormat`	(Optional) String that specifies the format for the covariance matrix. The choices are: • `'full'` - Default method. The covariance matrix is a full matrix. • `'diagonal'` - The covariance matrix is a diagonal matrix.

Description

`Fisher = mvnrfish(Data, Design, Covariance, MatrixFormat, CovarFormat)` computes a Fisher information matrix based on current maximum likelihood or least-squares parameter estimates.

`Fisher` is a `TOTALPARAMS`-by-`TOTALPARAMS` Fisher information matrix. The size of `TOTALPARAMS` depends on `MatrixFormat` and on current parameter estimates. If `MatrixFormat = 'full'`,

```
TOTALPARAMS = NUMPARAMS + NUMSERIES * (NUMSERIES + 1)/2
```

If `MatrixFormat = 'paramonly'`,

```
TOTALPARAMS = NUMPARAMS
```

Note `mvnrfish` operates slowly if you calculate the full Fisher information matrix.

Example

See "Multivariate Normal Linear Regression" on page 5-3.

See Also

`mvnrstd`, `mvnrmle`

mvnrmle

Purpose

Multivariate normal regression (ignore missing data)

Syntax

```
[Parameters, Covariance, Resid, Info] = mvnrmle(Data, Design,
MaxIterations, TolParam, TolObj, Covar0, CovarFormat)
```

Arguments

`Data`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. If a data sample has missing values, represented as `NaN`s, the sample is ignored. (Use `ecmmvnrmle` to handle missing data.)
`Design`	Matrix or a cell array that handles two model structures: • If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series. • If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values. If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.
`MaxIterations`	(Optional) Maximum number of iterations for the estimation algorithm. Default value is 100.

`TolParam`

(Optional) Convergence tolerance for estimation algorithm based on changes in model parameter estimates. Default value is `sqrt(eps)` which is about 1.0e-8 for double precision. The convergence test for changes in model parameters is

$$\left\|\mathbf{P}\mathrm{aram}_k - \mathbf{P}\mathrm{aram}_{k-1}\right\| < \mathbf{T}\mathrm{ol}\mathbf{P}\mathrm{aram} \times \left(1 + \left\|\mathbf{P}\mathrm{aram}_k\right|\right)$$

where `Param` represents the output `Parameters`, and iteration $k = 2, 3, \ldots$. Convergence is assumed when both the `TolParam` and `TolObj` conditions are satisfied. If both `TolParam` $\leq$ `0` and `TolObj` $\leq$ `0`, do the maximum number of iterations (`MaxIterations`), whatever the results of the convergence tests.

`TolObj`

(Optional) Convergence tolerance for estimation algorithm based on changes in the objective function. Default value is $\mathrm{eps} \wedge 3/4$ which is about 1.0e-12 for double precision. The convergence test for changes in the objective function is

$$\left|\mathbf{O}\mathrm{bj}_k - \mathbf{O}\mathrm{bj}_{k-1}\right| < \mathbf{T}\mathrm{ol}\mathbf{O}\mathrm{bj} \times \left(1 + \left|\mathbf{O}\mathrm{bj}_k\right|\right)$$

for iteration $k = 2, 3, \ldots$. Convergence is assumed when both the `TolParam` and `TolObj` conditions are satisfied. If both `TolParam` $\leq$ `0` and `TolObj` $\leq$ `0`, do the maximum number of iterations (`MaxIterations`), whatever the results of the convergence tests.

`Covar0`	(Optional) `NUMSERIES`-by-`NUMSERIES` matrix that contains a user-supplied initial or known estimate for the covariance matrix of the regression residuals.
`CovarFormat`	(Optional) String that specifies the format for the covariance matrix. The choices are: • `'full'` - Default method. Compute the full covariance matrix. • `'diagonal'` - Force the covariance matrix to be a diagonal matrix.

Description

`[Parameters, Covariance, Resid, Info] = mvnrmle(Data, Design, MaxIterations, TolParam, TolObj, Covar0, CovarFormat)` estimates a multivariate normal regression model without missing data. The model has the form

$$\mathrm{Data}_k \sim N(\mathrm{Design}_k \times \mathrm{Parameters}, \mathrm{Covariance})$$

for samples $k = 1, \ldots, \mathrm{NUMSAMPLES}$.

`mvnrmle` estimates a `NUMPARAMS`-by-`1` column vector of model parameters called `Parameters`, and a `NUMSERIES`-by-`NUMSERIES` matrix of covariance parameters called `Covariance`.

`mvnrmle(Data, Design)` with no output arguments plots the log-likelihood function for each iteration of the algorithm.

To summarize the outputs of `mvnrmle`:

- `Parameters` is a `NUMPARAMS`-by-`1` column vector of estimates for the parameters of the regression model.
- `Covariance` is a `NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance of the regression model's residuals.

- `Resid` is a `NUMSAMPLES`-by-`NUMSERIES` matrix of residuals from the regression. For any row with missing values in `Data`, the corresponding row of residuals is represented as all `NaN` missing values, since this routine ignores rows with `NaN` values.

Another output, `Info`, is a structure that contains additional information from the regression. The structure has these fields:

- `Info.Obj` – A variable-extent column vector, with no more than `MaxIterations` elements, that contains each value of the objective function at each iteration of the estimation algorithm. The last value in this vector, `Obj(end)`, is the terminal estimate of the objective function. If you do maximum likelihood estimation, the objective function is the log-likelihood function.
- `Info.PrevParameters` – `NUMPARAMS`-by-1 column vector of estimates for the model parameters from the iteration just before the terminal iteration.
- `Info.PrevCovariance` – `NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance parameters from the iteration just before the terminal iteration.

Notes

`mvnrmle` does not accept an initial parameter vector, because the parameters are estimated directly from the first iteration onward.

You can configure `Design` as a matrix if `NUMSERIES = 1` or as a cell array if `NUMSERIES` $\geq$ `1`.

- If `Design` is a cell array and `NUMSERIES` = 1, each cell contains a `NUMPARAMS` row vector.
- If `Design` is a cell array and `NUMSERIES` > 1, each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix.

These points concern how `Design` handles missing data:

- Although `Design` should not have `NaN` values, ignored samples due to `NaN` values in `Data` are also ignored in the corresponding `Design` array.
- If `Design` is a `1`-by-`1` cell array, which has a single `Design` matrix for each sample, no `NaN` values are permitted in the array. A model with this structure must have `NUMSERIES` ≥ `NUMPARAMS` with `rank(Design{1}) = NUMPARAMS`.
- Two functions for handling missing data, `ecmmvnrmle` and `ecmlsrmle`, are stricter about the presence of `NaN` values in `Design`.

Use the estimates in the optional output structure `Info` for diagnostic purposes.

Examples

See "Multivariate Normal Regression" on page 5-17, "Least-Squares Regression" on page 5-18, "Covariance-Weighted Least Squares" on page 5-19, "Feasible Generalized Least Squares" on page 5-20, and "Seemingly Unrelated Regression" on page 5-21.

References

Roderick J. A. Little and Donald B. Rubin, *Statistical Analysis with Missing Data*, 2nd ed., John Wiley & Sons, Inc., 2002.

Xiao-Li Meng and Donald B. Rubin, "Maximum Likelihood Estimation via the ECM Algorithm," *Biometrika*, Vol. 80, No. 2, 1993, pp. 267-278.

See Also

`ecmmvnrmle`, `mvnrstd`, `mvnrobj`

Purpose

Log-likelihood function for multivariate normal regression without missing data

Syntax

```
Objective = mvnrobj(Data, Design, Parameters, Covariance,
CovarFormat)
```

Arguments

`Data`

`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. If a data sample has missing values, represented as `NaN`s, the sample is ignored. (Use `ecmmvnrmle` to handle missing data.)

`Design`

A matrix or a cell array that handles two model structures:

- If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series.
- If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values.

  If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.

`Parameters`

`NUMPARAMS`-by-`1` column vector of estimates for the parameters of the regression model.

`Covariance`	`NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance of the residuals of the regression.
`CovarFormat`	(Optional) String that specifies the format for the covariance matrix. The choices are: • `'full'` - Default method. The covariance matrix is a full matrix. • `'diagonal'` - The covariance matrix is a diagonal matrix.

Description

`Objective = mvnrobj(Data, Design, Parameters, Covariance, CovarFormat)` computes the log-likelihood function based on current maximum likelihood parameter estimates without missing data. `Objective` is a scalar that contains the log-likelihood function.

Notes

You can configure `Design` as a matrix if `NUMSERIES = 1` or as a cell array if `NUMSERIES` $\geq$ `1`.

- If `Design` is a cell array and `NUMSERIES` = 1, each cell contains a `NUMPARAMS` row vector.
- If `Design` is a cell array and `NUMSERIES` > 1, each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix.

Although `Design` should not have `NaN` values, ignored samples due to `NaN` values in `Data` are also ignored in the corresponding `Design` array.

Examples

See “Multivariate Normal Regression” on page 5-17, “Least-Squares Regression” on page 5-18, “Covariance-Weighted Least Squares” on page 5-19, “Feasible Generalized Least Squares” on page 5-20, and “Seemingly Unrelated Regression” on page 5-21.

See Also

`ecmmvnrmle`, `ecmmvnrobj`, `mvnrmle`

Purpose

Evaluate standard errors for multivariate normal regression model

Syntax

```
[StdParameters, StdCovariance] = mvnrstd(Data, Design, Covariance,
CovarFormat)
```

Arguments

`Data`

`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` samples of a `NUMSERIES`-dimensional random vector. If a data sample has missing values, represented as `NaN`s, the sample is ignored. (Use `ecmmvnrmle` to handle missing data.)

`Design`

A matrix or a cell array that handles two model structures:

- If `NUMSERIES = 1`, `Design` is a `NUMSAMPLES`-by-`NUMPARAMS` matrix with known values. This structure is the standard form for regression on a single series.
- If `NUMSERIES` $\geq$ `1`, `Design` is a cell array. The cell array contains either one or `NUMSAMPLES` cells. Each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix of known values.

  If `Design` has a single cell, it is assumed to have the same `Design` matrix for each sample. If `Design` has more than one cell, each cell contains a `Design` matrix for each sample.

`Covariance`	`NUMSERIES`-by-`NUMSERIES` matrix of estimates for the covariance of the regression residuals.
`CovarFormat`	(Optional) String that specifies the format for the covariance matrix. The choices are: • `'full'` - Default method. The covariance matrix is a full matrix. • `'diagonal'` - The covariance matrix is a diagonal matrix.

Description

`[StdParameters, StdCovariance] = mvnrstd(Data, Design, Covariance, CovarFormat)` evaluates standard errors for a multivariate normal regression model without missing data. The model has the form

$$\mathrm{Data}_k \sim N(\mathrm{Design}_k \times \mathrm{Parameters}, \mathrm{Covariance})$$

for samples $k = 1, \ldots$, `NUMSAMPLES`.

`mvnrstd` computes two outputs:

- `StdParameters` is a `NUMPARAMS`-by-`1` column vector of standard errors for each element of `Parameters`, the vector of estimated model parameters.
- `StdCovariance` is a `NUMSERIES`-by-`NUMSERIES` matrix of standard errors for each element of `Covariance`, the matrix of estimated covariance parameters.

Note `mvnrstd` operates slowly when you calculate the standard errors associated with the covariance matrix `Covariance`.

Notes

You can configure `Design` as a matrix if `NUMSERIES = 1` or as a cell array if `NUMSERIES` $\geq$ `1`.

- If `Design` is a cell array and `NUMSERIES` = 1, each cell contains a `NUMPARAMS` row vector.
- If `Design` is a cell array and `NUMSERIES` > 1, each cell contains a `NUMSERIES`-by-`NUMPARAMS` matrix.

Examples

See "Multivariate Normal Regression" on page 5-17, "Least-Squares Regression" on page 5-18, "Covariance-Weighted Least Squares" on page 5-19, "Feasible Generalized Least Squares" on page 5-20, and "Seemingly Unrelated Regression" on page 5-21.

References

Roderick J. A. Little and Donald B. Rubin, *Statistical Analysis with Missing Data*, 2nd ed., John Wiley & Sons, Inc., 2002.

See Also

`ecmmvnrmle`, `ecmmvnrstd` , `mvnrmle`

Purpose

Covariance ignoring NaNs

Syntax

```
c = nancov(X)
c = nancov(..., 'pairwise')
```

Arguments

X	Financial times series object.
Y	Financial times series object.

Description

nancov for financial times series objects is based on the Statistics Toolbox function nancov. See nancov in the Statistics Toolbox documentation.

c = nancov(X), if X is a financial time series object with one series and returns the sample variance of the values in X, treating NaNs as missing values. For a financial time series object containing more than one series, where each row is an observation and each series a variable, nancov(X) is the covariance matrix computing using rows of X that do not contain any NaN values. nancov(X,Y), where X and Y are financial time series objects with the same number of elements, is equivalent to nancov([X(:) Y(:)]).

nancov(X) or nancov(X,Y) normalizes by (N-1) if N >1, where N is the number of observations after removing missing values. This makes nancov the best unbiased estimate of the covariance matrix if the observations are from a normal distribution. For N = 1, cov normalizes by N.

nancov(X,1) or nancov(X,Y,1) normalizes by N and produces the second moment matrix of the observations about their mean. nancov(X,Y,0) is the same as nancov(X,Y), and nancov(X,0) is the same as nancov(X).

c = nancov(..., 'pairwise') computes c(*i,j*) using rows with no NaN values in columns *i* or *j*. The result may not be a positive definite

matrix. `c = nancov(..., 'complete')` is the default, and it omits rows with any `NaN` values, even if they are not in column *i* or *j*. The mean is removed from each column before calculating the result.

Examples

To generate random data having nonzero covariance between column 4 and the other columns:

```
x = randn(30, 4);                 % uncorrelated data
x(:, 4) = sum(x, 2);              % introduce correlation
x(2, 3) = NaN;                    % introduce one missing value
f = fints((today:today+29)', x);  % create a fints object using x
c = nancov(f)                     % compute sample covariance
```

See Also

`cov`, `nanvar`, `var`

nanmax

Purpose

Maximum ignoring NaNs

Syntax

```
m = nanmax(X)
[m,ndx] = nanmax(X)
m = nanmax(X,Y)
[m,ndx] = nanmax(X,[],DIM)
```

Arguments

X	Financial times series object.
Y	Financial times series object or scalar.
DIM	Dimension of X.

Description

nanmax for financial times series objects is based on the Statistics Toolbox function nanmax. See nanmax in the Statistics Toolbox documentation.

m = nanmax(X) returns the maximum of a financial time series object X with NaNs treated as missing. m is the largest non-NaN element in X.

[m,ndx] = nanmax(X) returns the indices of the maximum values in X. If the values along the first nonsingleton dimension contain multiple maximal elements, the index of the first one is returned.

m = nanmax(X,Y) returns an array the same size as X and Y with the largest elements taken from X or Y. Only Y can be a scalar double.

[m,ndx] = nanmax(X,[],DIM) operates along the dimension DIM.

Examples

To compute nanmax for the following dates:

```
dates = {'01-Jan-2007';'02-Jan-2007';'03-Jan-2007'};
f = fints(dates, magic(3));
f.series1(1) = nan;
f.series2(3) = nan;
```

```
f.series3(2) = nan;

[nmax, maxidx] = nanmax(f)

nmax =
     4     5     6

maxidx =
     3     2     1
```

See Also

max, nanmean, nanmedian, nanmin, nanstd, nanvar

nanmean

Purpose

Mean ignoring NaNs

Syntax

```
m = nanmean(X)
m = nanmean(X,DIM)
```

Arguments

X	Financial times series object.
DIM	Dimension along which the operation is conducted.

Description

nanmean for financial times series objects is based on the Statistics Toolbox function nanmean. See nanmean in the Statistics Toolbox documentation.

m = nanmean(X) returns the sample mean of a financial time series object X, treating NaNs as missing values. m is a row vector containing the mean value of the non-NaN elements in each series.

m = nanmean(X,DIM) takes the mean along dimension DIM of X.

Examples

To compute nanmean for the following dates:

```
dates = {'01-Jan-2007';'02-Jan-2007';'03-Jan-2007'};
f = fints(dates, magic(3));
f.series1(1) = nan;
f.series2(3) = nan;
f.series3(2) = nan;

nmean = nanmean(f)

nmean =

    3.5000    3.0000    4.0000
```

See Also

mean, nanmax, nanmin, nanstd, nansum, nanvar

Purpose

Median ignoring NaNs

Syntax

```
m = nanmedian(X)
m = nanmedian(X,DIM)
```

Arguments

X	Financial times series object.
DIM	Dimension along which the operation is condcuted.

Description

nanmedian for financial times series objects is based on the Statistics Toolbox function nanmedian. See nanmedian in the Statistics Toolbox documentation.

m = nanmedian(X) returns the sample median of a financial time series object X, treating NaNs as missing values. m is a row vector containing the median value of non-NaN elements in each column.

m = nanmedian(X,DIM) takes the median along the dimension DIM of X.

Examples

To compute nanmedian for the following dates:

```
dates = {'01-Jan-2007';'02-Jan-2007';'03-Jan-2007';'04-Jan-2007'};
f = fints(dates, magic(4));
f.series1(1) = nan;
f.series2(2) = nan;
f.series3([1 3]) = nan;

nmedian = nanmedian(f)

nmedian =
    5.0000    7.0000   12.5000   10.0000
```

See Also

mean, nanmax, nanmin, nanstd, nansum, nanvar

nanmin

Purpose

Minimum ignoring NaNs

Syntax

```
m = nanmin(X)
[m,ndx] = nanmin(X)
m = nanmin(X,Y)
[m,ndx] = nanmin(X,[],DIM)
```

Arguments

X	Financial times series object.
Y	Financial times series object or scalar.
DIM	Dimension along which the operation is conducted.

Description

nanmin for financial times series objects is based on the Statistics Toolbox function nanmin. See nanmin in the Statistics Toolbox documentation.

m = nanmin(X) returns the minimum of a financial time series object X with NaNs treated as missing. m is the smallest non-NaN element in X.

[m,ndx] = nanmin(X) returns the indices of the minimum values in X. If the values along the first nonsingleton dimension contain multiple elements, the index of the first one is returned.

m = nanmin(X,Y) returns an array the same size as X and Y with the smallest elements taken from X or Y. Only Y can be a scalar double.

[m,ndx] = nanmin(X, [], DIM) operates along the dimension DIM.

Examples

To compute nanmin for the following dates:

```
dates = {'01-Jan-2007';'02-Jan-2007';'03-Jan-2007'};
f = fints(dates, magic(3));
f.series1(1) = nan;
f.series2(3) = nan;
f.series3(2) = nan;
```

```
[nmin, minidx] = nanmin(f)
nmin =
     3     1     2
minidx =
     2     1     3
```

See Also

mean, nanmax, nanstd, nanvar

nanstd

Purpose

Standard deviation ignoring NaNs

Syntax

```
y = nanstd(X)
y = nanstd(X,1)
y = nanstd(X,FLAG,DIM)
```

Arguments

X	Financial times series object.
FLAG	Normalization flag.
DIM	Dimension along which the operation is conducted.

Description

nanstd for financial times series objects is based on the Statistics Toolbox function nanstd. See nanstd in the Statistics Toolbox documentation.

y = nanstd(X) returns the sample standard deviation of the values in a financial time series object X, treating NaNs as missing values. y is the standard deviation of the non-NaN elements of X.

nanstd normalizes y by (N – 1), where N is the sample size. This is the square root of an unbiased estimator of the variance of the population from which X is drawn, as long as X consists of independent, identically distributed samples and data are missing at random.

y = nanstd(X,1) normalizes by N and produces the square root of the second moment of the sample about its mean. nanstd(X,0) is the same as nanstd(X).

y = nanstd(X,flag,dim) takes the standard deviation along the dimension dim of X. Set the value of flag to 0 to normalize the result by n – 1; set the value of flag to 1 to normalize the result by n.

Examples

To compute nanstd for the following dates:

```
dates = {'01-Jan-2007';'02-Jan-2007';'03-Jan-2007'};
```

```
f = fints(dates, magic(3));
f.series1(1) = nan;
f.series2(3) = nan;
f.series3(2) = nan;

nstd = nanstd(f)
```

See Also

nanmax, nanmean, nanmedian, nanmin, nanvar, std

nansum

Purpose

Sum ignoring NaNs

Syntax

```
y = nansum(X)
y = nansum(X,DIM)
```

Arguments

X	Financial time series object.
DIM	Dimension along which the operation is conducted.

Description

nansum for financial times series objects is based on the Statistics Toolbox function nansum. See nansum in the Statistics Toolbox documentation.

y = nansum(X) returns the sum of a financial time series object X, treating NaNs as missing values. y is the sum of the non-NaN elements in X.

y = nansum(X,DIM) takes the sum along dimension DIM of X.

Examples

To compute nansum for the following dates:

```
dates = {'01-Jan-2007';'02-Jan-2007';'03-Jan-2007'};
f = fints(dates, magic(3));
f.series1(1) = nan;
f.series2(3) = nan;
f.series3(2) = nan;

nsum = nansum(f)

nsum =
     7     6     8
```

See Also

nanmax, nanmean, nanmedian, nanmin, nanstd, nanvar

Purpose

Variance ignoring NaNs

Syntax

```
y = nanvar(X)
y = nanvar(X,1)
y = nanvar(X,W)
y = nanvar(X,W,DIM)
```

Arguments

X	Financial times series object.
W	Weight vector.
DIM	Dimension along which the operation is conducted.

Description

nanvar for financial times series objects is based on the Statistics Toolbox function nanvar. See nanvar in the Statistics Toolbox documentation.

y = nanvar(X) returns the sample variance of the values in a financial time series object X, treating NaNs as missing values. y is the variance of the non-NaN elements of each series in X.

nanvar normalizes y by N – 1 if N > 1, where N is the sample size of the non-NaN elements. This is an unbiased estimator of the variance of the population from which X is drawn, as long as X consists of independent, identically distributed samples, and data are missing at random. For N = 1, y is normalized by N.

y = nanvar(X,1) normalizes by N and produces the second moment of the sample about its mean. nanvar(X, 0) is the same as nanvar(X).

y = nanvar(X,W) computes the variance using the weight vector W. The length of W must equal the length of the dimension over which nanvar operates, and its non-NaN elements must be nonnegative. Elements of X corresponding to NaN elements of Ware ignored.

y = nanvar(X,W,DIM) takes the variance along dimension DIM of X.

Examples

To compute nanvar:

```
f = fints((today:today+1)', [4 -2 1; 9  5 7])
f.series1(1) = nan;
f.series3(2) = nan;

nvar = nanvar(f)

nvar =
         0   24.5000         0
```

See Also

nanmax, nanmean, nanmedian, nanmin, nanstd, var

Purpose

Negative volume index

Syntax

```
nvi = negvolidx(closep, tvolume, initnvi)
nvi = negvolidx([closep tvolume], initnvi)
nvits = negvolidx(tsobj)
nvits = negvolidx(tsobj, initnvi, ParameterName, ParameterValue,
...)
```

Arguments

`closep`	Closing price (vector).
`tvolume`	Volume traded (vector).
`initnvi`	(Optional) Initial value for negative volume index (Default = 100).
`tsobj`	Financial time series object.
`ParameterName`	Valid parameter names are: • `CloseName`: closing prices series name • `VolumeName`: volume traded series name
`ParameterValue`	Parameter values are the strings that represent the valid parameter names.

Description

`nvi = negvolidx(closep, tvolume, initnvi)` calculates the negative volume index from a set of stock closing prices (`closep`) and volume traded (`tvolume`) data. `nvi` is a vector representing the negative volume index. If `initnvi` is specified, `negvolidx` uses that value instead of the default (100).

`nvi = negvolidx([closep tvolume], initnvi)` accepts a two-column matrix, the first column representing the closing prices (`closep`) and the second representing the volume traded (`tvolume`). If `initnvi` is specified, `negvolidx` uses that value instead of the default (100).

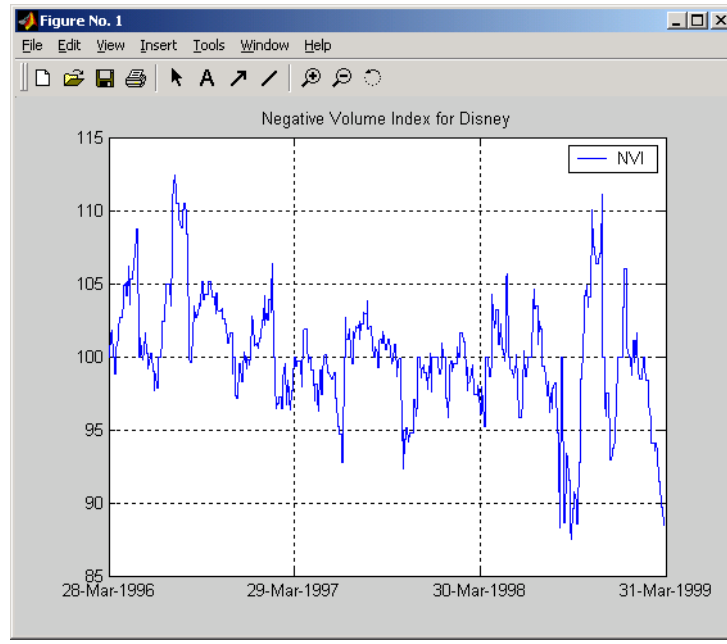
`nvits = negvolidx(tsobj)` calculates the negative volume index from the financial time series object `tsobj`. The object must contain, at least, the series `Close` and `Volume`. The `nvits` output is a financial time series object with dates similar to `tsobj` and a data series named `NVI`. The initial value for the negative volume index is arbitrarily set to 100.

`nvits = negvolidx(tsobj, initnvi, ParameterName, ParameterValue, ...)` accepts parameter name/ parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Parameter values are the strings that represent the valid parameter names.

Examples

Compute the negative volume index for Disney stock and plot the results:

```
load disney.mat
dis_NegVol = negvolidx(dis)
plot(dis_NegVol)
title('Negative Volume Index for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 193 - 194.

See Also

`onbalvol`, `posvolidx`

Purpose

Nominal rate of return

Syntax

```
Return = nomrr(Rate, NumPeriods)
```

Arguments

`Rate`	Effective annual percentage rate. Enter as a decimal fraction.
`NumPeriods`	Number of compounding periods per year, an integer.

Description

`Return = nomrr(Rate, NumPeriods)` calculates the nominal rate of return.

Examples

To find the nominal annual rate of return based on an effective annual percentage rate of 9.38% compounded monthly

```
Return = nomrr(0.0938, 12)
```

returns

```
Return =
          0.0900 (9.0%)
```

See Also

`effrr`, `irr`, `mirr`, `taxedrr`, `xirr`

Purpose

Current date and time

Syntax

```
t = now
```

Description

`t = now` returns the current date and time as a serial date number. To return the time only, use `rem(now,1)`. To return the date only, use `floor(now)`.

Examples

```
t1 = now, t2 = rem(now,1)

t1 =

   7.2908e+05


t2 =

    0.4013
```

See Also

`date`, `datenum`, `today`

nweekdate

Purpose

Date of specific occurrence of weekday in month

Syntax

```
Date = nweekdate(n, Weekday, Year, Month, Same)
```

Arguments

`n`	Nth occurrence of the weekday in a month. Enter as integer from 1 through 5.
`Weekday`	Weekday whose date you seek. Enter as integer from 1 through 7.
	`1` Sunday
	`2` Monday
	`3` Tuesday
	`4` Wednesday
	`5` Thursday
	`6` Friday
	`7` Saturday
`Year`	Year. Enter as a four-digit integer.
`Month`	Month. Enter as an integer from 1 through 12.
`Same`	(Optional) Weekday that must occur in the same week with `Weekday`. Enter as an integer from 0 through 7, where 0 = ignore (default) and 1 through 7 are as for `Weekday`.

Description

`Date = nweekdate(n, Weekday, Year, Month, Same)` returns the serial date number for the specific occurrence of the weekday in the given year and month, and in a week that also contains the weekday `Same`.

If `n` is larger than the last occurrence of `Weekday`, `Date = 0`.

Any input can contain multiple values, but if so, all other inputs must contain the same number of values or a single value that applies to all. For example, if `Year` is a 1-by-n vector of integers, then `Month` must be a 1-by-n vector of integers or a single integer. `Date` is then a 1-by-n vector of date numbers.

Use the function `datestr` to convert serial date numbers to formatted date strings.

Examples

To find the first Thursday in May 2001

```
Date = nweekdate(1, 5, 2001, 5); datestr(Date)

ans =

03-May-2001
```

To find the first Thursday in a week that also contains a Wednesday in May 2001

```
Date = nweekdate(2, 5, 2001, 5, 4); datestr(Date)

ans =

10-May-2001
```

To find the third Monday in February for 2001, 2002, and 2003

```
Year = [2001:2003];

Date = nweekdate(3, 2, Year, 2)

Date =
       730901      731265      731629

datestr(Date)

ans =
```

```
19-Feb-2001
18-Feb-2002
17-Feb-2003
```

See Also

fbusdate, lbusdate, lweekdate

Purpose

On-Balance Volume (OBV)

Syntax

```
obv = onbalvol(closep, tvolume)
obv = onbalvol([closep tvolume])
obvts = onbalvol(tsobj)
obvts = onbalvol(tsobj, ParameterName, ParameterValue, ...)
```

Arguments

`closep`	Closing price (vector)
`tvolume`	Volume traded
`tsobj`	Financial time series object

Description

`obv = onbalvol(closep, tvolume)` calculates the On-Balance Volume (OBV) from the stock closing price (`closep`) and volume traded (`tvolume`) data.

`obv = onbalvol([closep tvolume])` accepts a two-column matrix representing the closing price (`closep`) and volume traded (`tvolume`), in that order.

`obvts = onbalvol(tsobj)` calculates the OBV from the stock data in the financial time series object `tsobj`. The object must minimally contain series names `Close` and `Volume`. The `obvts` output is a financial time series object with the same dates as `tsobj` and a series named `OnBalVol`.

`obvts = onbalvol(tsobj, ParameterName, ParameterValue, ...)` accepts parameter name/ parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

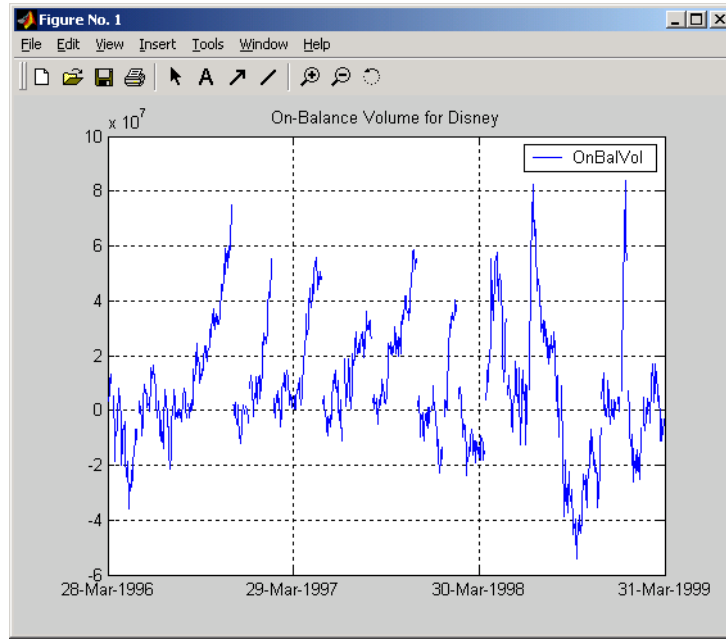
- `CloseName`: closing prices series name
- `VolumeName`: volume traded series name

Parameter values are the strings that represent the valid parameter names.

Examples

Compute the OBV for Disney stock and plot the results:

```
load disney.mat
dis_OnBalVol = onbalvol(dis)
plot(dis_OnBalVol)
title('On-Balance Volume for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 207 - 209.

See Also

`negvolidx`

Purpose

Option profit

Syntax

```
Profit = opprofit(AssetPrice, Strike, Cost, PosFlag, OptType)
```

Arguments

`AssetPrice`	Asset price.
`Strike`	Strike or exercise price.
`Cost`	Cost of the option.
`PosFlag`	Option position. 0 = long, 1 = short.
`OptType`	Option type. 0 = call option, 1 = put option.

Description

`Profit = opprofit(AssetPrice, Strike, Cost, PosFlag, OptType)` returns the profit of an option.

Examples

Buying (going long on) a call option with a strike price of $90 on an underlying asset with a current price of $100 for a cost of $4

```
Profit = opprofit(100, 90, 4, 0, 0)
```

returns

```
Profit =
          6.00
```

a profit of $6 if the option is exercised under these conditions.

See Also

`binprice`, `blsprice`

Purpose

Periodic payment given number of advance payments

Syntax

```
Payment = payadv(Rate, NumPeriods, PresentValue, FutureValue,
Advance)
```

Arguments

`Rate`	Lending or borrowing rate per period. Enter as a decimal fraction. Must be greater than or equal to 0.
`NumPeriods`	Number of periods in the life of the instrument.
`PresentValue`	Present value of the instrument.
`FutureValue`	Future value or target value to be attained after `NumPeriods` periods.
`Advance`	Number of advance payments. If the payments are made at the beginning of the period, add 1 to `Advance`.

Description

`Payment = payadv(Rate, NumPeriods, PresentValue, FutureValue, Advance)` returns the periodic payment given a number of advance payments.

Examples

The present value of a loan is $1000.00 and it will be paid in full in 12 months. The annual interest rate is 10% and three payments are made at closing time. Using this data

```
Payment = payadv(0.1/12, 12, 1000, 0, 3)
```

returns

```
Payment =

            85.94
```

for the periodic payment.

See Also

`amortize`, `payodd`, `payper`

payodd

Purpose

Payment of loan or annuity with odd first period

Syntax

```
Payment = payodd(Rate, NumPeriods, PresentValue, FutureValue, Days)
```

Arguments

`rate`	Interest rate per period. Enter as a decimal fraction.
`NumPeriods`	Number of periods in the life of the instrument.
`PresentValue`	Present value of the instrument.
`FutureValue`	Future value or target value to be attained after `NumPeriods` periods.
`Days`	Actual number of days until the first payment is made.

Description

`Payment = payodd(Rate, NumPeriods, PresentValue, FutureValue, Days)` returns the payment for a loan or annuity with an odd first period.

Examples

A two-year loan for $4000 has an annual interest rate of 11%. The first payment will be made in 36 days. To find the monthly payment

```
Payment = payodd(0.11/12, 24, 4000, 0, 36)
```

returns

```
Payment =

          186.77
```

See Also

`amortize`, `payadv`, `payper`

Purpose

Periodic payment of loan or annuity

Syntax

```
Payment = payper(Rate, NumPeriods, PresentValue, FutureValue, Due)
```

Arguments

`Rate`	Interest rate per period. Enter as a decimal fraction.
`NumPeriods`	Number of payment periods in the life of the instrument.
`PresentValue`	Present value of the instrument.
`FutureValue`	(Optional) Future value or target value to be attained after `NumPeriods` periods. Default = 0.
`Due`	(Optional) When payments are due: 0 = end of period (default), or 1 = beginning of period.

Description

`Payment = payper(Rate, NumPeriods, PresentValue, FutureValue, Due)` returns the periodic payment of a loan or annuity.

Examples

Find the monthly payment for a three-year loan of $9000 with an annual interest rate of 11.75%

```
Payment = payper(0.1175/12, 36, 9000, 0, 0)
```

returns

```
Payment =

          297.86
```

See Also

`amortize`, `fvfix`, `payadv`, `payodd`, `pvfix`

payuni

Purpose

Uniform payment equal to varying cash flow

Syntax

```
Series = payuni(CashFlow, Rate)
```

Arguments

`CashFlow`	A vector of varying cash flows. Include the initial investment as the initial cash flow value (a negative number).
`Rate`	Periodic interest rate. Enter as a decimal fraction.

Description

`Series = payuni(CashFlow, Rate)` returns the uniform series value of a varying cash flow.

Examples

This cash flow represents the yearly income from an initial investment of $10,000. The annual interest rate is 8%.

Year 1	$2000
Year 2	$1500
Year 3	$3000
Year 4	$3800
Year 5	$5000

To calculate the uniform series value

```
Series = payuni([-10000 2000 1500 3000 3800 5000], 0.08)
```

returns

```
Series =
```

```
429.63
```

See Also

fvfix, fvvar, irr, pvfix, pvvar

pcalims

Purpose

Linear inequalities for individual asset allocation

Syntax

```
[A,b] = pcalims(AssetMin, AssetMax, NumAssets)
```

Arguments

`AssetMin`	Scalar or `NASSETS` vector of minimum allocations in each asset. `NaN` indicates no constraint.
`AssetMax`	Scalar or `NASSETS` vector of maximum allocations in each asset. `NaN` indicates no constraint.
`NumAssets`	(Optional) Number of assets. Default = length of `AssetMin` or `AssetMax`.

Description

`[A,b] = pcalims(AssetMin, AssetMax, NumAssets)` specifies the lower and upper bounds of portfolio allocations in each of `NumAssets` available asset investments.

`A` is a matrix and `b` is a vector such that `A*PortWts' <= b`, where `PortWts` is a `1`-by-`NASSETS` vector of asset allocations.

If `pcalims` is called with fewer than two output arguments, the function returns `A` concatenated with `b` `[A,b]`.

Examples

Set the minimum weight in every asset to 0 (no short-selling), and set the maximum weight of IBM stock to 0.5 and CSCO to 0.8, while letting the maximum weight in INTC float.

Asset	IBM	INTC	CSCO
Min. Wt.	0	0	0
Max. Wt.	0.5		0.8

```
AssetMin = 0
AssetMax = [0.5 NaN 0.8]
[A,b] = pcalims(AssetMin, AssetMax)

A =
     1     0     0
     0     0     1
    -1     0     0
     0    -1     0
     0     0    -1

b =

    0.5000
    0.8000
         0
         0
         0
```

Portfolio weights of 50% in IBM and 50% in INTC satisfy the constraints.

Set the minimum weight in every asset to 0 and the maximum weight to 1.

Asset	IBM	INTC	CSCO
Min. Wt.	0	0	0
Max. Wt.	1	1	1

```
AssetMin = 0
AssetMax = 1
NumAssets = 3

[A,b] = pcalims(AssetMin, AssetMax, NumAssets)
```

```
A =

     1     0     0
     0     1     0
     0     0     1
    -1     0     0
     0    -1     0
     0     0    -1

b =
    1
    1
    1
    0
    0
    0
```

Portfolio weights of 50% in IBM and 50% in INTC satisfy the constraints.

See Also

`pcgcomp`, `pcglims`, `pcpval`, `portcons`, `portopt`

Purpose

Linear inequalities for asset group comparison constraints

Syntax

```
[A,b] = pcgcomp(GroupA, AtoBmin, AtoBmax, GroupB)
```

Arguments

`GroupA` `GroupB`	Number of groups (`NGROUPS`) by number of assets (`NASSETS`) specifications of groups to compare. Each row specifies a group. For a specific group, `Group(i,j) = 1` if the group contains asset `j`; otherwise, `Group(i,j) = 0`.
`AtoBmin` `AtoBmax`	Scalar or `NGROUPS`-long vectors of minimum and maximum ratios of allocations in `GroupA` to allocations in `GroupB`. `NaN` indicates no constraint between the two groups. Scalar bounds are applied to all group pairs. The total number of assets allocated to `GroupA` divided by the total number of assets allocated to `GroupB` is >= `AtoBmin` and <= `AtoBmax`.

Description

`[A,b] = pcgcomp(GroupA, AtoBmin, AtoBmax, GroupB)` specifies that the ratio of allocations in one group to allocations in another group is at least `AtoBmin` to 1 and at most `AtoBmax` to 1. Comparisons can be made between an arbitrary number of group pairs `NGROUPS` comprising subsets of `NASSETS` available investments.

`A` is a matrix and `b` a vector such that `A*PortWts' <= b`, where `PortWts` is a 1-by-`NASSETS` vector of asset allocations.

If `pcgcomp` is called with fewer than two output arguments, the function returns `A` concatenated with `b` `[A,b]`.

Examples

Asset	INTC	XOM	RD
Region	North America	North America	Europe
Sector	Technology	Energy	Energy

Group	Min. Exposure	Max. Exposure
North America	0.30	0.75
Europe	0.10	0.55
Technology	0.20	0.50
Energy	0.20	0.80

Make the North American energy sector compose exactly 20% of the North American investment.

```
%          INTC  XOM  RD
GroupA = [   0    1   0  ];  % North American Energy
GroupB = [   1    1   0  ];  % North America

AtoBmin = 0.20;
AtoBmax = 0.20;

[A,b] = pcgcomp(GroupA, AtoBmin, AtoBmax, GroupB)

A =

    0.2000    -0.8000     0
   -0.2000     0.8000     0

b =

   0
   0
```

Portfolio weights of 40% for INTC, 10% for XOM, and 50% for RD satisfy the constraints.

See Also

`pcalims`, `pcglims`, `pcpval`, `portcons`, `portopt`

pcglims

Purpose

Linear inequalities for asset group minimum and maximum allocation

Syntax

```
[A,b] = pcglims(Groups, GroupMin, GroupMax)
```

Arguments

`Groups`	Number of groups (`NGROUPS`) by number of assets (`NASSETS`) specification of which assets belong to which group. Each row specifies a group. For a specific group, `Group(i,j) = 1` if the group contains asset `j`; otherwise, `Group(i,j) = 0`.
`GroupMin` `GroupMax`	Scalar or `NGROUPS`-long vectors of minimum and maximum combined allocations in each group. `NaN` indicates no constraint. Scalar bounds are applied to all groups.

Description

`[A,b] = pcglims(Groups, GroupMin, GroupMax)` specifies minimum and maximum allocations to groups of assets. An arbitrary number of groups, `NGROUPS`, comprising subsets of `NASSETS` investments, is allowed.

`A` is a matrix and `b` a vector such that `A*PortWts' <= b`, where `PortWts` is a 1-by-`NASSETS` vector of asset allocations.

If `pcglims` is called with fewer than two output arguments, the function returns `A` concatenated with `b` `[A,b]`.

Examples

Asset	INTC	XOM	RD
Region	North America	North America	Europe
Sector	Technology	Energy	Energy

Group	Min. Exposure	Max. Exposure
North America	0.30	0.75
Europe	0.10	0.55
Technology	0.20	0.50
Energy	0.50	0.50

Set the minimum and maximum investment in various groups.

```
%           INTC  XOM  RD
Groups = [   1    1   0  ;  % North America
             0    0   1  ;  % Europe
             1    0   0  ;  % Technology
             0    1   1  ]; % Energy

GroupMin = [0.30
            0.10
            0.20
            0.50];

GroupMax = [0.75
            0.55
            0.50
            0.50];

[A,b] = pcglims(Groups, GroupMin, GroupMax)

A =

    -1    -1     0
     0     0    -1
    -1     0     0
     0    -1    -1
     1     1     0
     0     0     1
     1     0     0
```

```
     0     1     1

b =

   -0.3000
   -0.1000
   -0.2000
   -0.5000
    0.7500
    0.5500
    0.5000
    0.5000
```

Portfolio weights of 50% in INTC, 25% in XOM, and 25% in RD satisfy the constraints.

See Also

pcalims, pcgcomp, pcpval, portcons, portopt

Purpose

Linear inequalities for fixing total portfolio value

Syntax

```
[A,b] = pcpval(PortValue, NumAssets)
```

Arguments

`PortValue`	Scalar total value of asset portfolio (sum of the allocations in all assets). `PortValue = 1` specifies weights as fractions of the portfolio and return and risk numbers as rates instead of value.
`NumAssets`	Number of available asset investments.

Description

`[A,b] = pcpval(PortValue, NumAssets)` scales the total value of a portfolio of `NumAssets` assets to `PortValue`. All portfolio weights, bounds, return, and risk values except `ExpReturn` and `ExpCovariance` (see `portopt`) are in terms of `PortValue`.

`A` is a matrix and `b` a vector such that `A*PortWts' <= b`, where `PortWts` is a 1-by-`NASSETS` vector of asset allocations.

If `pcpval` is called with fewer than two output arguments, the function returns `A` concatenated with `b` `[A,b]`.

Examples

Scale the value of a portfolio of three assets = 1, so all return values are rates and all weight values are in fractions of the portfolio.

```
PortValue = 1;
NumAssets = 3;

[A,b] = pcpval(PortValue, NumAssets)

A =

     1     1     1
```

```
     -1     -1     -1

b =

     1
    -1
```

Portfolio weights of 40%, 10%, and 50% in the three assets satisfy the constraints.

See Also

`pcalims`, `pcgcomp`, `pcglims`, `portcons`, `portopt`

Purpose

Periodic average of FINTS object

Syntax

```
avgfts = peravg(tsobj)
avgfts = peravg(tsobj, numperiod)
avgfts = peravg(tsobj, daterange)
```

Arguments

`tsobj`	Financial time series object
`numperiod`	(Optional) Integer specifying the number of data points over which each periodic average should be averaged
`daterange`	(Optional) Time period over which the data is averaged

Description

`peravg` calculates periodic averages of a financial time series object. Periodic averages are calculated from the values per period defined. If the period supplied is a string, it is assumed as a range of date string. If the period is entered as numeric, the number represents the number of data points (financial time series periods) to be included in a period for the calculation. For example, if you enter `'01/01/98::01/01/99'` as the period input argument, `peravg` returns the average of the time series between those dates, inclusive. However, if you enter the number `5` as the period input, `peravg` returns a series of averages from the time series data taken 5 date points (financial time series periods) at a time.

`avgfts = peravg(tsobj, numperiod)` returns a structure `avgfts` that contains the periodic (per `numperiod` periods) average of the financial time series object. `avgfts` has field names identical to the data series names of `tsobj`.

`avgfts = peravg(tsobj, daterange)` returns a structure `avgfts` that contains the periodic (as specified by `daterange`) average of the

financial time series object. `avgfts` has field names identical to the data series names of `tsobj`.

Note `peravg` calculates periodic averages of a FINTS object. Periodic averages are calculated from the values per period defined. If the period supplied is a string, it is assumed as a range of date strings. If the period is entered as numeric, the number represents the number of data points to be included in a period for the calculation.

Examples

If you enter `01-Jan-2001::03-Jan-2001` as the period input argument, `peravg` returns the average of the time series between those dates, inclusive. However, if you enter the number `5` as the period input, `peravg` returns a series of averages from the time series data, taken 5 date points at a time.

```
%% Create the FINTS object %%
dates = ['01-Jan-2001';'01-Jan-2001'; '02-Jan-2001'; ...
'02-Jan-2001'; '03-Jan-2001';'03-Jan-2001'];
times = ['11:00';'12:00';'11:00';'12:00';'11:00';'12:00'];
dates_times = cellstr([dates, repmat(' ', size(dates, 1), 1), times]);
data  = [(1:6)', 2*(1:6)'];
myFts = fints(dates_times, data, {'Data1', 'Data2'}, 1, 'My first FINTS')

%% Create the FINTS object %%

[p, pFts] = peravg(myFts, 3)
p =
 Data1: [2 5]
 Data2: [4 10]

 pFts =

  desc:  My first FINTS
  freq:  Daily (1)
```

```
  'dates:  (2)'    'times:  (2)'    'Data1:  (2)'    'Data2:  (2)'
  '02-Jan-2001'    '11:00'          [          2]    [          4]
  '03-Jan-2001'    '12:00'          [          5]    [         10]


[p, pFts] = peravg(myFts,'01-Jan-2001 12:00::03-Jan-2001 11:00')
p =
   Data1: 3.5000
   Data2: 7

 pFts =

   desc:  My first FINTS
   freq:  Daily (1)

   'dates:  (1)'    'times:  (1)'    'Data1:  (1)'    'Data2:  (1)'
   '03-Jan-2001'    '11:00'          [     3.5000]    [          7]
```

See Also

`mean`, `tsmovavg`

`mean` in the MATLAB documentation

periodicreturns

Purpose

Periodic total returns from total return prices

Syntax

```
TotalReturn = periodicreturns(TotalReturnPrices, Period)
```

Arguments

`TotalReturnPrices`	Number of observations (`NUMOBS`) by number of assets (`NASSETS`) matrix of total return prices for a given security. Column 1 contains MATLAB serial date numbers. The remaining columns contain total return price data.
`Period`	(Optional) Periodicity flag used to compute total returns: `'d'` = daily values `'m'` = monthly values

Description

`TotalReturn = periodicreturns(TotalReturnPrices)` calculates the daily total returns from a daily total return price series.

`TotalReturn = periodicreturns(TotalReturnPrices, Period)` calculates the total returns for a periodicity you specify from a daily total return price series.

`TotalReturn` is a `NUMOBS`-by-`NASSETS` matrix containing month-end dates and return values. Each row represents an observation. Column 1 contains month-end dates in MATLAB serial date number format. The remaining columns contain monthly return values.

See Also

`totalreturnprice`

Purpose

Plot data series

Syntax

```
plot(tsobj)
hp = plot(tsobj)
plot(tsobj, linefmt)
hp = plot(tsobj, linefmt)
plot(..., volumename, bar)
hp = plot(..., volumename, bar)
```

Arguments

`tsobj`	Financial time series object.
`linefmt`	(Optional) Line format.
`volumename`	(Optional) Specifies which data series is the volume series. `volumename` must be the exact data series name for the volume column (case sensitive).
`bar`	(Optional) • `bar = 0` (default). Plot volume as a line. • `bar = 1`. Plot volume as a bar chart. The width of each bar is the same as the default in `bar, barh`.

Description

`plot(tsobj)` plots the data series contained in the object `tsobj`. Each data series will be a line. `plot` automatically generates a legend and dates on the *x*-axis. Grid is turned on by default. `plot` uses the default color order as if plotting a matrix.

The `plot` command automatically creates subplots when multiple time series are encountered, and they differ greatly on their decimal scales. For example, subplots are generated if one time series data set is in the 10s and another is in the 10,000s.

`hp = plot(tsobj)` additionally returns the handle(s) to the object(s) inside the plot figure. If there are multiple lines in the plot, `hp` is a vector of multiple handles.

`plot(tsobj, linefmt)` plots the data series in `tsobj` using the line format specified. For a list of possible line formats, see `plot` in the MATLAB documentation. The plot legend is not generated, but the dates on the *x*-axis and the plot grid are. The specified line format is applied to all data series; that is, all data series will have the same line type.

`hp = plot(tsobj, linefmt)` plots the data series in `tsobj` using the format specified. The plot legend is not generated, but the dates on the *x*-axis and the plot grid are. The specified line format is applied to all data series, that is, all data series can have the same line type. If there are multiple lines in the plot, `hp` is a vector of multiple handles.

`plot(..., volumename, bar)` additionally specifies which data series is the volume. The volume is plotted in a subplot below the other data series. If `bar = 1`, the volume is plotted as a bar chart. Otherwise, a line plot is used.

`hp = plot(..., volumename, bar)` returns handles for each line. If `bar = 1`, the handle to the patch for the bars is also returned.

Note To turn the legend off, enter `legend off` at the MATLAB command line. Once you turn it off, the legend is essentially deleted. To turn it back on, recreate it using the `legend` command as if you are creating it for the first time. To turn the grid off, enter `grid off`. To turn it back on, enter `grid on`.

See Also

`candle`, `chartfts`, `highlow`

`grid`, `legend`, and `plot` in the MATLAB documentation

Purpose

Financial time series addition

Syntax

```
newfts = tsobj_1 + tsobj_2
newfts = tsobj + array
newfts = array + tsobj
```

Arguments

`tsobj_1, tsobj_2`	A pair of financial time series objects.
`array`	A scalar value or array with the number of rows equal to the number of dates in `tsobj` and the number of columns equal to the number of data series in `tsobj`.

Description

`plus` is an element-by-element addition of the components.

`newfts = tsobj_1 + tsobj_2` adds financial time series objects. If an object is to be added to another object, both objects must have the same dates and data series names, although the order need not be the same. The order of the data series, when one financial time series object is added to another, follows the order of the first object.

`newfts = tsobj + array` adds an array element by element to a financial time series object.

`newfts = array + tsobj` adds a financial time series object element by element to an array.

See Also

`minus`, `rdivide`, `times`

pointfig

Purpose

Point and figure chart

Syntax

```
pointfig(Asset)
```

Description

`pointfig(Asset)` plots a point and figure chart for a vector of price data `Asset`. Upward price movements are plotted as `X`'s and downward price movements are plotted as `O`'s.

See Also

`bolling`, `candle`, `dateaxis`, `highlow`, `movavg`

Purpose

Optimal capital allocation to efficient frontier portfolios

Syntax

```
[RiskyRisk, RiskyReturn, RiskyWts, RiskyFraction, OverallRisk,
OverallReturn] = portalloc(PortRisk, PortReturn, PortWts,
RisklessRate, BorrowRate, RiskAversion)
```

Arguments

`PortRisk`	Standard deviation of each risky asset efficient frontier portfolio. A number of portfolios (`NPORTS`) by 1 vector.
`PortReturn`	Expected return of each risky asset efficient frontier portfolio. An `NPORTS`-by-`1` vector.
`PortWts`	Weights allocated to each asset. An `NPORTS` by number of assets (`NASSETS`) matrix of weights allocated to each asset. Each row represents an efficient frontier portfolio of risky assets. Total of all weights in a portfolio is 1.
`RisklessRate`	Risk-free lending rate. A decimal number.
`BorrowRate`	(Optional) Borrowing rate. A decimal number. If borrowing is not desired, or not an option, set to `NaN` (default).
`RiskAversion`	(Optional) Coefficient of investor's degree of risk aversion. Higher numbers indicate greater risk aversion. Typical coefficients range between 2.0 and 4.0 (Default = 3).

Note Consider that a less risk-averse investor would be expected to accept much greater risk and, consequently, a more risk-averse investor would accept less risk for a given level of return. Therefore, making the `RiskAversion`argument higher reflects the risk-return tradeoff in the data.

Description

`[RiskyRisk, RiskyReturn, RiskyWts, RiskyFraction, OverallRisk, OverallReturn] = portalloc(PortRisk, PortReturn, PortWts, RisklessRate, BorrowRate, RiskAversion)` computes the optimal risky portfolio, and the optimal allocation of funds between the risky portfolio and the risk-free asset.

`RiskyRisk` is the standard deviation of the optimal risky portfolio.

`RiskyReturn` is the expected return of the optimal risky portfolio.

`RiskyWts` is a 1-by-`NASSETS` vector of weights allocated to the optimal risky portfolio. The total of all weights in the portfolio is 1.

`RiskyFraction` is the fraction of the complete portfolio allocated to the risky portfolio.

`OverallRisk` is the standard deviation of the optimal overall portfolio.

`OverallReturn` is the expected rate of return of the optimal overall portfolio.

`portalloc` generates a plot of the optimal capital allocation if you invoke it without output arguments.

Examples

Generate the efficient frontier from the asset data.

```
ExpReturn = [0.1 0.2 0.15];
```

```
ExpCovariance = [0.005   -0.010    0.004
                -0.010    0.040   -0.002
                 0.004   -0.002    0.023];
[PortRisk, PortReturn, PortWts] = portopt(ExpReturn,...
ExpCovariance);
```

Find the optimal risky portfolio and allocate capital. The risk free investment return is 8%, and the borrowing rate is 12%.

```
RisklessRate  = 0.08;
BorrowRate    = 0.12;
RiskAversion  = 3;

[RiskyRisk, RiskyReturn, RiskyWts, RiskyFraction, ...
OverallRisk, OverallReturn] = portalloc(PortRisk, PortReturn,...
PortWts, RisklessRate, BorrowRate, RiskAversion)

RiskyRisk =

    0.1283

RiskyReturn =

    0.1788

RiskyWts =

    0.0265    0.6023    0.3712

RiskyFraction =

    1.1898
OverallRisk =

    0.1527

OverallReturn =
```

```
0.1899
```

References

Bodie, Kane, and Marcus, *Investments*, Second Edition, Chapters 6 and 7.

See Also

`frontcon`, `portrand`, `portstats`

Purpose

Compute risk-adjusted alphas and returns for one or more assets

Syntax

```
portalpha(Asset, Benchmark)
  portalpha(Asset, Benchmark, Cash)
  portalpha(Asset, Benchmark, Cash, Choice)
  Alpha = portalpha(Asset, Benchmark, Cash, Choice)
  [Alpha, RAReturn] = portalpha(Asset, Benchmark, Cash, Choice)
```

Arguments

`Asset`	`NUMSAMPLES x NUMSERIES` matrix with `NUMSAMPLES` observations of asset returns for `NUMSERIES` asset return series.
`Benchmark`	`NUMSAMPLES` vector of returns for a benchmark asset. The periodicity must be the same as the periodicity of `Asset`. For example, if `Asset` is monthly data, then `Benchmark` should be monthly returns.
`Cash`	(Optional) Either a scalar return for a riskless asset or a vector of asset returns to be a proxy for a "riskless" asset. In either case, the periodicity must be the same as the periodicity of `Asset`. For example, if `Asset` is monthly data, then `Cash` must be monthly returns. If no value is supplied, the default value for `Cash` returns is 0.
`Choice`	(Optional) A number, string, or cell array of numbers or strings to indicate one or more measures to be computed from among a number of risk-adjusted alphas and return measures. The number of choices selected in `Choice` is `NUMCHOICES`. The current list of choices is given in the following table:

Code	Description
'xs'	Excess Return (no risk adjustment)
'sml'	Security Market Line
'capm'	Jensen's Alpha
'mm'	Modigliani & Modigliani
'gh1'	Graham-Harvey 1
'gh2'	Graham-Harvey 2
'all'	Compute all measures

Choice is specified by using the code from the table (for example, to select the Modigliani & Modigliani measure, Choice = 'mm'). A single choice is either a string or a scalar cell array with a single code from the table.

Multiple choices can be selected with a cell array of choice codes (for example, to select both Graham-Harvey measures, Choice = {'gh1','gh2'}). To select all choices, specify Choice = 'all'. If no value is supplied, the default choice is to compute the excess return with Choice = 'xs'. Choice is not case sensitive.

Description

Given NUMSERIES assets with NUMSAMPLES returns in a NUMSAMPLES-by-NUMSERIES matrix Asset, a NUMSAMPLES vector of Benchmark returns, and either a scalar Cash return or a NUMSAMPLES vector of Cash returns, compute risk-adjusted alphas and returns for one or more methods specified by Choice.

To summarize the outputs of portalpha:

- `Alpha` is a `NUMCHOICES`-by-`NUMSERIES` matrix of risk-adjusted alphas for each series in `Asset` with each row corresponding to a specified measure in `Choice`.
- `RAReturn` is a `NUMCHOICES`-by-`NUMSERIES` matrix of risk-adjusted returns for each series in `Asset` with each row corresponding to a specified measure in `Choice`.

Note `NaN` values in the data are ignored and, if `NaN`s are present, some results could be unpredictable. Although the alphas are comparable across measures, risk-adjusted returns depend on whether the `Asset` or `Benchmark` is levered or unlevered to match its risk with the alternative. If `Choice = 'all'`, the order of rows in `Alpha` and `RAReturn` follows the order in the table. In addition, `Choice = 'all'` overrides all other choices.

Examples

See “Risk-Adjusted Return Example” on page 4-11.

References

John Lintner, "The Valuation of Risk Assets and the Selection of Risky Investments in Stocks Portfolios and Capital Budgets," *Review of Economics and Statistics*, Vol. 47, No. 1, February 1965, pp. 13-37.

John R. Graham and Campbell R. Harvey, "Market Timing Ability and Volatility Implied in Investment Newsletters’ Asset Allocation Recommendations," *Journal of Financial Economics*, Vol. 42, 1996, pp. 397-421.

Franco Modigliani and Leah Modigliani, "Risk-Adjusted Performance: How to Measure It and Why," *Journal of Portfolio Management*, Vol. 23, No. 2, Winter 1997, pp. 45-54.

Jan Mossin, "Equilibrium in a Capital Asset Market," *Econometrica*, Vol. 34, No. 4, October 1966, pp. 768-783.

William F. Sharpe, "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk," *Journal of Finance*, Vol. 19, No. 3, September 1964, pp. 425-442.

See Also

`inforatio`, `sharpe`

Purpose

Portfolio constraints

Syntax

```
ConSet = portcons(varargin)
```

Description

Using linear inequalities, `portcons` generates a matrix of constraints for a portfolio of asset investments. The matrix `ConSet` is defined as `ConSet = [A b]`. `A` is a matrix and `b` a vector such that `A*PortWts' <= b` sets the value, where `PortWts` is a `1`-by-number of assets (`NASSETS`) vector of asset allocations.

`ConSet = portcons('ConstType', Data1, ..., DataN)` creates a matrix `ConSet`, based on the constraint type `ConstType`, and the constraint parameters `Data1, ..., DataN`.

`ConSet = portcons('ConstType1', Data11, ..., Data21, ..., Data2N, ...)` creates a matrix `ConSet`, based on the constraint types `ConstTypeN`, and the corresponding constraint parameters `DataN1, ..., DataNN`.

Constraint Type	Description	Values
Default	All allocations are >= 0; no short selling allowed. Combined value of portfolio allocations normalized to 1.	`NumAssets` (required). Scalar representing number of assets in portfolio.
`PortValue`	Fix total value of portfolio to `PVal`.	`PVal` (required). Scalar representing total value of portfolio. `NumAssets` (required). Scalar representing number of assets in portfolio. See `pcpval`.

Constraint Type	Description	Values
AssetLims	Minimum and maximum allocation per asset.	AssetMin (required). Scalar or vector of length NASSETS, specifying minimum allocation per asset. AssetMax (required). Scalar or vector of length NASSETS, specifying maximum allocation per asset. NumAssets (optional). See pcalims.
GroupLims	Minimum and maximum allocations to asset group.	Groups (required). NGROUPS-by-NASSETS matrix specifying which assets belong to each group. GroupMin (required). Scalar or a vector of length NGROUPS, specifying minimum combined allocations in each group. GroupMax (required). Scalar or a vector of length NGROUPS, specifying maximum combined allocations in each group. See pcglims.
GroupComparison	Group-to-group comparison constraints.	GroupA (required). NGROUPS-by-NASSETS matrix specifying first group in the comparison. AtoBmin (required). Scalar or vector of length NGROUPS specifying minimum ratios of allocations in GroupA to allocations in GroupB. AtoBmax (required). Scalar or vector of length NGROUPS specifying maximum ratios of allocations in GroupA to allocations in GroupB. GroupB (required). NGROUPS-by-NASSETS matrix specifying second group in the comparison. See pcgcomp.
Custom	Custom linear inequality	A (required). NCONSTRAINTS-by-NASSETS matrix, specifying weights for each asset in each inequality equation.

Constraint Type	Description	Values
	constraints `A*PortWts' <= b`.	`b` (required). Vector of length `NCONSTRAINTS` specifying the right hand sides of the inequalities. **Note** For more information using `Custom`, see "Specifying Additional Constraints" on page 3-17.

Examples

Constrain a portfolio of three assets:

Asset	IBM	HPQ	XOM
Group	A	A	B
Min. Wt.	0	0	0
Max. Wt.	0.5	0.9	0.8

```
NumAssets = 3;
PVal = 1; % Scale portfolio value to 1.
AssetMin = 0;
AssetMax = [0.5 0.9 0.8];
GroupA = [1 1 0];
GroupB = [0 0 1];
AtoBmax = 1.5 % Value of assets in Group A at most 1.5 times value
              % in group B.

ConSet = portcons('PortValue', PVal, NumAssets,'AssetLims',...
AssetMin, AssetMax, NumAssets, 'GroupComparison',GroupA, NaN,...
AtoBmax, GroupB)
```

```
ConSet =

    1.0000    1.0000    1.0000    1.0000
   -1.0000   -1.0000   -1.0000   -1.0000
    1.0000         0         0    0.5000
         0    1.0000         0    0.9000
         0         0    1.0000    0.8000
   -1.0000         0         0         0
         0   -1.0000         0         0
         0         0   -1.0000         0
    1.0000    1.0000   -1.5000         0
```

Portfolio weights of 30% in IBM, 30% in HPQ, and 40% in XOM satisfy the constraints.

See Also

`pcalims`, `pcgcomp`, `pcglims`, `pcpval`, `portopt`

Purpose

Portfolios on constrained efficient frontier

Syntax

```
[PortRisk, PortReturn, PortWts] = portopt(ExpReturn, ExpCovariance,
NumPorts, PortReturn, ConSet, varargin)
```

Arguments

`ExpReturn`	1 by number of assets (`NASSETS`) vector specifying the expected (mean) return of each asset.
`ExpCovariance`	`NASSETS`-by-`NASSETS` matrix specifying the covariance of the asset returns.
`NumPorts`	(Optional) Number of portfolios generated along the efficient frontier. Returns are equally spaced between the maximum possible return and the minimum risk point. If `NumPorts` is empty (entered as `[]`), computes 10 equally spaced points.
`PortReturn`	(Optional) Expected return of each portfolio. A number of portfolios (`NPORTS`) by 1 vector. If not entered or empty, `NumPorts` equally spaced returns between the minimum and maximum possible values are used.

`ConSet`	(Optional) Constraint matrix for a portfolio of asset investments, created using `portcons`. If not specified, a default is created.

`varargin`	(Optional) `varargin` supports the following parameter-value pairs:
	• `'algorithm'` – Defines which algorithm to use with `portopt`. Use either a value of `'lcprog'` or `'quadprog'` to indicate the algorithm to use. The default is `'lcprog'`.
	• `'maxiter'` – Maximum number of iterations before termination of algorithm. The default is 100000.
	• `'tiebreak'` – Method to break ties for pivot selection. This value pair applies only to `'lcprog'` algorithm. The default is `'first'`. Options are:
	  - `'first'` – Selects pivot with lowest index.
	  - `'last'` – Selects pivot with highest index.
	  - `'random'` – Selects pivot at random.
	• `'tolcon'` – Tolerance for constraint violations. This value pair applies only to `'lcprog'` algorithm. The default is 1.0e-6.
	• `'tolpiv'` – Pivot value below which a number is considered to be zero. This value pair applies only to `'lcprog'`algorithm. The default is 1.0e-9.

Description

`[PortRisk, PortReturn, PortWts] = portopt(ExpReturn, ExpCovariance, NumPorts, PortReturn, ConSet, varargin)` returns the mean-variance efficient frontier with user-specified

covariance, returns, and asset constraints (ConSet). Given a collection of NASSETS risky assets, computes a portfolio of asset investment weights that minimize the risk for given values of the expected return. The portfolio risk is minimized subject to constraints on the total portfolio value, the individual asset minimum and maximum allocation, the asset group minimum and maximum allocation, or the asset group-to-group comparison.

PortRisk is an NPORTS-by-1 vector of the standard deviation of each portfolio.

PortReturn is an NPORTS-by-1 vector of the expected return of each portfolio.

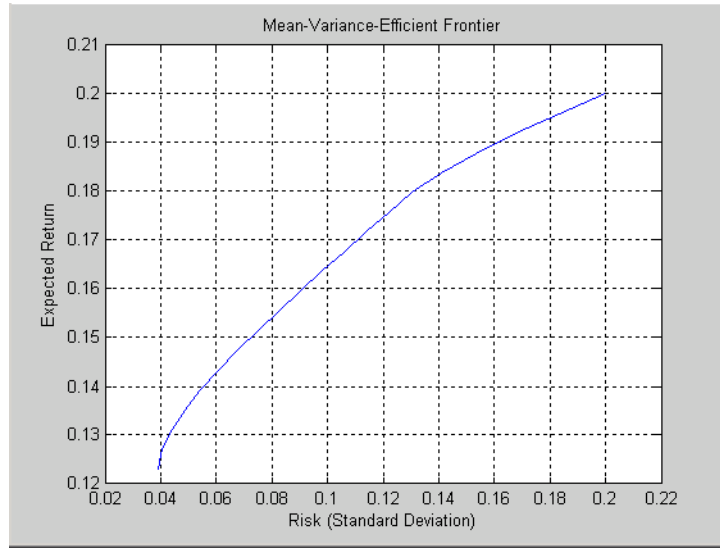
PortWts is an NPORTS-by-NASSETS matrix of weights allocated to each asset. Each row represents a portfolio. The total of all weights in a portfolio is 1.

If portopt is invoked without output arguments, it returns a plot of the efficient frontier.

Examples

Plot the risk-return efficient frontier of portfolios allocated among three assets. Connect 20 portfolios along the frontier having evenly spaced returns. By default, choose among portfolios without short-selling and scale the value of the portfolio to 1.

```
ExpReturn = [0.1 0.2 0.15];

ExpCovariance = [0.005   -0.010    0.004
                -0.010    0.040   -0.002
                 0.004   -0.002    0.023];

NumPorts = 20;
portopt(ExpReturn, ExpCovariance, NumPorts)
```



Return the two efficient portfolios that have returns of 16% and 17%. Limit to portfolios that have at least 20% of the allocation in the first asset, and cap the total value in the first and third assets at 50% of the portfolio.

```
ExpReturn = [0.1 0.2 0.15];

ExpCovariance = [0.005   -0.010    0.004
                -0.010    0.040   -0.002
                 0.004   -0.002    0.023];

PortReturn = [0.16
              0.17];

NumAssets = 3;

AssetMin = [0.20 NaN NaN];

Group    = [1    0   1];
```

```
GroupMax = 0.50;

ConSet = portcons('Default', NumAssets, 'AssetLims', AssetMin,...
NaN,'GroupLims', Group, NaN, GroupMax);

[PortRisk, PortReturn, PortWts] = portopt(ExpReturn,...
ExpCovariance, [], PortReturn, ConSet)

PortRisk =

    0.0919
    0.1138

PortReturn =

    0.1600
    0.1700

PortWts =

    0.3000    0.5000    0.2000
    0.2000    0.6000    0.2000
```

See Also

ewstats, frontcon, frontier, portcons, portstats

portrand

Purpose

Randomized portfolio risks, returns, and weights

Syntax

```
[PortRisk, PortReturn, PortWts] = portrand(Asset, Return,
Points, Method)
portrand(Asset, Return, Points, Method)
```

Arguments

`Asset` Matrix of time series data. Each row is an observation and each column represents a single security.

`Return` (Optional) Row vector where each column represents the rate of return for the corresponding security in `Asset`. By default, `Return` is computed by taking the average value of each column of `Asset`.

`Points` (Optional) Scalar that specifies how many random points should be generated. Default = 1000.

`Method` (Optional) A string that specifies how to generate random portfolios from the set of portfolios with two possible methods:

- `'uniform'` – Uniformly-distributed portfolio weights (default method). The `'uniform'` method generates portfolio weights that are uniformly-distributed on the set of portfolio weights.
- `'geometric'` – Concentrated portfolio weights around the geometric center of the set of portfolios. The `'geometric'` method generates portfolio weights that are concentrated around the geometric center of the set of portfolio weights.

Note The `'uniform'` and `'geometric'` methods generate weights that are distributed symmetrically around the geometric center of the set of weights.

Description

`[PortRisk, PortReturn, PortWts] = portrand(Asset, Return, Points, Method)` returns the risks, rates of return, and weights of random portfolio configurations.

`PortRisk`	`Points`-by-1 vector of standard deviations.
`PortReturn`	`Points`-by-1 vector of expected rates of return.
`PortWts`	`Points` by number of securities matrix of asset weights. Each row of `PortWts` is a different portfolio configuration.

`portrand(Asset, Return, Points, Method)` plots the points representing each portfolio configuration. It does not return any data to the MATLAB workspace.

Note Portfolios are selected at random from a set of portfolios such that portfolio weights are non-negative and sum to 1. The sample mean and covariance of asset returns are used to compute portfolio returns for each random portfolio.

References

Bodie, Kane, and Marcus, *Investments*, Chapter 7.

See Also `frontcon`, `portror`, `portvar`

Purpose

Portfolio expected rate of return

Syntax

```
R = portror(Return, Weight)
```

Arguments

`Return`	`1`-by-`N` matrix of rates of return. Each column of `Return` represents the rate of return for a single security
`Weight`	`M`-by-`N` matrix of weights. Each row of `Weight` represents a different weighting combination of the assets in the portfolio.

Description

`R = portror(Return, Weight)` returns a `1`-by-`M` vector for the expected rate of return.

Examples

A portfolio is made up of two assets ABC and XYZ having expected rates of return of 10% and 14%, respectively. If 40% percent of the portfolio's funds are allocated to asset ABC and the remaining funds are allocated to asset XYZ, the portfolio's expected rate of return is:

```
r = portror([.1 .14],[.4 .6])
r =
0.1240
```

References

Bodie, Kane, and Marcus, *Investments*, Chapter 7.

See Also

`frontcon`, `portrand`, `portvar`

portsim

Purpose

Monte Carlo simulation of correlated asset returns

Syntax

```
RetSeries = portsim(ExpReturn, ExpCovariance, NumObs, RetIntervals,
NumSim, Method)
```

Arguments

`ExpReturn`	1 by number of assets (`NASSETS`) vector specifying the expected (mean) return of each asset.
`ExpCovariance`	`NASSETS`-by-`NASSETS` matrix of asset return covariances. `ExpCovariance` must be symmetric and positive semidefinite (no negative eigenvalues). The standard deviations of the returns are `ExpSigma = sqrt(diag(ExpCovariance))`.
`NumObs`	Positive scalar integer indicating the number of consecutive observations in the return time series. If `NumObs` is entered as the empty matrix `[]`, the length of `RetIntervals` is used.
`RetIntervals`	(Optional) Positive scalar or number of observations (`NUMOBS`)-by-`1` vector of interval times between observations. If `RetIntervals` is not specified, all intervals are assumed to have length 1.

`NumSim`	(Optional) Positive scalar integer indicating the number of simulated sample paths (realizations) of `NUMOBS` observations. Default = 1 (single realization of `NUMOBS` correlated asset returns).
`Method`	(Optional) String indicating the type of Monte Carlo simulation: `'Exact'` (default) generates correlated asset returns in which the sample mean and covariance match the input mean (`ExpReturn`) and covariance (`ExpCovariance`) specifications. `'Expected'` generates correlated asset returns in which the sample mean and covariance are statistically equal to the input mean and covariance specifications. (The expected value of the sample mean and covariance are equal to the input mean (`ExpReturn`) and covariance (`ExpCovariance`) specifications.) For either method the sample mean and covariance returned are appropriately scaled by `RetIntervals`.

Description

`portsim` simulates correlated returns of `NASSETS` assets over `NUMOBS` consecutive observation intervals. Asset returns are simulated as the proportional increments of constant drift, constant volatility stochastic processes, thereby approximating continuous-time geometric Brownian motion.

`RetSeries` is a `NUMOBS`-by-`NASSETS`-by-`NUMSIM` three-dimensional array of correlated, normally distributed, proportional asset returns. Asset returns over an interval of length dt are given by

$$\frac{dS}{S} = \mu dt + \sigma dz = \mu dt + \sigma \varepsilon \sqrt{dt}$$

where S is the asset price, μ is the expected rate of return, σ is the volatility of the asset price, and ε represents a random drawing from a standardized normal distribution.

Notes

- When *Method* is `'Exact'`, the sample mean and covariance of all realizations (scaled by `RetIntervals`) match the input mean and covariance. When the returns are subsequently converted to asset prices, all terminal prices for a given asset are in close agreement. Although all realizations are drawn independently, they produce similar terminal asset prices. Set *Method* to `'Expected'` to avoid this behavior.
- The returns from the portfolios in `PortWts` are given by `PortReturn = PortWts * RetSeries(:,:,1)'`, where `PortWts` is a matrix in which each row contains the asset allocations of a portfolio. Each row of `PortReturn` corresponds to one of the portfolios identified in `PortWts`, and each column corresponds to one of the observations taken from the first realization (the first plane) in `RetSeries`. See `portopt` and `portstats` for portfolio specification and optimization.

Examples

Example 1. Distinction Between Simulation Methods

This example highlights the distinction between the `Exact` and `Expected` methods of simulation.

Consider a portfolio of five assets with the following expected returns, standard deviations, and correlation matrix based on daily asset returns (where `ExpReturn` and `Sigmas` are divided by 100 to convert percentages to returns):

```
ExpReturn     = [0.0246  0.0189  0.0273  0.0141  0.0311]/100;
```

```
Sigmas        = [0.9509  1.4259  1.5227  1.1062  1.0877]/100;
Correlations  = [1.0000  0.4403  0.4735  0.4334  0.6855
                 0.4403  1.0000  0.7597  0.7809  0.4343
                 0.4735  0.7597  1.0000  0.6978  0.4926
                 0.4334  0.7809  0.6978  1.0000  0.4289
                 0.6855  0.4343  0.4926  0.4289  1.0000];
```

Convert the correlations and standard deviations to a covariance matrix.

```
ExpCovariance = corr2cov(Sigmas, Correlations);

ExpCovariance =

  1.0e-003 *

    0.0904    0.0597    0.0686    0.0456    0.0709
    0.0597    0.2033    0.1649    0.1232    0.0674
    0.0686    0.1649    0.2319    0.1175    0.0816
    0.0456    0.1232    0.1175    0.1224    0.0516
    0.0709    0.0674    0.0816    0.0516    0.1183
```

Assume that there are 252 trading days in a calendar year, and simulate two sample paths (realizations) of daily returns over a two-year period. Since `ExpReturn` and `ExpCovariance` are expressed daily, set `RetIntervals = 1`.

```
StartPrice    = 100;
NumObs        = 504;   % two calendar years of daily returns
NumSim        = 2;
RetIntervals  = 1;     % one trading day
NumAssets     = 5;
```

To illustrate the distinction between methods, simulate two paths by each method, starting with the same random number state.

```
randn('state',0);
RetExact = portsim(ExpReturn, ExpCovariance, NumObs, ...
```

```
RetIntervals, NumSim, 'Exact');
randn('state',0);
RetExpected = portsim(ExpReturn, ExpCovariance, NumObs, ...
RetIntervals, NumSim, 'Expected');
```

If you compare the mean and covariance of `RetExact` with the inputs (`ExpReturn` and `ExpCovariance`), you will observe that they are almost identical.

At this point, `RetExact` and `RetExpected` are both `504-by-5-by-2` arrays. Now assume an equally weighted portfolio formed from the five assets and create arrays of portfolio returns in which each column represents the portfolio return of the corresponding sample path of the simulated returns of the five assets. The portfolio arrays `PortRetExact` and `PortRetExpected` are `504-by-2` matrices.

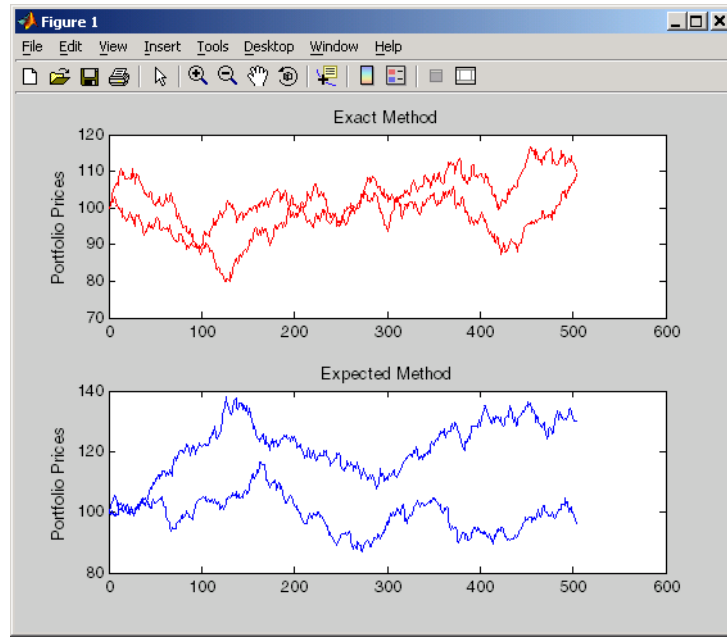
```
Weights         = ones(NumAssets, 1)/NumAssets;
PortRetExact    = zeros(NumObs, NumSim);
PortRetExpected = zeros(NumObs, NumSim);

for i = 1:NumSim
    PortRetExact(:,i)    = RetExact(:,:,i) * Weights;
    PortRetExpected(:,i) = RetExpected(:,:,i) * Weights;
end
```

Finally, convert the simulated portfolio returns to prices and plot the data. In particular, note that since the `Exact` method matches expected return and covariance, the terminal portfolio prices are virtually identical for each sample path. This is not true for the `Expected` simulation method.

Although this example examines portfolios, the same methods apply to individual assets as well. Thus, `Exact` simulation is most appropriate when unique paths are required to reach the same terminal prices.

```
PortExact   = ret2tick(PortRetExact, ...
repmat(StartPrice,1,NumSim));
PortExpected = ret2tick(PortRetExpected, ...
```

```
repmat(StartPrice,1,NumSim));
subplot(2,1,1), plot(PortExact, '-r')
ylabel('Portfolio Prices')
title('Exact Method')
subplot(2,1,2), plot(PortExpected, '-b')
ylabel('Portfolio Prices')
title('Expected Method')
```



Example 2. Interaction Between `ExpReturn`, `ExpCovariance` and `RetIntervals`

Recall that `portsim` simulates correlated asset returns over an interval of length dt, given by the equation

$$\frac{dS}{S} = \mu dt + \sigma dz = \mu dt + \sigma \varepsilon \sqrt{dt}$$

where S is the asset price, μ is the expected rate of return, σ is the volatility of the asset price, and ε represents a random drawing from a standardized normal distribution.

The time increment dt is determined by the optional input `RetIntervals`, either as an explicit input argument or as a unit time increment by default. Regardless, the periodicity of `ExpReturn`, `ExpCovariance` and `RetIntervals` must be consistent. For example, if `ExpReturn` and `ExpCovariance` are annualized, then `RetIntervals` must be in years. This point is often misunderstood.

To illustrate the interplay among `ExpReturn`, `ExpCovariance`, and `RetIntervals`, consider a portfolio of five assets with the following expected returns, standard deviations, and correlation matrix based on daily asset returns.

```
ExpReturn     = [0.0246  0.0189  0.0273  0.0141  0.0311]/100;

Sigmas        = [0.9509  1.4259  1.5227  1.1062  1.0877]/100;

Correlations  = [1.0000  0.4403  0.4735  0.4334  0.6855
                 0.4403  1.0000  0.7597  0.7809  0.4343
                 0.4735  0.7597  1.0000  0.6978  0.4926
                 0.4334  0.7809  0.6978  1.0000  0.4289
                 0.6855  0.4343  0.4926  0.4289  1.0000];
```

Convert the correlations and standard deviations to a covariance matrix of daily returns.

```
ExpCovariance = corr2cov(Sigmas, Correlations);
```

Assume 252 trading days per calendar year, and simulate a single sample path of daily returns over a four-year period. Since the `ExpReturn` and `ExpCovariance` inputs are expressed daily, set `RetIntervals = 1`.

```
StartPrice    = 100;
NumObs        = 1008;    % four calendar years of daily returns
RetIntervals  = 1;       % one trading day
```

```
NumAssets     = length(ExpReturn);
randn('state',0);
RetSeries1 = portsim(ExpReturn, ExpCovariance, NumObs, ...
RetIntervals, 1, 'Expected');
```

Now annualize the daily data, thereby changing the periodicity of the data, by multiplying `ExpReturn` and `ExpCovariance` by 252 and dividing `RetIntervals` by 252 (`RetIntervals` = 1/252 of a year).

Resetting the random number generator to its initial state, you can reproduce the results.

```
randn('state',0);
RetSeries2 = portsim(ExpReturn*252, ExpCovariance*252, ...
NumObs, RetIntervals/252, 1, 'Expected');
```

Assume an equally weighted portfolio and compute portfolio returns associated with each simulated return series.

```
Weights  = ones(NumAssets, 1)/NumAssets;

PortRet1 = RetSeries2 * Weights;
PortRet2 = RetSeries2 * Weights;
```

Comparison of the data reveals that `PortRet1` and `PortRet2` are identical.

Example 3. Univariate Geometric Brownian Motion

This example simulates a univariate geometric Brownian motion process. It is based on an example found in Hull, *Options, Futures, and Other Derivatives*, 5th Edition (see example 12.2 on page 236). In addition to verifying Hull's example, it also graphically illustrates the lognormal property of terminal stock prices by a rather large Monte Carlo simulation.

First, assume you own a stock with an initial price of $20, an annualized expected return of 20% and volatility of 40%. Simulate the daily price

process for this stock over the course of one full calendar year (252 trading days).

```
StartPrice    = 20;
ExpReturn     = 0.2;
ExpCovariance = 0.4^2;
NumObs        = 252;
NumSim        = 10000;
RetIntervals  = 1/252;
```

Note that `RetIntervals` is expressed in years, consistent with the fact that `ExpReturn` and `ExpCovariance` are annualized. Also, note that `ExpCovariance` is entered as a variance rather than the more familiar standard deviation (volatility).

Now set the random number generator state, and simulate 10,000 trials (realizations) of stock returns over a full calendar year of 252 trading days.

```
randn('state',10);
RetSeries = squeeze(portsim(ExpReturn, ExpCovariance, NumObs, ...
RetIntervals, NumSim, 'Expected'));
```

The `squeeze` function reformats the output array of simulated returns from a `252-by-1-by-10000` array to more convenient `252-by-10000` array. (Recall that `portsim` is fundamentally a multivariate simulation engine).

In accordance with Hull's equations 12.4 and 12.5 on page 236

$$E(S_T) = S_0 e^{\mu T}$$

$$var(S_T) = S_0^2 e^{2\mu T}(e^{\sigma^2 T} - 1)$$

convert the simulated return series to a price series and compute the sample mean and the variance of the terminal stock prices.

```
StockPrices = ret2tick(RetSeries, repmat(StartPrice, 1, NumSim));
```

```
SampMean = mean(StockPrices(end,:))

SampMean =

   24.4587

SampVar = var(StockPrices(end,:))

SampVar =

  104.2016
```

Compare these values with the values you obtain by using Hull's equations.

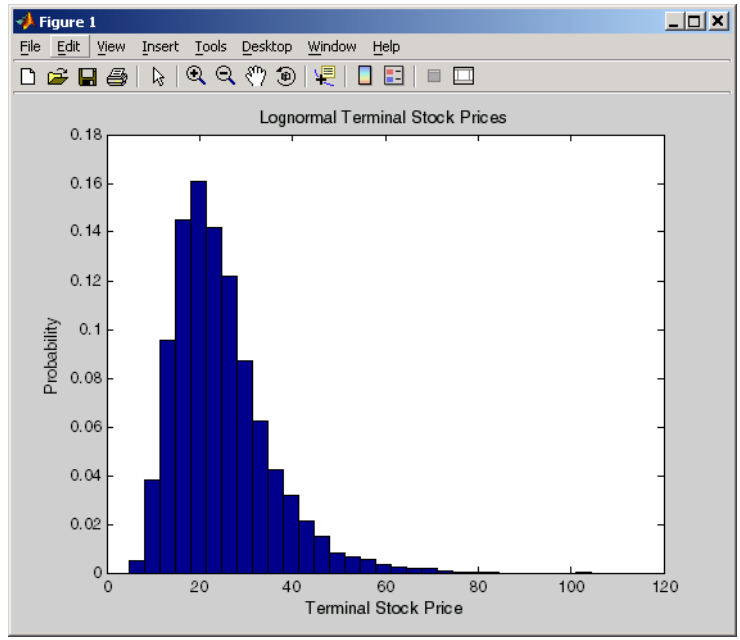
```
ExpValue = StartPrice*exp(ExpReturn)

ExpValue =

   24.4281

ExpVar = ...
StartPrice*StartPrice*exp(2*ExpReturn)*(exp((ExpCovariance)) - 1)

ExpVar =

  103.5391
```

These results are very close to the results shown in Hull's example 12.2.

Next, display the sample density function of the terminal stock price after one calendar year. From the sample density function, the lognormal distribution of terminal stock prices is apparent.

```
[count, BinCenter] = hist(StockPrices(end,:), 30);
figure
bar(BinCenter, count/sum(count), 1, 'r')
```

```
xlabel('Terminal Stock Price')
ylabel('Probability')
title('Lognormal Terminal Stock Prices')
```



References

Hull, John, C., *Options, Futures, and Other Derivatives*, Upper Saddle River, New Jersey: Prentice-Hall. 5th ed., 2003, ISBN 0-13-009056-5.

See Also

`ewstats`, `portopt`, `portstats`, `randn`, `ret2tick`

Purpose

Portfolio expected return and risk

Syntax

```
[PortRisk, PortReturn] = portstats(ExpReturn, ExpCovariance,
PortWts)
```

Arguments

`ExpReturn`	1-by-number of assets (`NASSETS`) vector specifying the expected (mean) return of each asset.
`ExpCovariance`	`NASSETS`-by-`NASSETS` matrix specifying the covariance of the asset returns.
`PortWts`	(Optional) Number of portfolios (`NPORTS`) by `NASSETS` matrix of weights allocated to each asset. Each row represents a different weighting combination. Default = `1/NASSETS` (equally weighted).

Description

`[PortRisk, PortReturn] = portstats(ExpReturn, ExpCovariance, PortWts)` computes the expected rate of return and risk for a portfolio of assets.

`PortRisk` is an `NPORTS`-by-1 vector of the standard deviation of each portfolio.

`PortReturn` is an `NPORTS`-by-1 vector of the expected return of each portfolio.

Examples

```
ExpReturn = [0.1 0.2 0.15];

ExpCovariance = [0.0100   -0.0061    0.0042
                -0.0061    0.0400   -0.0252
                 0.0042   -0.0252    0.0225 ];
```

```
PortWts=[0.4 0.2 0.4; 0.2 0.4 0.2];

[PortRisk, PortReturn] = portstats(ExpReturn, ExpCovariance,...
PortWts)

PortRisk =

    0.0560
    0.0550

PortReturn =

    0.1400
    0.1300
```

See Also

frontcon

Purpose

Variance for portfolio of assets

Syntax

```
V = portvar(Asset, Weight)
```

Arguments

`Asset`	`M`-by-`N` matrix of `M` asset returns for `N` securities.
`Weight`	`R`-by-`N` matrix of `R` portfolio weights for `N` securities. Each row of `Weight` constitutes a portfolio of securities in `Asset`.

Description

`V = portvar(Asset, Weight)` returns the portfolio variance as an `R`-by-`1`vector (assuming `Weight` is a matrix of size `R`-by-`N`) with each row representing a variance calculation for each row of `Weight`.

`V = portvar(Asset)` assigns each security an equal weight when calculating the portfolio variance.

References

Bodie, Kane, and Marcus, *Investments*, Chapter 7.

See Also

`frontcon`, `portrand`, `portror`

portvrisk

Purpose

Portfolio value at risk (VaR)

Syntax

```
ValueAtRisk = portvrisk(PortReturn, PortRisk, RiskThreshold,
PortValue)
```

Arguments

`PortReturn`	Number of portfolios (`NPORTS`)-by-`1` vector or scalar of the expected return of each portfolio over the period.
`PortRisk`	`NPORTS`-by-`1` vector or scalar of the standard deviation of each portfolio over the period.
`RiskThreshold`	(Optional) `NPORTS`-by-`1` vector or scalar specifying the loss probability. Default = 0.05 (5%).
`PortValue`	(Optional) `NPORTS`-by-`1` vector or scalar specifying the total value of asset portfolio. Default = 1.

Description

`ValueAtRisk = portvrisk(PortReturn, PortRisk, RiskThreshold, PortValue)` returns the maximum potential loss in the value of a portfolio over one period of time, given the loss probability level `RiskThreshold`.

`ValueAtRisk` is an `NPORTS`-by-1 vector of the estimated maximum loss in the portfolio, predicted with a confidence probability of 1-`RiskThreshold`.

If `PortValue` is not given, `ValueAtRisk` is presented on a per-unit basis. A value of 0 indicates no losses.

Examples

This example computes `ValueAtRisk` on a per-unit basis.

```
PortReturn = 0.29/100;
```

```
PortRisk = 3.08/100;
RiskThreshold = [0.01;0.05;0.10];
PortValue = 1;
ValueAtRisk = portvrisk(PortReturn,PortRisk,...
RiskThreshold,PortValue)
ValueAtRisk =

    0.0688
    0.0478
    0.0366
```

This example computes `ValueAtRisk` with actual values.

```
PortReturn = [0.29/100;0.30/100];
PortRisk = [3.08/100;3.15/100];
RiskThreshold = 0.10;
PortValue = [1000000000;500000000];
ValueAtRisk = portvrisk(PortReturn,PortRisk,...
RiskThreshold,PortValue)
ValueAtRisk =

  1.0e+007 *
    3.6572
    1.8684
```

See Also

`frontcon`, `portopt`

posvolidx

Purpose

Positive volume index

Syntax

```
pvi = posvolidx(closep, tvolume, initpvi)
pvi = posvolidx([closep tvolume], initpvi)
pvits = posvolidx(tsobj)
pvits = posvolidx(tsobj, initpvi, ParameterName, ParameterValue, ...)
```

Arguments

`closep`	Closing price (vector).
`tvolume`	Volume traded (vector).
`initpvi`	(Optional) Initial value for positive volume index. Default = 100.
`tsobj`	Financial time series object.

Description

`pvi = posvolidx(closep, tvolume, initpvi)` calculates the positive volume index from a set of stock closing prices (`closep`) and volume traded (`tvolume`) data. `pvi` is a vector representing the positive volume index. If `initpvi` is specified, `posvolidx` uses that value instead of the default (100).

`pvi = posvolidx([closep tvolume], initpvi)` accepts a two-column matrix, the first column representing the closing prices (`closep`) and the second representing the volume traded (`tvolume`). If `initpvi` is specified, `posvolidx` uses that value instead of the default (100).

`pvits = posvolidx(tsobj)` calculates the positive volume index from the financial time series object `tsobj`. The object must contain, at least, the series `Close` and `Volume`. The `pvits` output is a financial time series object with dates similar to `tsobj` and a data series named `PVI`. The initial value for the positive volume index is arbitrarily set to 100.

`pvits = posvolidx(tsobj, initpvi, ParameterName, ParameterValue,...)` accepts parameter name/parameter value pairs

as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

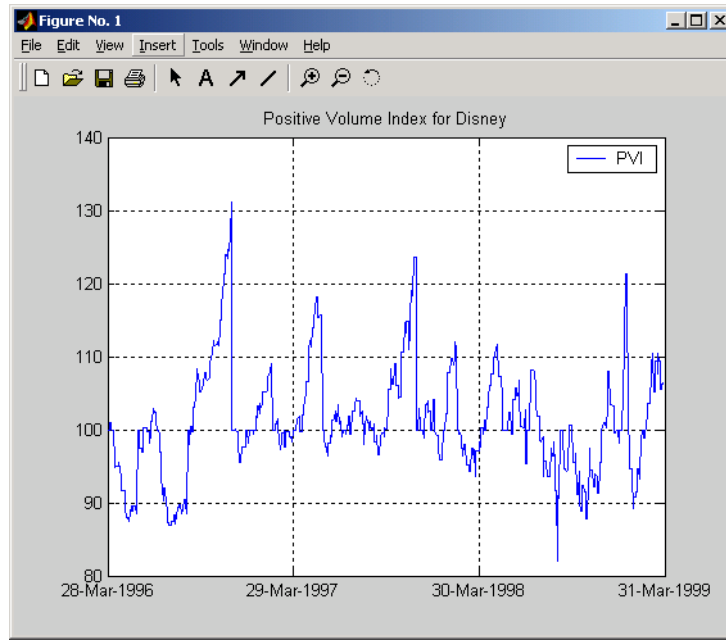
- `CloseName`: closing prices series name
- `VolumeName`: volume traded series name

Parameter values are the strings that represent the valid parameter names.

Examples

Compute the positive volume index for Disney stock and plot the results:

```
load disney.mat
dis_PosVol = posvolidx(dis)
plot(dis_PosVol)
title('Positive Volume Index for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 236 - 238.

See Also

`onbalvol`, `negvolidx`

Purpose

Financial time series power

Syntax

```
newfts = tsobj .^ array
newfts = array .^tsobj
newfts = tsobj_1 .^ tsobj_2
```

Arguments

`tsobj`	Financial time series object.
`array`	Scalar value or array with the number of rows equal to the number of dates in `tsobj` and the number of columns equal to the number of data series in `tsobj`.
`tsobj_1, tsobj_2`	Pair of financial time series objects.

Description

`newfts = tsobj .^ array` raises all values in the data series of the financial time series object `tsobj` element by element to the power indicated by the array value. The results are stored in another financial time series object `newfts`. The `newfts` object contains the same data series names as `tsobj`.

`newfts = array .^ tsobj` raises the array values element by element to the values contained in the data series of the financial time series object `tsobj`. The results are stored in another financial time series object `newfts`. The `newfts` object contains the same data series names as `tsobj`.

`newfts = tsobj_1 .^ tsobj_2` raises the values in the object `tsobj_1` element by element to the values in the object `tsobj_2`. The data series names, the dates, and the number of data points in both series must be identical. `newfts` contains the same data series names as the original time series objects.

See Also

`minus`, `plus`, `rdivide`, `times`

prbyzero

Purpose

Price bonds in portfolio by set of zero curves

Syntax

```
BondPrices = prbyzero(Bonds, Settle, ZeroRates, ZeroDates)
```

Arguments

`Bonds` Coupon bond information used to compute prices. A number of bonds (`NUMBONDS`)-by-`6` matrix where each row describes a bond. The first two columns are required; the rest are optional but must be added in order. All rows in `Bonds` must have the same number of columns. Columns are [`Maturity CouponRate Face Period Basis EndMonthRule`] where:

`Maturity`	Maturity date as a serial date number or date string.
`CouponRate`	Decimal number indicating the annual percentage rate used to determine the coupons payable on a bond.
`Face`	(Optional) Face or par value of the bond. Default = 100.
`Period`	(Optional) Coupons per year of the bond. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.

`Basis`

(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`

(Optional) End-of-month rule. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

`Settle`	Serial date number of the settlement date.
`ZeroRates`	`NUMDATES`-by-`NUMCURVES` matrix of observed zero rates, as decimal fractions. Each column represents a rate curve. Each row represents an observation date.
`ZeroDates`	`NUMDATES`-by-`1` column of dates for observed zeros

Description

`BondPrices = prbyzero(Bonds, Settle, ZeroRates, ZeroDates)` computes the bond prices in a portfolio using a set of zero curves.

`BondPrices` is a `NUMBONDS`-by-`NUMCURVES` matrix of clean bond prices. Each column is derived from the corresponding zero curve in `ZeroRates`.

In addition, you can use the Fixed-Income Toolbox™ method `getZeroRates` for an `IRDataCurve` object with a `Dates` property to create a vector of dates and data acceptable for `prbyzero`. For more information, see "Converting an IRDataCurve or IRFunctionCurve Object".

Examples

This example uses `zbtprice` to compute a zero curve given a portfolio of coupon bonds and their prices. It then reverses the process, using the zero curve as input to `prbyzero` to compute the prices.

```
Bonds = [datenum('6/1/1998') 0.0475 100 2 0 0;
         datenum('7/1/2000') 0.06 100 2 0 0;
         datenum('7/1/2000') 0.09375 100 6 1 0;
         datenum('6/30/2001') 0.05125 100 1 3 1;
         datenum('4/15/2002') 0.07125 100 4 1 0;
         datenum('1/15/2000') 0.065 100 2 0 0;
         datenum('9/1/1999') 0.08 100 3 3 0;
         datenum('4/30/2001') 0.05875 100 2 0 0;
         datenum('11/15/1999') 0.07125 100 2 0 0;
         datenum('6/30/2000') 0.07 100 2 3 1;
         datenum('7/1/2001') 0.0525 100 2 3 0;
         datenum('4/30/2002') 0.07 100 2 0 0];
```

```
Prices = [ 99.375;
           99.875;
          105.75 ;
           96.875;
          103.625;
          101.125;
          103.125;
           99.375;
          101.0  ;
          101.25 ;
           96.375;
          102.75 ];

Settle = datenum('12/18/1997');
```

Set semiannual compounding for the zero curve, on an actual/365 basis. Derive the zero curve within 50 iterations.

```
OutputCompounding = 2;
OutputBasis = 3;
MaxIterations = 50;
```

Execute `zbtprice`

```
[ZeroRates, ZeroDates] = zbtprice(Bonds, Prices, Settle,...
OutputCompounding, OutputBasis, MaxIterations)
```

which returns the zero curve at the maturity dates.

```
ZeroRates =

             0.0616
             0.0609
             0.0658
             0.0590
             0.0648
```

```
                0.0655
                0.0606
                0.0601
                0.0642
                0.0621
                0.0627

ZeroDates =

                 729907
                 730364
                 730439
                 730500
                 730667
                 730668
                 730971
                 731032
                 731033
                 731321
                 731336
```

Now execute `prbyzero`

```
BondPrices = prbyzero(Bonds, Settle, ZeroRates, ZeroDates)
```

which returns

```
BondPrices =

                 99.38
                 98.80
                106.83
                 96.88
                103.62
                101.13
                103.12
                 99.36
```

```
101.00
101.25
 96.37
102.74
```

In this example `zbtprice` and `prbyzero` do not exactly reverse each other. Many of the bonds have the end-of-month rule off (`EndMonthRule = 0`). The rule subtly affects the time factor computation. If you set the rule on (`EndMonthRule = 1`) everywhere in the `Bonds` matrix, then `prbyzero` returns the original prices, except when the two incompatible prices fall on the same maturity date.

See Also

`tr2bonds`, `zbtprice`

Purpose

Price rate of change

Syntax

```
proc = prcroc(closep, nperiods)
procts = prcroc(tsobj, nperiods)
procts = prcroc(tsobj, nperiods, ParameterName, ParameterValue)
```

Arguments

`closep`	Closing price
`nperiods`	(Optional) Period difference. Default = 12.
`tsobj`	Financial time series object

Description

`proc = prcroc(closep, nperiods)` calculates the price rate of change `proc` from the closing price `closep`. If `nperiods` periods is specified, the price rate of change is calculated between the current closing price and the closing price `nperiods` ago.

`procts = prcroc(tsobj, nperiods)` calculates the price rate of change `procts` from the financial time series object `tsobj`. `tsobj` must contain a data series named `Close`. The output `procts` is a financial time series object with similar dates as `tsobj` and a data series named `PriceROC`. If `nperiods` is specified, the price rate of change is calculated between the current closing price and the closing price `nperiods` ago.

`procts = prcroc(tsobj, nperiods, ParameterName, ParameterValue)` specifies the name for the required data series when it is different from the default name. The valid parameter name is

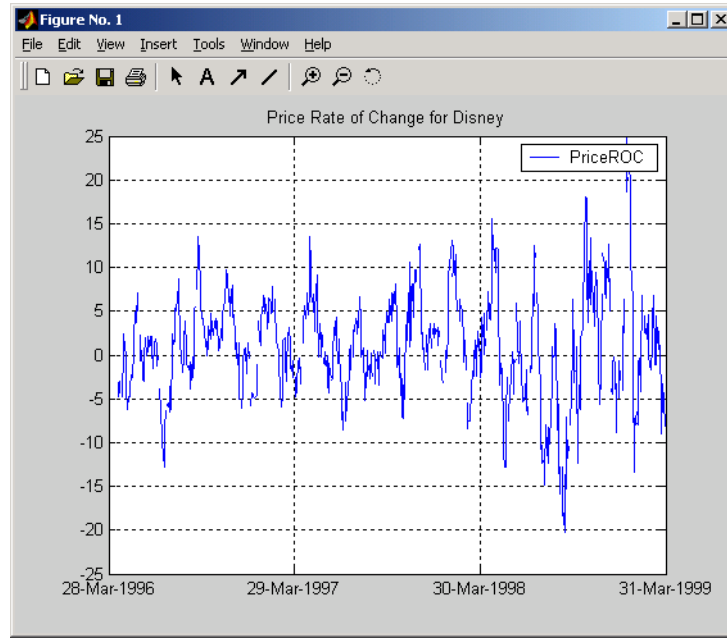
- `CloseName`: closing price series name

The parameter value is a string that represents the valid parameter name.

Examples

Compute the price rate of change for Disney stock and plot the results:

```
load disney.mat
dis_PriceRoc = prcroc(dis)
plot(dis_PriceRoc)
title('Price Rate of Change for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 243 - 245.

See Also

`volroc`

Purpose

Price of discounted security

Syntax

```
Price = prdisc(Settle, Maturity, Face, Discount, Basis)
```

Arguments

`Settle`	Enter as serial date number or date string. Settle must be earlier than or equal to `Maturity`.
`Maturity`	Enter as serial date number or date string.
`Face`	Redemption (par, face) value.
`Discount`	Bank discount rate of the security. Enter as decimal fraction.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)

- 12 = actual/365 (ISDA)

Description

`Price = prdisc(Settle, Maturity, Face, Discount, Basis)` returns the price of a security whose yield is quoted as a bank discount rate (for example, U. S. Treasury bills).

Examples

Using this data

```
Settle = '10/14/2000';
Maturity = '03/17/2001';
Face = 100;
Discount = 0.087;
Basis = 2;

Price = prdisc(Settle, Maturity, Face, Discount, Basis)
```

returns

```
Price =

        96.2783
```

References

Mayle, *Standard Securities Calculation Methods*, Volumes I-II, 3rd edition. Formula 2.

See Also

`acrudisc`, `bndprice`, `discrate`, `prmat`, `ylddisc`

priceandvol

Purpose

Price and volume chart

Syntax

```
priceandvol(X)
```

Arguments

X	M-by-6 matrix where the columns are date, open, high, low, close, and volume.

Description

`priceandvol(X)` plots the asset data displaying the open, high, low, and closing prices on one axis and the volume on a second axis.

Examples

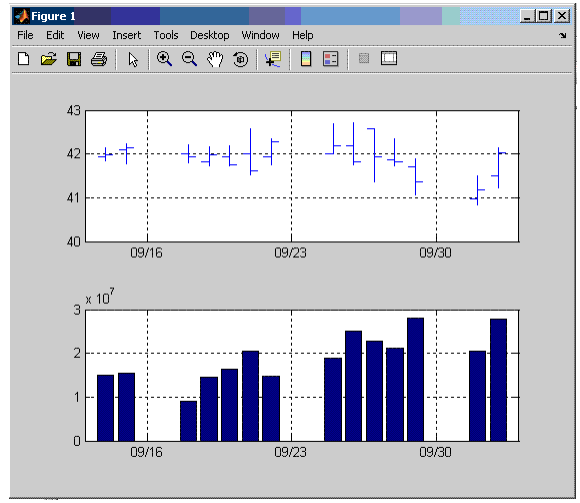
If asset `X` is an `M`-by-`6` matrix for date, open, high, low, close, and volume:

```
X = [...

733299.00        41.93        42.15        41.83        41.99   15045445.00;...
733300.00        42.09        42.24        41.76        42.14   15346658.00;...
733303.00        42.00        42.20        41.78        41.93    9034397.00;...
733304.00        41.82        42.16        41.70        41.98   14486275.00;...
733305.00        41.94        42.19        41.70        41.75   16389872.00;...
733306.00        42.00        42.57        41.50        41.61   20475208.00;...
733307.00        41.93        42.35        41.74        42.29   14833200.00;...
733310.00        42.01        42.70        42.01        42.19   18945176.00;...
733311.00        42.18        42.72        41.73        41.82   25188101.00;...
733312.00        42.57        42.57        41.33        41.93   22689878.00;...
733313.00        41.86        42.35        41.71        41.81   21084723.00;...
733314.00        41.70        41.90        41.04        41.37   27963619.00;...
733317.00        40.98        41.49        40.82        41.17   20385033.00;...
733318.00        41.50        42.15        41.21        42.02   27783775.00]
```

then the price volume chart is

```
priceandvol(X)
```

which plots the asset data displaying the open, high, low, and closing prices on one axis and the volume on a second axis.



See Also

`bolling`, `candle`, `highlow`, `kagi`, `linebreak`, `movavg`, `pointfig`, `renko`, `volarea`

Purpose

Price with interest at maturity

Syntax

```
[Price, AccruInterest] = prmat(Settle, Maturity, Issue, Face,
CouponRate, Yield, Basis)
```

Arguments

`Settle`	Enter as serial date number or date string. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Enter as serial date number or date string.
`Issue`	Enter as serial date number or date string.
`Face`	Redemption (par, face) value.
`CouponRate`	Enter as decimal fraction.
`Yield`	Annual yield. Enter as decimal fraction.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)

- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Description

`[Price, AccruInterest] = prmat(Settle, Maturity, Issue, Face, CouponRate, Yield, Basis)` returns the price and accrued interest of a security that pays interest at maturity. This function also applies to zero-coupon bonds or pure discount securities by setting `CouponRate = 0`.

Examples

Using this data

```
Settle = '02/07/2002';
Maturity = '04/13/2002';
Issue = '10/11/2001';
Face = 100;
CouponRate = 0.0608;
Yield = 0.0608;
Basis = 1;

[Price, AccruInterest] = prmat(Settle, Maturity, Issue, Face,...
CouponRate, Yield, Basis)
```

returns

```
Price =

   99.9784

AccruInterest =

    1.9591
```

References

Mayle, *Standard Securities Calculation Methods*, Volumes I-II, 3rd edition. Formula 4.

See Also `acrubond`, `acrudisc`, `bndprice`, `prdisc`, `yldmat`

Purpose

Price of Treasury bill

Syntax

```
Price = prtbill(Settle, Maturity, Face, Discount)
```

Arguments

`Settle`	Enter as serial date number or date string. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Enter as serial date number or date string.
`Face`	Redemption (par, face) value.
`Discount`	Discount rate of the Treasury bill. Enter as decimal fraction.

Description

`Price = prtbill(Settle, Maturity, Face, Discount)` returns the price for a Treasury bill.

Examples

The settlement date of a Treasury bill is February 10, 2002, the maturity date is August 6, 2002, the discount rate is 3.77%, and the par value is $1000. Using this data

```
Price = prtbill('2/10/2002', '8/6/2002', 1000, 0.0377)
```

returns

```
Price =
        981.4642
```

References

Bodie, Kane, and Marcus, *Investments*, pages 41-43.

See Also

`beytbill`, `yldtbill`

pvfix

Purpose

Present value with fixed periodic payments

Syntax

```
PresentVal = pvfix(Rate, NumPeriods, Payment, ExtraPayment, Due)
```

Arguments

`rate`	Periodic interest rate, as a decimal fraction.
`NumPeriods`	Number of periods.
`Payment`	Periodic payment.
`ExtraPayment`	(Optional) Payment received other than `Payment` in the last period. Default = 0.
`Due`	(Optional) When payments are due or made: 0 = end of period (default), or 1 = beginning of period.

Description

`PresentVal = pvfix(Rate, NumPeriods, Payment, ExtraPayment, Due)` returns the present value of a series of equal payments.

Examples

$200 is paid monthly into a savings account earning 6%. The payments are made at the end of the month for five years. To find the present value of these payments

```
PresentVal = pvfix(0.06/12, 5*12, 200, 0, 0)
```

returns

```
PresentVal =

                10345.11
```

See Also

`fvfix`, `fvvar`, `payper`, `pvvar`

Purpose

Price and Volume Trend (PVT)

Syntax

```
pvt = pvtrend(closep, tvolume)
pvt = pvtrend([closep tvolume])
pvtts = pvtrend(tsobj)
pvtts = pvtrend(tsobj, ParameterName, ParameterValue, ...)
```

Arguments

`closep`	Closing price.
`tvolume`	Volume traded.
`tsobj`	Financial time series object.
`ParameterName`	Valid parameter names are: • `CloseName`: closing prices series name • `VolumeName`: volume traded series name
`ParameterValue`	Parameter values are the strings that represent the valid parameter names.

Description

`pvt = pvtrend(closep, tvolume)` calculates the Price and Volume Trend (PVT) from the stock closing price (`closep`) data and the volume traded (`tvolume`) data.

`pvt = pvtrend([closep tvolume])` accepts a two-column matrix in which the first column contains the closing prices (`closep`) and the second contains the volume traded (`tvolume`).

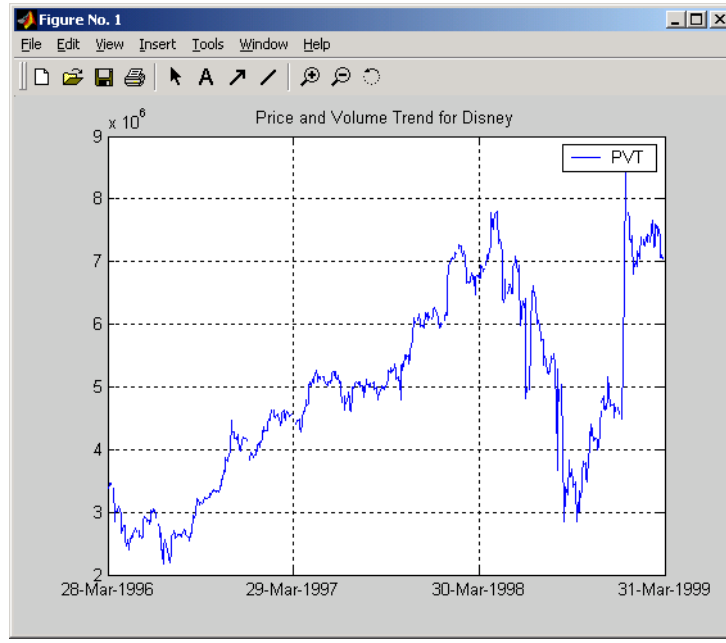
`pvtts = pvtrend(tsobj)` calculates the PVT from the stock data contained in the financial time series object `tsobj`. The object `tsobj` must contain the closing price series `Close` and the volume traded series `Volume`. The output `pvtts` is a financial time series object with dates similar to `tsobj` and a data series named `PVT`.

`pvtts = pvtrend(tsobj, ParameterName, ParameterValue, ...)` accepts parameter name/ parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Parameter values are the strings that represent the valid parameter names.

Examples

Compute the PVT for Disney stock and plot the results:

```
load disney.mat
dis_PVTrend = pvtrend(dis)
plot(dis_PVTrend)
title('Price and Volume Trend for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 239 - 240.

Purpose

Present value of varying cash flow

Syntax

```
PresentVal = pvvar(CashFlow, Rate, IrrCFDates)
```

Arguments

`CashFlow`	A vector of varying cash flows. Include the initial investment as the initial cash flow value (a negative number).
`Rate`	Periodic interest rate. Enter as a decimal fraction.
`IrrCFDates`	(Optional) For irregular (nonperiodic) cash flows, a vector of dates on which the cash flows occur. Enter dates as serial date numbers or date strings. Default assumes `CashFlow` contains regular (periodic) cash flows.

Description

`PresentVal = pvvar(CashFlow, Rate, IrrCFDates)` returns the net present value of a varying cash flow.

Examples

This cash flow represents the yearly income from an initial investment of $10,000. The annual interest rate is 8%.

Year 1	$2000
Year 2	$1500
Year 3	$3000
Year 4	$3800
Year 5	$5000

To calculate the net present value of this regular cash flow

```
PresentVal = pvvar([-10000 2000 1500 3000 3800 5000], 0.08)
```

returns

```
PresentVal =

              1715.39
```

An investment of $10,000 returns this irregular cash flow. The original investment and its date are included. The periodic interest rate is 9%.

Cash Flow	Dates
($10000)	January 12, 1987
$2500	February 14, 1988
$2000	March 3, 1988
$3000	June 14, 1988
$4000	December 1, 1988

To calculate the net present value of this irregular cash flow

```
CashFlow = [-10000, 2500, 2000, 3000, 4000];

IrrCFDates = ['01/12/1987'
              '02/14/1988'
              '03/03/1988'
              '06/14/1988'
              '12/01/1988'];

PresentVal = pvvar(CashFlow, 0.09, IrrCFDates)
```

returns

```
PresentVal =
```

```
142.16
```

See Also

fvfix, fvvar, irr, payuni, pvfix

pyld2zero

Purpose

Zero curve given par yield curve

Syntax

```
[ZeroRates, CurveDates] = pyld2zero(ParRates, CurveDates, Settle,
Compounding, Basis, InputCompounding)
```

Arguments

`ParRates`	Column vector of annualized implied par yield rates, as decimal fractions. (Par yields = coupon rates.) In aggregate, the yield rates in `ParRates` constitute an implied par yield curve for the investment horizon represented by `CurveDates`.
`CurveDates`	Column vector of maturity dates (as serial date numbers) that correspond to the par rates.
`Settle`	Serial date number that is the common settlement date for the par rates.
`Compounding`	(Optional) Scalar value representing the periodicity in which the output zero rates are compounded when annualized. Allowed values are:

1	Annual compounding
2	Semiannual compounding (default)
3	Compounding three times per year
4	Quarterly compounding
6	Bimonthly compounding
12	Monthly compounding
365	Daily compounding

`Basis` (Optional) Day-count basis used to annualize the zero rates.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`InputCompounding` (Optional) Scalar value representing the periodicity in which the input par rates were compounded when annualized. The default is the value for `Compounding`.

Description

`[ZeroRates, CurveDates] = pyld2zero(ParRates, CurveDates, Settle, Compounding, Basis, InputCompounding)` returns a zero curve given a par yield curve and its maturity dates.

`ZeroRates`	Column vector of decimal fractions. In aggregate, the rates in `ZeroRates` constitute a zero curve for the investment horizon represented by `CurveDates`.
`CurveDates`	Column vector of maturity dates (as serial date numbers) corresponding to the zero rates. This vector is the same as the input vector `CurveDates`.

Examples

Given

- A par yield curve over a set of maturity dates
- A settlement date
- Annual compounding for the input par rates and monthly compounding for the output zero curve

compute a zero yield curve.

```
ParRates = [0.0479
            0.0522
            0.0540
            0.0540
            0.0536
            0.0532
            0.0532
            0.0539
            0.0558
            0.0543];

CurveDates = [datenum('06-Nov-2000')
      datenum('11-Dec-2000')
      datenum('15-Jan-2001')
      datenum('05-Feb-2001')
      datenum('04-Mar-2001')
      datenum('02-Apr-2001')
      datenum('30-Apr-2001')
```

```
      datenum('25-Jun-2001')
      datenum('04-Sep-2001')
      datenum('12-Nov-2001')];

Settle = datenum('03-Nov-2000');
InputCompounding = 1;
Compounding = 12;

[ZeroRates, CurveDates] = pyld2zero(ParRates, CurveDates,...
Settle, Compounding, [], InputCompounding)

ZeroRates =

    0.0484
    0.0529
    0.0549
    0.0550
    0.0547
    0.0544
    0.0545
    0.0551
    0.0572
    0.0557

CurveDates =

      730796
      730831
      730866
      730887
      730914
      730943
      730971
      731027
      731098
      731167
```

For readability, `ParRates` and `ZeroRates` are shown only to the basis point. However, MATLAB computes them at full precision. If you enter `ParRates` as shown, `ZeroRates` may differ due to rounding.

See Also

`zero2pyld` and other functions for "Term Structure of Interest Rates" on page 2-37

Purpose

Financial time series division

Syntax

```
newfts = tsobj_1 ./ tsobj_2
newfts = tsobj ./ array
newfts = array ./ tsobj
```

Arguments

`tsobj_1, tsobj_2`	Pair of financial time series objects.
`array`	Scalar value or array with the number of rows equal to the number of dates in `tsobj` and the number of columns equal to the number of data series in `tsobj`.

Description

The `rdivide` method divides, element by element, the components of one financial time series object by the components of the other. You can also divide the whole object by an array or divide a financial time series object into an array.

If an object is to be divided by another object, both objects must have the same dates and data series names, although the order need not be the same. The order of the data series, when an object is divided by another object, follows the order of the first object.

`newfts = tsobj_1 ./ tsobj_2` divides financial time series objects element by element.

`newfts = tsobj ./ array` divides a financial time series object element by element by an array.

`newfts = array ./ tsobj` divides an array element by element by a financial time series object.

For financial time series objects, the `rdivide` operation is identical to the `mrdivide` operation.

See Also `minus`, `mrdivide`, `plus`, `times`

Purpose

Renko chart

Syntax

```
renko(X)
renko(X, threshold)
```

Arguments

`X`	`M`-by-`2` matrix where the first column contains date numbers and the second column is the asset price.
`threshold`	(Optional) Specifies a threshold value for asset price. By default, `threshold` is set to `1`.

Description

`renko(X)` plots asset price with respect to dates.

`renko(X, threshold)` plots the asset data, `X`, adding a new box only when the price has changed but at least the value specified by `threshold`.

Examples

If asset `X` is an `M`-by-`2` matrix of date numbers and asset price:

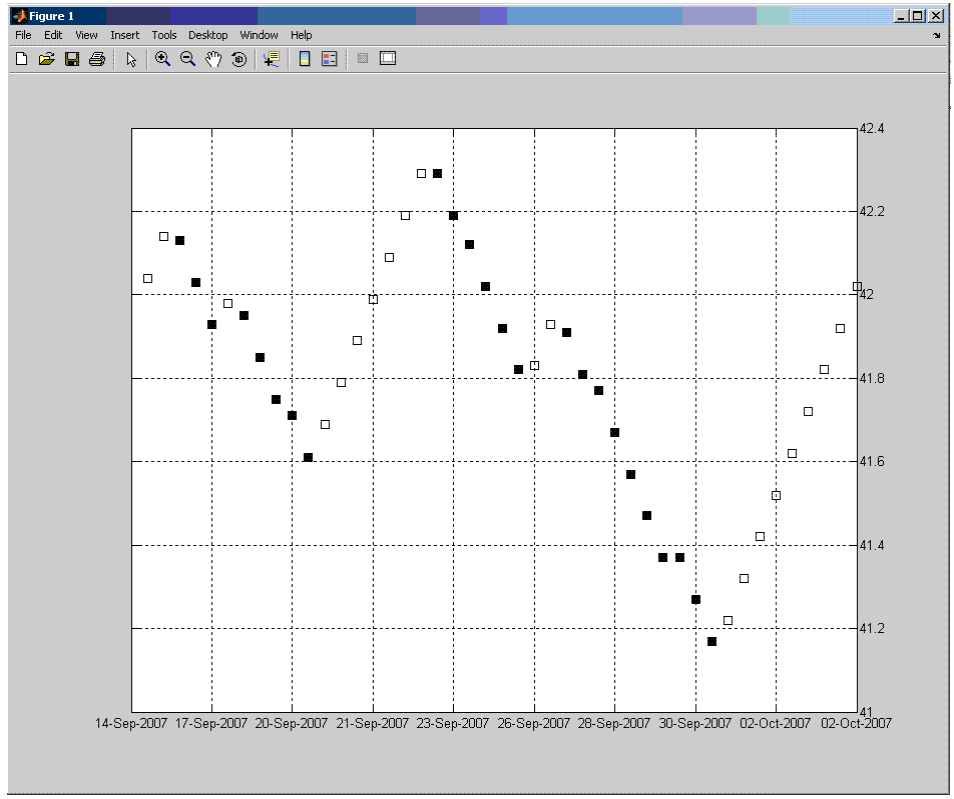
```
X = [...

733299.00          41.99;...
733300.00          42.14;...
733303.00          41.93;...
733304.00          41.98;...
733305.00          41.75;...
733306.00          41.61;...
733307.00          42.29;...
733310.00          42.19;...
733311.00          41.82;...
733312.00          41.93;...
733313.00          41.81;...
733314.00          41.37;...
733317.00          41.17;...
```

```
733318.00          42.02]
```

then the Renko chart is

```
renko(X)
```

which plots the asset prices with respect to dates.



See Also

bolling, candle, highlow, kagi, linebreak, movavg, pointfig, priceandvol, volarea

Purpose

Downsample data

Syntax

```
newfts = resamplets(oldfts, samplestep)
```

Description

`newfts = resamplets(oldfts, samplestep)` downsamples the data contained in the financial time series object `oldfts` every `samplestep` periods. For example, to have the new financial time series object contain every other data element from `oldfts`, set `samplestep` to `2`.

`newfts` is a financial time series object containing the same data series (names) as the input `oldfts`.

See Also

`filter`

Purpose

Convert return series to price series

Syntax

```
[TickSeries, TickTimes] = ret2tick(RetSeries, StartPrice,
RetIntervals, StartTime, Method)
```

Arguments

`RetSeries`	Number of observations (`NUMOBS`) by number of assets (`NASSETS`) time series array of asset returns associated with the prices in `TickSeries`. The *i*th return is quoted for the period `TickTimes(i)` to `TickTimes(i+1)` and is not normalized by the time increment between successive price observations.
`StartPrice`	(Optional) 1-by-`NASSETS` vector of initial asset prices or a single scalar initial price applied to all assets. Prices start at 1 if `StartPrice` is not specified.
`RetIntervals`	(Optional) Scalar or `NUMOBS`-by-1 vector of interval times between observations. If this argument is not specified, all intervals are assumed to have length 1.
`StartTime`	(Optional) Starting time for first observation, applied to the price series of all assets. The default is zero.
`Method`	(Optional) Character string indicating the method to convert asset returns to prices. Must be `'Simple'` (default) or `'Continuous'`. If *`Method`* is `'Simple'`, `ret2tick` uses simple periodic returns. If *`Method`* is `'Continuous'`, the function uses continuously compounded returns. Case is ignored for *`Method`*.

Description

`[TickSeries, TickTimes] = ret2tick(RetSeries, StartPrice, RetIntervals, StartTime, Method)` generates price values from the starting prices of `NASSETS` investments and `NUMOBS` incremental return observations.

`TickSeries` is a `NUMOBS+1`-by-`NASSETS` times series array of equity prices. The first row contains the oldest observations and the last row the most recent. Observations across a given row occur at the same time for all columns. Each column is a price series of an individual asset. If *`Method`* is unspecified or `'Simple'`, the prices are

```
TickSeries(i+1) = TickSeries(i)*[1 + RetSeries(i)]
```

If *`Method`* is `'Continuous'`, the prices are

```
TickSeries(i+1) = TickSeries(i)*exp[RetSeries(i)]
```

`TickTimes` is a `NUMOBS+1` column vector of monotonically increasing observation times associated with the prices in `TickSeries`. The initial time is zero unless specified in `StartTime`, and sequential observation times occur at unit increments unless specified in `RetIntervals`.

Examples

Compute the price increase of two stocks over a year's time based on three incremental return observations.

```
RetSeries = [0.10 0.12
             0.05 0.04
            -0.05 0.05];

RetIntervals = [182
                 91
                 92];

StartTime = datenum('18-Dec-2000');

[TickSeries,TickTimes] = ret2tick(RetSeries,[],RetIntervals,...
StartTime)
```

```
TickSeries =

    1.0000    1.0000
    1.1000    1.1200
    1.1550    1.1648
    1.0973    1.2230

TickTimes =

      730838
      731020
      731111
      731203

datestr(TickTimes)

ans =

18-Dec-2000
18-Jun-2001
17-Sep-2001
18-Dec-2001
```

See Also

portsim, tick2ret

Purpose

Convert return series to price series for time series object

Syntax

```
priceFts = ret2tick(returnFts)
priceFts = ret2tick(returnFts, 'PARAM1', VALUE1,
'PARAM2', VALUE2', ...)
```

Arguments

`returnFts`	Financial time series object of returns.
`'PARAM1'`	(Optional) `StartPrice` is a `Numeric` value and is a scalar or `1`-by-`N` vector of initial prices for each asset. If `StartPrice` is unspecified or empty, the initial price of all assets is 1.
`'PARAM2'`	(Optional) `StartTime` is `Date` value for a scalar date number or a single date string specifying the starting time for the first observation. This date is applied to the price series of all assets.

Note The first period price value of the resulting price series will not be reported if `StartTime` is not specified. The resulting price series will be scaled based on the `StartPrice`, even if `StartTime` is not supplied.

`'PARAM3'`	(Optional) *`Method`* is a character string indicating the method to convert asset returns to prices. The value must be defined as `'Simple'` (default) or `'Continuous'`. If *`Method`* is `'Simple'`, `ret2tick` uses simple periodic returns. If *`Method`* is `'Continuous'`, the function uses continuously compounded returns. Case is ignored for *`Method`*.

Description

`priceFts = ret2tick(returnFts, 'PARAM1', VALUE1, 'PARAM2', VALUE2', ...)` generates a financial time series object of prices.

If *`Method`* is unspecified or `'Simple'`, the prices are

```
PriceSeries(i+1) = PriceSeries(i)*[1 + ReturnSeries(i)]
```

If *`Method`* is `'Continuous'`, the prices are

```
PriceSeries(i+1) = PriceSeries(i)*exp[ReturnSeries(i)]
```

Examples

Compute the price series from the following return series:

```
RetSeries = [0.10 0.12
             0.05 0.04
            -0.05 0.05]
```

Use the following dates:

```
Dates = {'18-Jun-2001'; '17-Sep-2001'; '18-Dec-2001'}
```

where

```
ret = fints(Dates, RetSeries)
ret =
desc:  (none)
freq:  Unknown (0)

'dates:  (3)'    'series1:  (3)'    'series2:  (3)'
'18-Jun-2001'    [       0.1000]    [       0.1200]
'17-Sep-2001'    [       0.0500]    [       0.0400]
'18-Dec-2001'    [      -0.0500]    [       0.0500]
```

`PriceFtS` is computed as:

```
PriceFts = ret2tick(ret, 'StartPrice', 100, 'StartTime', '18-Dec-2000')
```

```
PriceFts =

desc:  (none)
freq:  Unknown (0)

'dates:  (4)'    'series1:  (4)'    'series2:  (4)'
'18-Dec-2000'    [          100]    [          100]
'18-Jun-2001'    [     110.0000]    [     112.0000]
'17-Sep-2001'    [     115.5000]    [     116.4800]
'18-Dec-2001'    [     109.7250]    [     122.3040]
```

See Also

portsim, tick2ret

rmfield

Purpose

Remove data series

Syntax

```
fts = rmfield(tsobj, fieldname)
```

Arguments

`tsobj`	Financial time series object.
`fieldname`	String array containing the data series name to remove a single series from the object. Cell array of data series names to remove multiple data series from the object at the same time.

Description

`fts = rmfield(tsobj, fieldname)` removes the data series `fieldname` and its contents from the financial time series object `tsobj`.

See Also

`chfield`, `extfield`, `fieldnames`, `getfield`, `isfield`

Purpose

Relative Strength Index (RSI)

Syntax

```
rsi = rsindex(closep, nperiods)
rsits = rsindex(tsobj, nperiods)
rsits = rsindex(tsobj, nperiods, ParameterName, ParameterValue)
```

Arguments

`closep`	Vector of closing prices.
`nperiods`	(Optional) Number of periods. Default = 14.
`tsobj`	Financial time series object.

Description

`rsi = rsindex(closep, nperiods)` calculates the Relative Strength Index (RSI) from the closing price vector `closep`.

`rsits = rsindex(tsobj, nperiods)` calculates the RSI from the closing price series in the financial time series object `tsobj`. The object `tsobj` must contain at least the series `Close`, representing the closing prices. The output `rsits` is a financial time series object whose dates are the same as `tsobj` and whose data series name is `RSI`.

`rsits = rsindex(tsobj, nperiods, ParameterName, ParameterValue)` accepts a parameter name/parameter value pair as input. This pair specifies the name for the required data series if it is different from the expected default name. The valid parameter name is

`CloseName`: closing prices series name

The parameter value is the string that represents the valid parameter name.

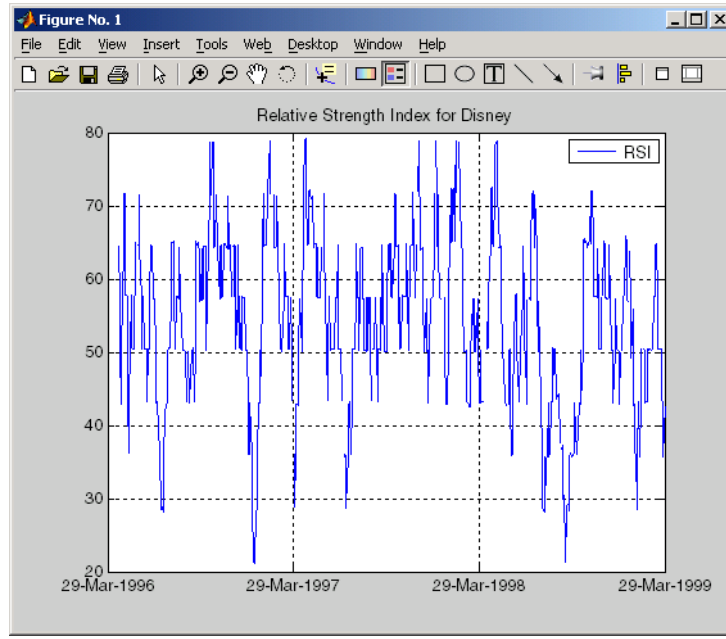
1. The relative strength factor is calculated by dividing the average of the gains by the average of the losses within a specified time period: `RS = (average gains)/(average losses)`.

2 The first value of `RSI`, `RISI(1)`, is set as `NaN` to preserve the dimensions of `CLOSEP`.

Examples

Compute the RSI for Disney stock and plot the results:

```
load disney.mat
dis_RSI = rsindex(dis)
plot(dis_RSI)
title('Relative Strength Index for Disney')
```



References

Murphy, John J., *Technical Analysis of the Futures Market*, New York Institute of Finance, 1986, pp. 295-302.

See Also

`negvolidx`, `posvolidx`

Purpose

Seconds of date or time

Syntax

```
Seconds = second(Date)
```

Description

`Seconds = second(Date)` returns the seconds given a serial date number or a date string.

Examples

```
Seconds = second(738647.558427893)
```

or

```
Seconds = second('06-May-2022, 13:24:08.17')
```

returns

```
Seconds =

            8.1700
```

See Also

`datevec`, `hour`, `minute`

selectreturn

Purpose

Portfolio configurations from 3-D efficient frontier

Syntax

```
PortConfigs = selectreturn(AllMean, All Covariance, Target)
```

Arguments

`AllMean`	Number of curves (`NCURVES`) by 1 cell array where each element is a 1-by-`NASSETS` (number of assets) vector of the expected asset returns used to generate each curve on the surface.
`AllCovariance`	`NCURVES`-by-1 cell array where each element is an `NASSETS`-by-`NASSETS` vector of the covariance matrix used to generate each curve on the surface.
`Target`	Target return value for each curve in the frontier.

Description

`PortConfigs = selectreturn(AllMean, All Covariance, Target)` returns the portfolio configurations for a target return given the average return and covariance for a rolling efficient frontier.

PortConfigs is a `NASSETS`-by-`NCURVES` matrix of asset allocation weights needed to obtain the target rate of return.

See Also

`frontier`

Purpose

Set content of specific field

Syntax

```
newfts = setfield(tsobj, field, V)
newfts = setfield(tsobj, field, {dates}, V)
```

Description

`setfield` treats the contents of fields in a time series object (`tsobj`) as fields in a structure.

`newfts = setfield(tsobj, field, V)` sets the contents of the specified field to the value `V`. This is equivalent to the syntax `S.field = V`.

`newfts = setfield(tsobj, field, {dates}, V)` sets the contents of the specified field for the specified dates. `dates` can be individual cells of date strings or a cell of a date string range using the `::` operator, for example,
`'03/01/99::03/31/99'`. Dates can contain time-of-day information.

Examples

Example 1. Set the closing value for all days to 3890.

```
load dji30short
format bank
myfts1 = setfield(myfts1, 'Close', 3890);
```

Example 2. Set values for specific times on specific days.

First create a financial time series containing time-of-day data.

```
dates = ['01-Jan-2001';'01-Jan-2001'; '02-Jan-2001'; ...
         '02-Jan-2001'; '03-Jan-2001';'03-Jan-2001'];
times = ['11:00';'12:00';'11:00';'12:00';'11:00';'12:00'];
dates_times = cellstr([dates, repmat(' ',size(dates,1),1),...
                       times]);
myfts = fints(dates_times,[(1:4)'; nan; 6],{'Data1'},1,...
              'My FINTS')


myfts =
```

```
    desc:  My FINTS
    freq:  Daily (1)

    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [          4]
    '03-Jan-2001'    '11:00'          [        NaN]
    '     "     '    '12:00'          [          6]
```

Now use `setfield` to replace the data in `myfts` with new data starting at 12:00 on January 1, 2001 and ending at 11:00 on January 3, 2001.

```
S = setfield(myfts,'Data1',...
            {'01-Jan-2001 12:00::03-Jan-2001 11:00'},(102:105)')

S =

    desc:  My FINTS
    freq:  Daily (1)

    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [       1.00]
    '     "     '    '12:00'          [     102.00]
    '02-Jan-2001'    '11:00'          [     103.00]
    '     "     '    '12:00'          [     104.00]
    '03-Jan-2001'    '11:00'          [     105.00]
    '     "     '    '12:00'          [       6.00]
```

See Also

`chfield`, `fieldnames`, `getfield`, `isfield`, `rmfield`

Purpose

Compute Sharpe ratio for one or more assets

Syntax

```
sharpe(Asset)
  sharpe(Asset, Cash)
  Ratio = sharpe(Asset, Cash)
```

Arguments

`Asset`	`NUMSAMPLES`-by-`NUMSERIES` matrix with `NUMSAMPLES` observations of asset returns for `NUMSERIES` asset return series.
`Cash`	(Optional) Either a scalar return for a riskless asset or a vector of asset returns to be a proxy for a riskless asset. In either case, the return periodicity must be the same as the periodicity of `Asset`. For example, if `Asset` is monthly data, then `Cash` must be monthly returns. If no value is supplied, the default value for `Cash` returns is 0.

Description

Given `NUMSERIES` assets with `NUMSAMPLES` returns for each asset in a `NUMSAMPLES`-by-`NUMSERIES` matrix `Asset` and given either a scalar `Cash` asset return or a vector of `Cash` asset returns, the Sharpe ratio is computed for each asset.

The output is `Ratio`, a `1`-by-`NUMSERIES` row vector of Sharpe ratios for each series in `Asset`. Any series in `Asset` with standard deviation of returns equal to 0 will have a `NaN` value for its Sharpe ratio.

Note If `Cash` is a vector, `Asset` and `Cash` need not have the same number of returns but must have the same periodicity of returns. The classic Sharpe ratio assumes that `Cash` is riskless. In reality, a short-term cash rate is not necessarily riskless. `NaN` values in the data are ignored.

Example

See “Sharpe Ratio Example” on page 4-6.

References

William F. Sharpe, "Mutual Fund Performance," *Journal of Business*, Vol. 39, No. 1, Part 2, January 1966, pp. 119-138.

See Also

`inforatio`, `portalpha`

Purpose

Number of dates and data series

Syntax

```
szfts = size(tsobj, dim)
[numRows, numCols] = size(tsobj)
```

Arguments

`tsobj`	Financial time series object.
`dim`	(Optional) A scalar that specifies the following dimension: `dim = 1` returns number of dates (rows). `dim = 2` returns number of data series (columns).

Description

`szfts = size(tsobj)` returns the number of dates (rows) and the number of data series (columns) in the financial time series object `tsobj`. The result is returned in the vector `szfts`, whose first element is the number of dates and second is the number of data series.

`szfts = size(tsobj, dim)` specifies the dimension you want to extract.

`numRows` returns a scalar representing the number of dates (rows).

`numCols` returns a scalar representing the number of data series (columns).

See Also

`length`

`size` in the MATLAB documentation

smoothts

Purpose

Smooth data

Syntax

```
output = smoothts(input)
output = smoothts(input, 'b', wsize)
output = smoothts(input, 'g', wsize, stdev)
output = smoothts(input, 'e', n)
```

Arguments

`input`	Financial time series object or a row-oriented matrix. In a row-oriented matrix, each row represents an individual set of observations.
`'b'`, `'g'`, or `'e'`	Smoothing method (essentially the type of filter used). Can be Exponential (`e`), Gaussian (`g`), or Box (`b`). Default = `b`.
`wsize`	Window size (scalar). Default = 5.
`stdev`	Scalar that represents the standard deviation of the Gaussian window. Default = 0.65.
`n`	For Exponential method, specifies window size or exponential factor, depending upon value. • `n > 1` (window size) or period length • `n < 1` and `> 0` (exponential factor: alpha) • `n = 1` (either window size or alpha) If `n` is not supplied, the defaults are `wsize = 5` and `alpha = 0.3333`.

Description

`smoothts` smooths the input data using the specified method.

`output = smoothts(input)` smooths the input data using the default Box method with window size, `wsize`, of `5`.

`output = smoothts(input, 'b', wsize)` smooths the input data using the Box (simple, linear) method. `wsize` specifies the width of the box to be used.

`output = smoothts(input, 'g', wsize, stdev)` smooths the input data using the Gaussian window method.

`output = smoothts(input, 'e', n)` smooths the input data using the Exponential method. `n` can represent the window size (period length) or alpha. If `n > 1`, `n` represents the window size. If `0 < n < 1`, `n` represents alpha, where

$$\alpha = \frac{2}{wsize + 1}$$

If `input` is a financial time series object, `output` is a financial time series object identical to `input` except for contents. If `input` is a row-oriented matrix, `output` is a row-oriented matrix of the same length.

See Also

`tsmovavg`

sortfts

Purpose

Sort financial time series

Syntax

```
sfts = sortfts(tsobj)
sfts = sortfts(tsobj, flag)
sfts = sortfts(tsobj, seriesnames, flag)
[sfts, sidx] = sortfts(...)
```

Arguments

`tsobj`	Financial time series object.
`flag`	(Optional) Sort order:
	`flag = 1;` increasing order (default)
	`flag = -1`; decreasing order
`seriesnames`	(Optional) String containing a data series name or cell array containing a list of data series names.

Description

`sfts = sortfts(tsobj)` sorts the financial time series object `tsobj` in increasing order based only upon the `'dates'` vector if `tsobj` does not contain time-of-day information. If the object includes time-of-day information, the sort is based upon a combination of the `'dates'` and `'times'` vectors. The `'times'` vector cannot be sorted individually.

`sfts = sortfts(tsobj, flag)` sets the order of the sort. `flag = 1`: increasing date and time order. `flag = -1`: decreasing date and time order.

`sfts = sortfts(tsobj, seriesnames, flag)` sorts the financial time series object `tsobj` based upon the data series name(s) `seriesnames`. The `seriesnames` argument can be a single string containing a data series name or a cell array containing a list of data series names. If the optional `flag` is set to `-1`, the sort is in decreasing order.

`[sfts, sidx] = sortfts(...)` additionally returns the index of the original object `tsobj` sorted based on `'dates'` or specified data series name(s).

See Also

`issorted`

`sort` and `sortrows` in the MATLAB documentation

spctkd

Purpose

Slow stochastics

Syntax

```
[spctk, spctd] = spctkd(fastpctk, fastpctd)
[spctk, spctd] = spctkd([fastpctk  fastpctd])
[spctk, spctd] = spctkd(fastpctk, fastpctd, dperiods, dmamethod)
[spctk, spctd] = spctkd([fastpctk  fastpctd], dperiods, dmamethod)
skdts = spctkd(tsobj)
skdts = spctkd(tsobj, dperiods, dmamethod)
skdts = spctkd(tsobj, dperiods, dmamethod, ParameterName,
ParameterValue, ...)
```

Arguments

`fastpctk`	Fast stochastic F%K (vector).
`fastpctd`	Fast stochastic F%D (vector).
`dperiods`	(Optional) %D periods. Default = 3.
`dmamethod`	(Optional) %D moving average method. Default = `'e'` (exponential).
`tsobj`	Financial time series object.

Description

`[spctk, spctd] = spctkd(fastpctk, fastpctd)` calculates the slow stochastics S%K and S%D. `spctk` and `spctd` are column vectors representing the respective slow stochastics. The inputs must be single column-oriented vectors containing the fast stochastics F%K and F%D.

`[spctk, spctd] = spctkd([fastpctk fastpctd])` accepts a two-column matrix as input. The first column contains the fast stochastic F%K values, and the second contains the fast stochastic F%D values.

`[spctk, spctd] = spctkd(fastpctk, fastpctd, dperiods, dmamethod)` calculates the slow stochastics, S%K and S%D, using the value of `dperiods` to set the number of periods and `dmamethod`

to indicate the moving average method. The inputs `fastpctk` and `fastpctk` must contain the fast stochastics, F%K and F%D, in column orientation. `spctk` and `spctd` are column vectors representing the respective slow stochastics.

Valid moving average methods for %D are exponential (`'e'`), triangular (`'t'`), and modified (`'m'`). See `tsmovavg` for explanations of these methods.

`[spctk, spctd] = spctkd([fastpctk fastpctd], dperiods, dmamethod)` accepts a two-column matrix rather than two separate vectors. The first column contains the F%K values, and the second contains the F%D values.

`skdts = spctkd(tsobj)` calculates the slow stochastics, S%K and S%D. `tsobj` must contain the fast stochastics, F%K and F%D, in data series named `PercentK` and `PercentD`. The `skdts` output is a financial time series object with the same dates as `tsobj`. Within `tsobj` the two series `SlowPctK` and `SlowPctD` represent the respective slow stochastics.

`skdts = spctkd(tsobj, dperiods, dmamethod)` lets you specify the length and the method of the moving average used to calculate S%D values.

`skdts = spctkd(tsobj, dperiods, dmamethod, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

- `KName`: F%K series name
- `DName`: F%D series name

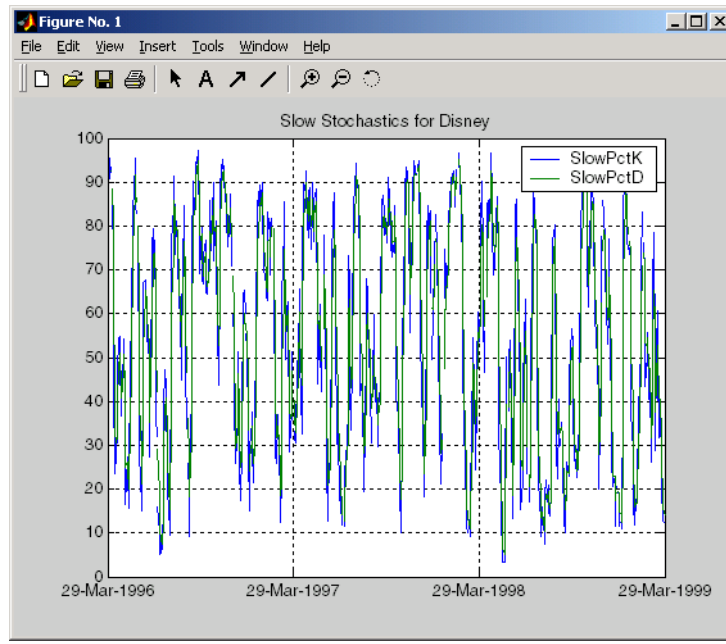
Parameter values are the strings that represent the valid parameter names.

Examples

Compute the slow stochastics for Disney stock and plot the results:

```
load disney.mat
```

```
dis_FastStoch = fpctkd(dis);
dis_SlowStoch = spctkd(dis_FastStoch);
plot(dis_SlowStoch)
title('Slow Stochastics for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 268 - 271.

See Also

`fpctkd`, `stochosc`, `tsmovavg`

Purpose

Standard deviation

Syntax

```
tsstd = std(tsobj)
tsstd = std(tsobj, flag)
```

Arguments

`tsobj`	Financial time series object.
`flag`	(Optional) Normalization factor:
	`flag = 1` normalizes by n (number of observations).
	`flag = 0` normalizes by n-1.

Description

`tsstd = std(tsobj)` computes the standard deviation of each data series in the financial time series object `tsobj` and returns the results in `tsstd`. The `tsstd` output is a structure with field name(s) identical to the data series name(s).

`tsstd = std(tsobj, flag)` normalizes the data as indicated by `flag`.

See Also

`hist`, `mean`

stochosc

Purpose

Stochastic oscillator

Syntax

```
stosc = stochosc(highp, lowp, closep)
stosc = stochosc([highp lowp closep])
stosc = stochosc(highp, lowp, closep, kperiods, dperiods, dmamethod)
stosc = stochosc([highp lowp closep], kperiods, dperiods, dmamethod)
stoscts = stochosc(tsobj, kperiods, dperiods, dmamethod)
stoscts = stochosc(tsobj, kperiods, dperiods, dmamethod,
ParameterName,  ParameterValue, ...)
```

Arguments

`highp`	High price (vector).
`lowp`	Low price (vector).
`closep`	Closing price (vector).
`kperiods`	(Optional) %K periods. Default = 10.
`dperiods`	(Optional) %D periods. Default = 3.
`damethod`	(Optional) %D moving average method. Default = `'e'` (exponential).
`tsobj`	Financial time series object.

Description

`stosc = stochosc(highp, lowp, closep)` calculates the fast stochastics F%K and F%D from the stock price data `highp` (high prices), `lowp` (low prices), and `closep` (closing prices). `stosc` is a two-column matrix whose first column is the F%K values and second is the F%D values.

`stosc = stochosc([highp lowp closep])` accepts a three-column matrix of high (`highp`), low (`lowp`), and closing prices (`closep`), in that order.

`stosc = stochosc(highp, lowp, closep, kperiods, dperiods, dmamethod)` calculates the fast stochastics F%K and F%D from the stock price data `highp` (high prices), `lowp` (low prices), and `closep` (closing prices). `kperiods` sets the %K period. `dperiods` sets the %D period. damethod specifies the %D moving average method. Valid moving average methods for %D are exponential (`'e'`) and triangular (`'t'`). See `tsmovavg` for explanations of these methods.

`stosc= stochosc([highp lowp closep], kperiods, dperiods, dmamethod)` accepts a three-column matrix of high (`highp`), low (`lowp`), and closing prices (`closep`), in that order.

`stoscts = stochosc(tsobj, kperiods, dperiods, dmamethod)` calculates the fast stochastics F%K and F%D from the stock price data in the financial time series object `tsobj`. `tsobj` must minimally contain the series `High` (high prices), `Low` (low prices), and `Close` (closing prices). `stoscts` is a financial time series object with similar dates to `tsobj` and two data series named `SOK` and `SOD`.

`stoscts = stochosc(tsobj, kperiods, dperiods, dmamethod, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

- `HighName`: high prices series name
- `LowName`: low prices series name
- `CloseName`: closing prices series name

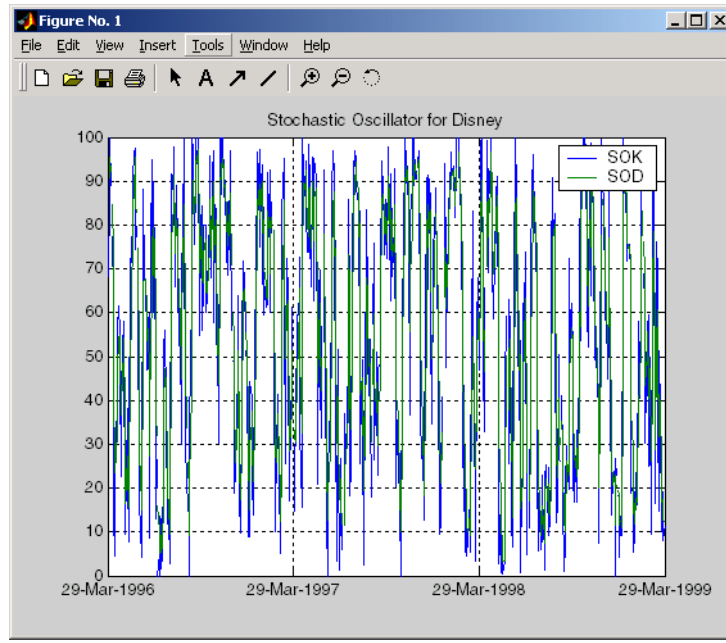
Parameter values are the strings that represent the valid parameter names.

Examples

Compute the stochastic oscillator for Disney stock and plot the results:

```
load disney.mat
dis_StochOsc = stochosc(dis)
plot(dis_StochOsc)
```

```
title('Stochastic Oscillator for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 268 - 271.

See Also

`fpctkd`, `spctkd`

Purpose

Content assignment

Description

`subasgn` assigns content to a component within a financial time series object. subasgn supports integer indexing or date string indexing into the time series object with values assigned to the designated components. *Serial date numbers cannot be used as indices.* To use date string indexing, enclose the date string(s) in a pair of single quotation marks `' '`.

You can use integer indexing on the object as in any other MATLAB matrix. It will return the appropriate entry(ies) from the object.

You must specify the component to which you want to assign values. An assigned value must be either a scalar or a column vector.

Examples

Given a time series `myfts` with a default data series name of `series1`,

```
myfts.series1('07/01/98::07/03/98') = [1 2 3]';
```

assigns the values 1, 2, and 3 corresponding to the first three days of July, 1998.

```
myfts('07/01/98::07/05/98')

ans =

      desc:  Data Assignment
      freq:  Daily (1)

      'dates:  (5)'    'series1:  (5)'
      '01-Jul-1998'    [            1]
      '02-Jul-1998'    [            2]
      '03-Jul-1998'    [            3]
      '04-Jul-1998'    [       4561.2]
      '05-Jul-1998'    [       5612.3]
```

When the financial time series object contains a time-of-day specification, you can assign data to a specific time on a specific day. For

example, create a financial time series object called `timeday` containing both dates and times:

```
dates = ['01-Jan-2001';'01-Jan-2001'; '02-Jan-2001'; ...
'02-Jan-2001'; '03-Jan-2001';'03-Jan-2001'];
times = ['11:00';'12:00';'11:00';'12:00';'11:00';'12:00'];
dates_times = cellstr([dates, repmat(' ',size(dates,1),1),...
times]);
timeday = fints(dates_times,(1:6)',{'Data1'},1,'My first FINTS')

timeday =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [          4]
    '03-Jan-2001'    '11:00'          [          5]
    '     "     '    '12:00'          [          6]
```

Use integer indexing to assign the value 999 to the first item in the object.

```
timeday(1) = 999

timeday =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [        999]
    '     "     '    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
```

```
    '     "     '    '12:00'          [          4]
    '03-Jan-2001'    '11:00'          [          5]
    '     "     '    '12:00'          [          6]
```

For value assignment using date strings, enclose the string in single quotation marks. If a date has multiple times, designating only the date and assigning a value results in every element of that date taking on the assigned value. For example, to assign the value 0.5 to all times-of-day on January 1, 2001, enter

```
timedata('01-Jan-2001') = 0.5
```

The result is

```
timedata =

    desc:  My first FINTS
    freq:  Daily (1)

    'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
    '01-Jan-2001'    '11:00'          [     0.5000]
    '     "     '    '12:00'          [     0.5000]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [          4]
    '03-Jan-2001'    '11:00'          [          5]
    '     "     '    '12:00'          [          6]
```

To access the individual components of the financial time series object, use the structure syntax. For example, to assign a range of data to all the data items in the series `Data1`, you can use

```
timedata.Data1 = (0: .1 : .5)'

timedata =

    desc:  My first FINTS
    freq:  Daily (1)
```

```
'dates:  (6)'    'times:  (6)'    'Data1:  (6)'
'01-Jan-2001'    '11:00'          [          0]
'     "     '    '12:00'          [     0.1000]
'02-Jan-2001'    '11:00'          [     0.2000]
'     "     '    '12:00'          [     0.3000]
'03-Jan-2001'    '11:00'          [     0.4000]
'     "     '    '12:00'          [     0.5000]
```

See Also

datestr, subsref

Purpose

Subscripted reference

Description

`subsref` implements indexing for a financial time series object. Integer indexing or date (and time) string indexing is allowed. *Serial date numbers cannot be used as indices.*

To use date string indexing, enclose the date string(s) in a pair of single quotation marks `' '`.

You can use integer indexing on the object as in any other MATLAB matrix. It returns the appropriate entry(ies) from the object.

Additionally, `subsref` lets you access the individual components of the object using the structure syntax.

Examples

Create a time series named `myfts`:

```
myfts = fints((datenum('07/01/98'):datenum('07/01/98')+4)',...
[1234.56; 2345.61; 3456.12; 4561.23; 5612.34], [], 'Daily',...
'Data Reference');
```

Extract the data for the single day July 1, 1998:

```
myfts('07/01/98')

ans =

     desc:  Data Reference
     freq:  Daily (1)

     'dates:  (1)'    'series1:  (1)'
     '01-Jul-1998'    [       1234.6]
```

Now, extract the data for the range of dates July 1, 1998, through July 5, 1998:

```
myfts('07/01/98::07/03/98')
ans =
     desc:  Data Reference
```

```
        freq:  Daily (1)
        'dates:  (3)'    'series1:  (3)'
        '01-Jul-1998'    [       1234.6]
        '02-Jul-1998'    [       2345.6]
        '03-Jul-1998'    [       3456.1]
```

You can use the MATLAB structure syntax to access the individual components of a financial time series object. To get the description field of `myfts`, enter

```
myfts.desc
```

at the command line, which returns

```
ans =
Data Reference
```

Similarly

```
myfts.series1
```

returns

```
 ans =
        desc:  Data Reference
        freq:  Daily (1)
        'dates:  (5)'    'series1:  (5)'
        '01-Jul-1998'    [       1234.6]
        '02-Jul-1998'    [       2345.6]
        '03-Jul-1998'    [       3456.1]
        '04-Jul-1998'    [       4561.2]
        '05-Jul-1998'    [       5612.3]
```

The syntax for integer indexing is the same as for any other MATLAB matrix. Create a new financial time series object containing both dates and times:

```
dates = ['01-Jan-2001';'01-Jan-2001'; '02-Jan-2001'; ...
```

```
          '02-Jan-2001'; '03-Jan-2001';'03-Jan-2001'];
times = ['11:00';'12:00';'11:00';'12:00';'11:00';'12:00'];
dates_times = cellstr([dates, repmat(' ',size(dates,1),1),...
                       times]);
anewfts = fints(dates_times,(1:6)',{'Data1'},1,'Another FinTs');
```

Use integer indexing to extract the second and third data items from the object.

```
anewfts(2:3)

ans =

    desc:  Another FinTs
    freq:  Daily (1)

    'dates:  (2)'    'times:  (2)'    'Data1:  (2)'
    '01-Jan-2001'    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
```

For date or string enclose the indexing string in a pair of single quotation marks.

If there is one date with multiple times, indexing with only the date returns all the times for that specific date:

```
anewfts('01-Jan-2001')

ans =

    desc:  Another FinTs
    freq:  Daily (1)

    'dates:  (2)'    'times:  (2)'    'Data1:  (2)'
    '01-Jan-2001'    '11:00'          [          1]
    '     "     '    '12:00'          [          2]
```

To specify one specific date and time, index with that date and time:

```
anewfts('01-Jan-2001 12:00')

ans =

    desc:  Another FinTs
    freq:  Daily (1)

    'dates:  (1)'    'times:  (1)'    'Data1:  (1)'
    '01-Jan-2001'    '12:00'          [          2]
```

To specify a range of dates and times, use the double colon (`::`) operator:

```
anewfts('01-Jan-2001 12:00::03-Jan-2001 11:00')

ans =

    desc:  Another FinTs
    freq:  Daily (1)

    'dates:  (4)'    'times:  (4)'    'Data1:  (4)'
    '01-Jan-2001'    '12:00'          [          2]
    '02-Jan-2001'    '11:00'          [          3]
    '     "     '    '12:00'          [          4]
    '03-Jan-2001'    '11:00'          [          5]
```

To request all the dates, times, and data, use the `::` operator without specifying any specific date or time:

```
anewfts('::')
```

See Also

`datestr`, `fts2mat`, `subsasgn`

Purpose

Portfolio weight accuracy

Syntax

```
return = targetreturn(Universe, Window, Offset, Weights)
```

Arguments

`Universe`	Number of observations (`NUMOBS`) by number of assets plus one (`NASSETS + 1`) array containing total return data for a group of securities. Each row represents an observation. Column 1 contains MATLAB serial date numbers. The remaining columns contain the total return data for each security.
`Window`	Number of data periods used to calculate frontier.
`Offset`	Increment in number of periods at which each frontier is generated.
`Weights`	Number of assets (`NASSETS`) by number of curves (`NCURVES`) matrix of asset allocation weights needed to obtain the target rate of return.

Description

`return = targetreturn(Universe, Window, Offset, Weights)` computes target return values for each window of data and given portfolio weights. These values should match the input target return used with `selectreturn`.

See Also

`frontier`, `portopt`, `selectreturn`

taxedrr

Purpose

After-tax rate of return

Syntax

```
Return = taxedrr(PreTaxReturn, TaxRate)
```

Arguments

`PreTaxReturn`	Nominal rate of return. Enter as a decimal fraction.
`TaxRate`	Tax rate. Enter as a decimal fraction.

Description

`Return = taxedrr(PreTaxReturn, TaxRate)` calculates the after-tax rate of return.

Examples

An investment has a 12% nominal rate of return and is taxed at a 30% rate. The after-tax rate of return is

```
Return = taxedrr(0.12, 0.30)

Return =
         0.0840
```

or 8.4%

See Also

`effrr`, `irr`, `mirr`, `nomrr`, `xirr`

Purpose

Treasury bond parameters given Treasury bill parameters

Syntax

```
[TBondMatrix, Settle] = tbl2bond(TBillMatrix)
```

Arguments

`TBillMatrix`	Treasury bill parameters. An `n`-by-`5` matrix where each row describes a Treasury bill. `n` is the number of Treasury bills. Columns are `[Maturity DaysMaturity Bid Asked AskYield]` where:
`Maturity`	Maturity date, as a serial date number. Use `datenum` to convert date strings to serial date numbers.
`DaysMaturity`	Days to maturity, as an integer. Days to maturity is quoted on a skip-day basis; the actual number of days from settlement to maturity is `DaysMaturity + 1`.
`Bid`	Bid bank-discount rate: the percentage discount from face value at which the bill could be bought, annualized on a simple-interest basis. A decimal fraction.
`Asked`	Asked bank-discount rate, as a decimal fraction.
`AskYield`	Asked yield: the bond-equivalent yield from holding the bill to maturity, annualized on a simple-interest basis and assuming a 365-day year. A decimal fraction.

Description

`[TBondMatrix, Settle] = tbl2bond(TBillMatrix)` restates U.S. Treasury bill market parameters in U.S. Treasury bond form as zero-coupon bonds. This function makes Treasury bills directly comparable to Treasury bonds and notes.

`TBondMatrix`	Treasury bond parameters. An `N`-by-`5` matrix where each row describes an equivalent Treasury (zero-coupon) bond. Columns are `[CouponRate Maturity Bid Asked AskYield]` where
`CouponRate`	Coupon rate, which is always 0.
`Maturity`	Maturity date, as a serial date number. This date is the same as the Treasury bill `Maturity` date.
`Bid`	Bid price based on $100 face value.
`Asked`	Asked price based on $100 face value.
`AskYield`	Asked yield to maturity: the effective return from holding the bond to maturity, annualized on a compound-interest basis.

Examples

Given published Treasury bill market parameters for December 22, 1997

```
TBill = [datenum('jan 02 1998')  10  0.0526  0.0522  0.0530
         datenum('feb 05 1998')  44  0.0537  0.0533  0.0544
         datenum('mar 05 1998')  72  0.0529  0.0527  0.0540];
```

Execute the function.

```
TBond = tbl2bond(TBill)

TBond =
            0  729760       99.854       99.855     0.053
            0  729790       99.344       99.349     0.0544
            0  729820       98.942       98.946     0.054
```

(Example output has been formatted for readability.)

See Also

`tr2bonds` and other functions for "Term Structure of Interest Rates" on page 2-37

thirdwednesday

Purpose

Find third Wednesday of month

Syntax

```
[BeginDates, EndDates] = thirdwednesday(Month, Year)
```

Arguments

`Month`	Month of delivery for Eurodollar futures.
`Year`	Four-digit year of delivery for Eurodollar futures, in sequence corresponding to a month in the `Month` input argument.

Inputs can be scalars or `n`-by-`1` vectors.

Description

`[BeginDates, EndDates] = thirdwednesday(Month, Year)` computes the beginning and end period date for a LIBOR contract (third Wednesdays of delivery months).

`BeginDates` is the beginning of three-month period contract as specified by `Month` and `Year`.

`EndDates` is the end of three-month period contract as specified by `Month` and `Year`.

Notes

1. All dates are returned as serial date numbers. Convert to strings using `datestr`.

2. The function returns duplicates if you supply identical months and years.

3. The function supports dates from January 2000 to December 2099.

Examples

Find the third Wednesday dates for swaps commencing in the month of October in the years 2002, 2003, and 2004.

```
Months = [10; 10; 10];
Year = [2002; 2003; 2004];
[BeginDates, EndDates] = thirdwednesday(Months, Year);

datestr(BeginDates)

ans =

16-Oct-2002
15-Oct-2003
20-Oct-2004

datestr(EndDates)

ans =

16-Jan-2003
15-Jan-2004
20-Jan-2005
```

thirtytwo2dec

Purpose

Thirty-second quotation to decimal

Syntax

```
OutNumber =  thirtytwo2dec(InNumber, InFraction)
```

Arguments

`InNumber`	Scalar or vector of input numbers without fractional component.
`InFraction`	Scalar or vector of fractional portions of each element in `InNumber`.

Description

`OutNumber = thirtytwo2dec(InNumber, InFraction)` changes the price quotation for a bond or bond future from a fraction with a denominator of 32 to a decimal.

`OutNumber` represents the sum of `InNumber` and `InFraction` expressed as a decimal.

Examples

Two bonds are quoted as 101-25 and 102-31. Convert these prices to decimal.

```
InNumber  = [101; 102];
InFraction = [25; 31]

OutNumber = thirtytwo2dec(InNumber, InFraction)

OutNumber =

    101.7813
    102.9688
```

See Also

`dec2thirtytwo`

Purpose

Convert price series to return series

Syntax

```
[RetSeries, RetIntervals] = tick2ret(TickSeries,
TickTimes, Method)
```

Arguments

`TickSeries`	Number of observations (`NUMOBS`) by number of assets (`NASSETS`) matrix of prices of equity assets. Each column is a price series of an individual asset. First row is oldest observation. Last row is most recent. Observations across a given row occur at the same time for all columns.
`TickTimes`	(Optional) `NUMOBS`-by-1 increasing vector of observation times associated with the prices in `TickSeries`. Times are serial date numbers (day units) or decimal numbers in arbitrary units (for example, yearly). If `TickTimes` is empty or missing, sequential observation times from 1, 2, ... `NUMOBS` are assumed.
`Method`	(Optional) Character string indicating the method to convert prices to asset returns. Must be `'Simple'` (default) or `'Continuous'`. If `Method` is `'Simple'`, `tick2ret` computes simple periodic returns. If `Method` is `'Continuous'`, returns are continuously compounded. Case is ignored for *`Method`*.

Description

`[RetSeries, RetIntervals] = tick2ret(TickSeries, TickTimes, Method)` computes the asset returns realized between `NUMOBS` observations of prices of `NASSETS` assets.

RetSeries is a (`NUMOBS-1`)-by-`NASSETS` time series array of asset returns associated with the prices in `TickSeries`. The *i*th return is quoted for the period `TickTimes(i)` to `TickTimes(i+1)` and is not normalized by

the time increment between successive price observations. If *Method* is unspecified or 'Simple', the returns are:

```
RetSeries(i) = TickSeries(i+1)/TickSeries(i) - 1
```

If *Method* is 'Continuous', the returns are:

```
RetSeries(i) = log[TickSeries(i+1)/TickSeries(i)]
```

RetIntervals is a (NUMOBS-1)-by-1 column vector of interval times between observations. If TickTimes is empty or unspecified, all intervals are assumed to have length 1.

Examples

Compute the periodic returns of two stocks observed in the first, second, third, and fourth quarters.

```
TickSeries = [100 80
              110 90
              115 88
              110 91];

TickTimes = [0
             6
             9
             12];

[RetSeries, RetIntervals] = tick2ret(TickSeries, TickTimes)

RetSeries =

    0.1000    0.1250
    0.0455   -0.0222
   -0.0435    0.0341

RetIntervals =

     6
```

```
     3
     3
```

See Also

ewstats, ret2tick

Purpose

Convert price series to return series for time series object

Syntax

```
returnFts = tick2ret(priceFts)
returnFts = tick2ret(priceFts, 'PARAM1', VALUE1,
'PARAM2', VALUE2', ...)
```

Arguments

`priceFts`	Financial time series object of prices.
`'PARAM1'`	(Optional) *`Method`* is a character string indicating the method to convert asset returns to prices. The value must be defined as `'Simple'` (default) or `'Continuous'`. If *`Method`* is `'Simple'`, `tick2ret` uses simple periodic returns. If *`Method`* is `'Continuous'`, the function uses continuously compounded returns. Case is ignored for *`Method`*.

Description

`returnFts = tick2ret(priceFts, 'PARAM1', VALUE1, 'PARAM2', VALUE2', ...)` generates a financial time series object of returns.

Note The *i*'th return is quoted for the period `PriceSeries`(*i*) to `PriceSeries`(*i*+1) and is not normalized by the time increment between successive price observations.

If *`Method`* is unspecified or `'Simple'`, the prices are

```
ReturnSeries(i) = PriceSeries(i+1)/PriceSeries(i)-1
```

If *`Method`* is `'Continuous'`, the prices are

```
ReturnSeries(i) = log[PriceSeries(i+1)/PriceSeries(i)]
```

Examples

Compute the return series from the following price series:

```
PriceSeries = [100.0000  100.0000
110.0000  112.0000
115.5000  116.4800
109.7250  122.3040]
```

Use the following dates:

```
Dates = {'18-Dec-2000'
'18-Jun-2001'
'17-Sep-2001'
'18-Dec-2001'}
```

where

```
p = fints(Dates, PriceSeries)
```

`returnFtS` is computed as:

```
returnFts = tick2ret(p)

returnFts =

desc:  (none)
freq:  Unknown (0)

'dates:  (3)'    'series1:  (3)'    'series2:  (3)'
'18-Jun-2001'    [       0.1000]    [       0.1200]
'17-Sep-2001'    [       0.0500]    [       0.0400]
'18-Dec-2001'    [      -0.0500]    [       0.0500]
```

See Also

`portsim`, `ret2tick`

time2date

Purpose

Dates from time and frequency

Syntax

```
Dates = time2date(Settle, TFactors, Compounding, Basis,
EndMonthRule)
```

Arguments

`Settle`	Settlement date. A vector of serial date numbers or date strings.
`TFactors`	A vector of time factors corresponding to the compounding value. `TFactors` must be equal to or greater than zero.

`Compounding`	(Optional) Scalar value representing the rate at which the input zero rates were compounded when annualized. Default = `2`. This argument determines the formula for the discount factors:
	
	`Compounding` = `1`, `2`, `3`, `4`, `6`, `12`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the compounding frequency, `Z` is the zero rate, and `T` is the time in periodic units; for example,`T = F` is one year.
	
	`Compounding` = `365`
	
	`Disc = (1 + Z/F)^(-T)`, where `F` is the number of days in the basis year and `T` is a number of days elapsed computed by basis.
	
	`Compounding` = `-1`
	
	`Disc = exp(-T*Z)`, where `T` is time in years.

`Basis`

(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule`

(Optional) End-of-month rule. A vector. This rule applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore rule, meaning that a bond's coupon payment date is always the same numerical day of the month. 1 = set rule on (default), meaning that a bond's coupon payment date is always the last actual day of the month.

Description

`Dates = time2date(Settle, TFactors, Compounding, Basis, EndMonthRule)` computes dates corresponding to the times occurring beyond the settlement date.

The `time2date` function is the inverse of `date2time`.

Examples

Show that `date2time` and `time2date` are the inverse of each other. First compute the time factors using `date2time`.

```
Settle = '1-Sep-2002';
Dates = datenum(['31-Aug-2005'; '28-Feb-2006'; '15-Jun-2006';
                 '31-Dec-2006']);
Compounding = 2;
Basis = 0;
EndMonthRule = 1;
TFactors = date2time(Settle, Dates, Compounding, Basis,...
                  EndMonthRule)

TFactors =

    5.9945
    6.9945
    7.5738
    8.6576
```

Now use the calculated `TFactors` in `time2date` and compare the calculated dates with the original set.

```
Dates_calc = time2date(Settle, TFactors, Compounding, Basis,...
                  EndMonthRule)

Dates_calc =

      732555
      732736
      732843
      733042
```

```
datestr(Dates_calc)

ans =

31-Aug-2005
28-Feb-2006
15-Jun-2006
31-Dec-2006
```

See Also

cftimes, date2time

times

Purpose

Financial time series multiplication

Syntax

```
newfts = tsobj_1 .* tsobj_2
newfts = tsobj .* array
newfts = array .* tsobj
```

Arguments

`tsobj_1, tsobj_2`	Pair of financial time series objects.
`array`	A scalar value or array with the number of rows equal to the number of dates in `tsobj` and the number of columns equal to the number of data series in `tsobj`.

Description

The `times` method multiplies element by element the components of one financial time series object by the components of the other. You can also multiply the entire object by an array.

If an object is to be multiplied by another object, both objects must have the same dates and data series names, although the order need not be the same. The order of the data series, when an object is multiplied by another object, follows the order of the first object.

`newfts = tsobj_1 .* tsobj_2` multiplies financial time series objects element by element.

`newfts = tsobj .* array` multiplies a financial time series object element by element by an array.

`newfts = array .* tsobj newfts = array / tsobj` multiplies an array element by element by a financial time series object.

For financial time series objects, the `times` operation is identical to the `mtimes` operation.

See Also

`minus`, `mtimes`, `plus`, `rdivide`

Purpose

Convert to annual

Syntax

```
newfts = toannual(oldfts)
newfts = toannual(oldfts, ParameterName, ParameterValue, ...)
```

Arguments

`oldfts`	Financial time series object.

Description

`newfts = toannual(oldfts)` converts a financial time series of any frequency to one of an annual frequency. The default end-of-year is the last business day of the December.

Note If `oldfts` contains time-of-day information, `newfts` displays the time-of-day as `'00:00'` for those days that did not previously exist in `oldfts`.

Empty (`[ ]`) passed as inputs for parameter pair values for `toannual` will trigger the use of the defaults.

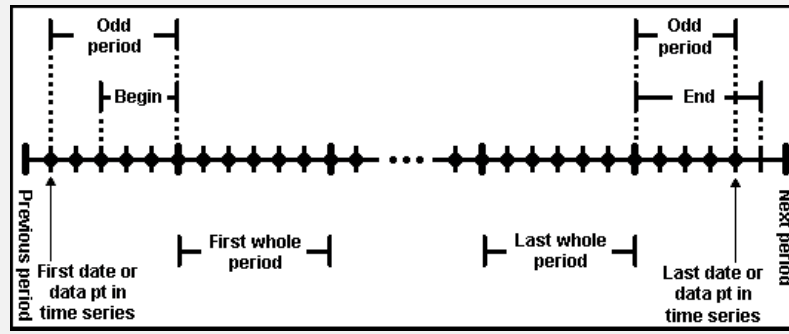
`newfts = toannual(oldfts, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input, as specified in the following table.

Parameter Name	Parameter Value	Description
`CalcMethod`	`CumSum`	Returns the cumulative sum of the values within each year. Data for missing dates are given the value `0`.
	`Exact`	Returns the exact value at the end-of-year date. No data manipulation occurs.

Parameter Name	Parameter Value	Description
	`Nearest`	(Default) Returns the values located at the end-of-year dates. If there is missing data, `Nearest` returns the nearest data point preceding the end-of-year date.
	`SimpAvg`	Returns an averaged annual value that only takes into account dates with data (non`NaN`) within each year.
	`v21x`	This mode is compatible with previous versions of this function (Version 2.1.x and earlier). It returns an averaged end-of-year value using a previous `toannual` algorithm. This algorithm takes into account all dates and data. For dates that do not contain any data, the data is assumed to be `0`.
Note If you set `CalcMethod` to `v21x`, settings for all of the following parameter name/parameter value pairs are not supported.		
`BusDays`	`0`	Returns a financial time series that ranges from (or between) the first date to the last date in `oldfts` (includes NYSE nonbusiness days and holidays).

Parameter Name	Parameter Value	Description
	1	(Default) Generates a monthly financial time series that ranges from the first date to the last date in `oldfts` (excludes NYSE nonbusiness days and holidays and weekends based on `AltHolidays` and `Weekend`). If an end-of-month date falls on a nonbusiness day or NYSE holiday, returns the last business day of the month. NYSE market closures, holidays, and weekends are observed if `AltHolidays` and `Weekend` are not supplied or empty ([]).
`DateFilter`	`Absolute`	(Default) Returns all annual dates between the start and end dates of `oldfts`. Some dates may be disregarded if `BusDays = 1`. **Note** The default is to create a time series with every date at the specified periodicity, which is with `DateFilter = Absolute`. If you use `DateFilter = Relative`, the endpoint effects do not apply since only your data defines which dates will appear in the output time series object.
	`Relative`	Returns only the annual dates that exist in `oldfts`. Some dates may be disregarded if `BusDays = 1`.

Parameter Name	Parameter Value	Description
ED	0	Annual period ends on the last day or last business day of the month.
	1 - 31	Specifies a particular annual day. Months that do not contain the specified day return the last day (or last business day) of the month (for example, ED = 31 does not exist for February.)
EM	1 - 12	(Default) The annual period ends on the last day (or last business day) of the specified month All subsequent annual dates are calculated from this month. Default annual month is December (12).
EndPtTol	[Begin, End]	Denotes the minimum number of days that constitute an odd annual period at the endpoints of the time series (before the first time series date and after the last end-of-year date). Begin and End must be -1 or any positive integer greater than or equal to 0. A single value input for 'EndPtTol' is the same as specifying that single value for Begin and End. -1 Exclude odd annual period dates and data from calculations. 0 (Default) Include odd annual period dates and data in calculations. n Number of days (any positive integer) that constitute an odd annual period. If there are insufficient days for a complete year, the endpoint data is ignored.

Parameter Name	Parameter Value	Description
The following diagram is a general depiction of the factors involved in the determination of endpoints for this function.		
		
`TimeSpec`	`First`	Returns only the observation that occurs at the first (earliest) time for a specific date.
	`Last`	(Default) Returns only the observation that occurs at the last (latest) time for a specific date.
`AltHolidays`		Vector of dates specifying an alternate set of market closure dates.
	`-1`	Excludes all holidays.
`Weekend`		Vector of length 7 containing 0's and 1's. The value 1 indicates a weekend day. The first element of this vector corresponds to Sunday. For example, when Saturday and Sunday are weekend days (default) then `Weekend = [1 0 0 0 0 0 1]`.

See Also

`convertto`, `todaily`, `tomonthly`, `toquarterly`, `tosemi`, `toweekly`

todaily

Purpose

Convert to daily

Syntax

```
newfts = todaily(oldfts)
newfts = todaily(oldfts, ParameterName, ParameterValue, ...)
```

Arguments

`oldfts`	Financial time series object

Description

`newfts = todaily(oldfts)` converts a financial time series of any frequency to a daily frequency.

Note If `oldfts` contains time-of-day information, `newfts` displays the time-of-day as `'00:00'` for those days that did not previously exist in `oldfts`.

Empty (`[ ]`) passed as inputs for parameter pair values for `todaily` will trigger the use of the defaults.

`newfts = todaily(oldfts, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input, as specified in the following table.

Parameter Name	Parameter Value	Description
`CalcMethod`	`Exact`	Returns the value located at specific dates/times. No data manipulation occurs.

Parameter Name	Parameter Value	Description
	`v21x`	This mode is compatible with previous versions of this function (Version 2.1.x and earlier). It returns a five-day business week that starts on Monday and ends on Friday.
Note If you set `CalcMethod` to `v21x`, settings for all of the following parameter name/parameter value pairs are not supported.		
`BusDays`	`0`	Generates a financial time series that ranges from (or between) the first date to the last date in `oldfts` (includes NYSE nonbusiness days and holidays).
	`1`	(Default) Generates a monthly financial time series that ranges from the first date to the last date in `oldfts` (excludes NYSE nonbusiness days and holidays and weekends based on `AltHolidays` and `Weekend`). If an end-of-month date falls on a nonbusiness day or NYSE holiday, returns the last business day of the month. NYSE market closures, holidays, and weekends are observed if `AltHolidays` and `Weekend` are not supplied or empty ([]).

Parameter Name	Parameter Value	Description
DateFilter	Absolute	(Default) Displays all daily dates between the start and end dates of oldfts. Some dates may be disregarded if BusDays = 1. **Note** The default is to create a time series with every date at the specified periodicity, which is with DateFilter = Absolute. If you use DateFilter = Relative, the endpoint effects do not apply since only your data defines which dates will appear in the output time series object.
	Relative	Displays only dates that exist in oldfts. Some dates may be disregarded if BusDays = 1.
TimeSpec	First	Returns only the observation that occurs at the first (earliest) time for a specific date.
	Last	(Default) Returns only the observation that occurs at the last (latest) time for a specific date.
AltHolidays		Vector of dates specifying an alternate set of market closure dates.
	-1	Excludes all holidays.
Weekend		Vector of length 7 containing 0's and 1's. The value 1 indicates a weekend day. The first element of this vector corresponds to Sunday. For example, when Saturday and Sunday are weekend days (default) then Weekend = [1 0 0 0 0 0 1].

See Also `convertto`, `toannual`, `tomonthly`, `toquarterly`, `tosemi`, `toweekly`

today

Purpose

Current date

Syntax

```
Datenum = today
```

Description

`Datenum = today` returns the current date as a serial date number.

Examples

```
Datenum = today
```

returns

```
Datenum =

        730695
```

on July 28, 2000.

See Also

`datenum`, `datestr`, `now`

Purpose

Fractional to decimal conversion

Syntax

```
usddec = todecimal(quote, fracpart)
```

Description

`usddec = todecimal(quote, fracpart)` returns the decimal equivalent, `usddec`, of a security whose price is normally quoted as a whole number and a fraction (`quote`). `fracpart` indicates the fractional base (denominator) with which the security is normally quoted (default = 32).

Examples

In the *Wall Street Journal,* bond prices are quoted in fractional form based on a denominator of 32. For example, if you see the quoted price is 100:05 it means 100 5/32. To find the equivalent decimal value, enter

```
usddec = todecimal(100.05)

usddec =
   100.1563
usddec = todecimal(97.04, 16)

usddec =
   97.2500
```

Note The convention of using `.` (period) as a substitute for `:` (colon) in the input is adopted from Excel software.

See Also

`toquoted`

tomonthly

Purpose

Convert to monthly

Syntax

```
newfts = tomonthly(oldfts)
newfts = tomonthly(oldfts, ParameterName, ParameterValue, ...)
```

Arguments

`oldfts`	Financial time series object.

Description

`newfts = tomonthly(oldfts)` converts a financial time series of any frequency to a monthly frequency. The default end-of-month day is the last business day of the month.

Note If `oldfts` contains time-of-day information, `newfts` displays the time-of-day as `00:00` for those days that did not previously exist in `oldfts`.

Empty (`[ ]`) passed as inputs for parameter pair values for `tomonthly` will trigger the use of the defaults.

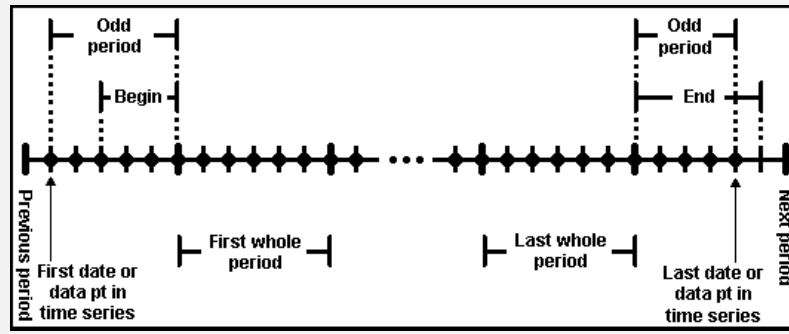
`newfts = tomonthly(oldfts, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input, as specified in the following table.

Parameter Name	Parameter Value	Description
`CalcMethod`	`CumSum`	Returns the cumulative sum of the values within each month. Data for missing dates are given the value `0`.

Parameter Name	Parameter Value	Description
	`Exact`	Returns the exact value at the end-of-month date. No data manipulation occurs.
	`Nearest`	(Default) Returns the values located at the end-of-month date. If there is missing data, 'Nearest' returns the nearest data point preceding the end-of-month date.
	`SimpAvg`	Returns an averaged monthly value that only takes into account dates with data (non`NaN`) within each month.
	`v21x`	This mode is compatible with previous versions of this function (Version 2.1.x and earlier). It returns an averaged end-of-month value using a previous `tomonthly` algorithm. This algorithm takes into account all dates and data. For dates that do not contain any data, the data is assumed to be `0`.
	Note If you set `CalcMethod` to `v21x`, settings for all of the following parameter name/parameter value pairs are not supported.	
`BusDays`	`0`	Generates a monthly financial time series that ranges from the first date to the last date in `oldfts` (includes NYSE nonbusiness days and holidays).

Parameter Name	Parameter Value	Description
	1	(Default) Generates a monthly financial time series that ranges from the first date to the last date in `oldfts` (excludes NYSE nonbusiness days and holidays and weekends based on `AltHolidays` and `Weekend`). If an end-of-month date falls on a nonbusiness day or NYSE holiday, returns the last business day of the month. NYSE market closures, holidays, and weekends are observed if `AltHolidays` and `Weekend` are not supplied or empty ([]).
`DateFilter`	`Absolute`	(Default) Returns all monthly dates between the start and end dates of `oldfts`. Some dates may be disregarded if `BusDays = 1`. **Note** The default is to create a time series with every date at the specified periodicity, which is with `DateFilter = Absolute`. If you use `DateFilter = Relative`, the endpoint effects do not apply since only your data defines which dates will appear in the output time series object.
	`Relative`	Returns only monthly dates that exist in `oldfts`. Some dates may be disregarded if `BusDays = 1`.

Parameter Name	Parameter Value	Description
ED	0	(Default) The end-of-month date is the last day (or last business day) of the month.
	1 - 31	Returns values on the specified end-of-month day. Months that do not contain the specified end-of-month day return the last day of the month instead (for example, ED = 31 does not exist for February). If end-of-month falls on a NYSE non-business day or holiday, the previous business day is returned if BusDays = 1.
EndPtTol	[Begin, End]	Denotes the minimum number of days that constitute an odd month at the end points of the time series (before the first whole period and after the last whole period). Begin and End must be -1 or any positive integer greater than or equal to 0. A single value input for EndPtTol is the same as specifying that single value for Begin and End. -1 Do not include odd month dates and data in calculations. 0 (Default) Include all odd month dates and data in calculations. n Number of days that constitute an odd month. If the minimum number of days is not met, the odd month dates and data are ignored.

Parameter Name	Parameter Value	Description
The following diagram is a general depiction of the factors involved in the determination of end points for this function.		
		
`TimeSpec`	`First`	Returns only the observation that occurs at the first (earliest) time for a specific date.
	`Last`	(Default) Returns only the observation that occurs at the last (latest) time for a specific date.
`AltHolidays`		Vector of dates specifying an alternate set of market closure dates.
	`-1`	Excludes all holidays.
`Weekend`		Vector of length 7 containing 0's and 1's. The value 1 indicates a weekend day. The first element of this vector corresponds to Sunday. For example, when Saturday and Sunday are weekend days (default) then `Weekend = [1 0 0 0 0 0 1]`.

See Also

`convertto`, `toannual`, `todaily`, `toquarterly`, `tosemi`, `toweekly`

Purpose

Convert to quarterly

Syntax

```
newfts = toquarterly(oldfts)
newfts = toquarterly(oldfts, ParameterName, ParameterValue, ...)
```

Arguments

`oldfts`	Financial time series object

Description

`newfts = toquarterly(oldfts)` converts a financial time series of any frequency to a quarterly frequency. The default quarterly days are the last business day of March, June, September, and December.

Note If `oldfts` contains time-of-day information, `newfts` displays the time-of-day as `00:00` for those days that did not previously exist in `oldfts`.

Empty (`[ ]`) passed as inputs for parameter pair values for `toquarterly` will trigger the use of the defaults.

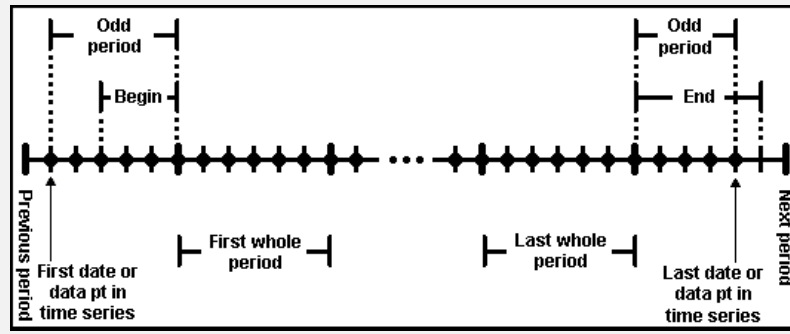
`newfts = toquarterly(oldfts, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input, as specified in the following table.

Parameter Name	Parameter Value	Description
`CalcMethod`	`CumSum`	Returns the cumulative sum of the values between each quarter. Data for missing dates are given the value `0`.

Parameter Name	Parameter Value	Description
	`Exact`	Returns the exact value at the end-of-quarter date. No data manipulation occurs.
	`Nearest`	(Default) Returns the values located at the end-of-quarter date. If there is missing data, `Nearest` returns the nearest data point preceding the end-of-quarter date.
	`SimpAvg`	Returns an averaged quarterly value that only takes into account dates with data (non`NaN`) within each quarter.
	`v21x`	This mode is compatible with previous versions of this function (Version 2.1.x and earlier). It returns an averaged end-of-quarter value using a previous `toquarterly` algorithm. This algorithm takes into account all dates and data. For dates that do not contain any data, the data is assumed to be `0`.
	Note If you set `CalcMethod` to `v21x`, settings for all of the following parameter name/parameter value pairs are not supported.	
`BusDays`	`0`	Generates a financial time series that ranges from (or between) the first date to the last date in `oldfts` (includes NYSE nonbusiness days and holidays).

Parameter Name	Parameter Value	Description
	`1`	(Default) Generates a financial time series that ranges from the first date to the last date in `oldfts` (excludes NYSE nonbusiness days and holidays and weekends based on `AltHolidays` and `Weekend`). If an end-of-quarter date falls on a nonbusiness day or NYSE holiday, returns the last business day of the quarter. NYSE market closures, holidays, and weekends are observed if `AltHolidays` and `Weekend` are not supplied or empty ([]).
`DateFilter`	`Absolute`	(Default) Returns all quarterly dates between the start and end dates of `oldfts`. Some dates may be disregarded if `BusDays = 1`. **Note** The default is to create a time series with every date at the specified periodicity, which is with `DateFilter = Absolute`. If you use `DateFilter = Relative`, the endpoint effects do not apply since only your data defines which dates will appear in the output time series object.
	`Relative`	Returns only quarterly dates that exist in `oldfts`. Some dates may be disregarded if `BusDays = 1`.

Parameter Name	Parameter Value	Description
ED	0	(Default) The end-of-quarter date is the last day (or last business day) of the quarter.
	1 - 31	Specifies a particular end-of-quarter day. Months that do not contain the specified end-of-quarter day return the last day of the quarter instead (for example, ED = 31 does not exist for February).
EM	1 - 12	Last month of the first quarter. All subsequent quarterly dates are based on this month. The default end-of-first-quarter month is March (3).
EndPtTol	[Begin, End]	Denotes the minimum number of days that constitute a odd quarter at the endpoints of the time series (before the first whole period and after the last whole period). Begin and End must be -1 or any positive integer greater than or equal to 0. A single value input for EndPtTol is the same as specifying that single value for Begin and End. -1 Do not include odd quarter dates and data in calculations. 0 (Default) Include all odd quarter dates and data in calculations. n Number of days (any positive integer) that constitute an odd quarter. If there are insufficient days for a complete quarter, the odd quarter dates and data are ignored.

Parameter Name	Parameter Value	Description
The following diagram is a general depiction of the factors involved in the determination of endpoints for this function.		
		
`TimeSpec`	`First`	Returns only the observation that occurs at the first (earliest) time for a specific date.
	`Last`	(Default) Returns only the observation that occurs at the last (latest) time for a specific date.
`AltHolidays`		Vector of dates specifying an alternate set of market closure dates.
	`-1`	Excludes all holidays.
`Weekend`		Vector of length 7 containing 0's and 1's. The value 1 indicates a weekend day. The first element of this vector corresponds to Sunday. For example, when Saturday and Sunday are weekend days (default) then `Weekend = [1 0 0 0 0 0 1]`.

See Also

`convertto`, `toannual`, `todaily`, `tomonthly`, `tosemi`, `toweekly`

Purpose

Decimal to fractional conversion

Syntax

```
quote = toquoted(usddec, fracpart)
```

Description

`quote = toquoted(usddec, fracpart)` returns the fractional equivalent, `quote`, of the decimal figure, `usddec`, based on the fractional base (denominator), `fracpart`. The fractional bases are the ones used for quoting equity prices in the United States (denominator 2, 4, 8, 16, or 32). If `fracpart` is not entered, the denominator 32 is assumed.

Examples

A United States equity price in decimal form is 101.625. To convert this to fractional form in eighths of a dollar:

```
quote = toquoted(101.625, 8)

quote =
        101.05
```

The answer is interpreted as 101 5/8.

Note The convention of using `.` (period) as a substitute for `:` (colon) in the output is adopted from Excel software.

See Also

`todecimal`

Purpose

Convert to semiannual

Syntax

```
newfts = tosemi(oldfts)
newfts = tosemi(oldfts, ParameterName, ParameterValue, ...)
```

Arguments

`oldfts`	Financial time series object.

Description

`newfts = tosemi(oldfts)` converts a financial time series of any frequency to a semiannual frequency. The default semiannual days are the last business day of June and December.

Note If `oldfts` contains time-of-day information, `newfts` displays the time-of-day as `00:00` for those days that did not previously exist in `oldfts`.

Empty (`[ ]`) passed as inputs for parameter pair values for `tosemi` will trigger the use of the defaults.

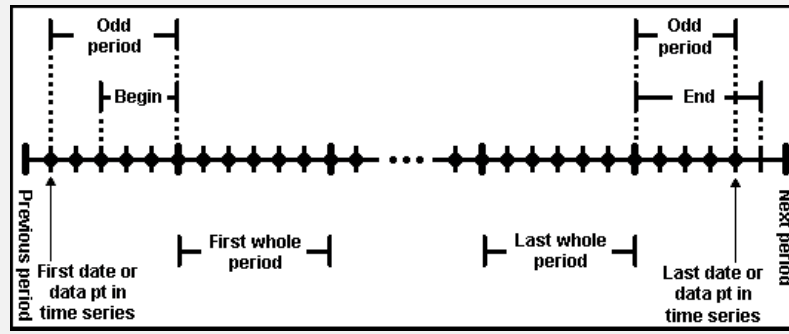
`newfts = tosemi(oldfts, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input, as specified in the following table.

Parameter Name	Parameter Value	Description
`CalcMethod`	`CumSum`	Returns the cumulative sum of the values within each semiannual period. Data for missing dates are given the value `0`.

Parameter Name	Parameter Value	Description
	`Exact`	Returns the exact value at the end-of-period date. No data manipulation occurs.
	`Nearest`	(Default) Returns the values located at the end-of-period date. If there is missing data, `Nearest` returns the nearest data point preceding the end-of-period date.
	`SimpAvg`	Returns an averaged semiannual value that only takes into account dates with data (non`NaN`) within each semiannual period.
	`v21x`	This mode is compatible with previous versions of this function (Version 2.1.x and earlier). It returns an averaged end-of-period value using a previous `tosemi` algorithm. This algorithm takes into account all dates and data. For dates that do not contain any data, the data is assumed to be `0`.
	Note If you set `CalcMethod` to `v21x`, settings for all of the following parameter name/parameter value pairs are not supported.	
`BusDays`	`0`	Generates a financial time series that ranges from (or between) the first date to the last date in `oldfts` (includes NYSE nonbusiness days and holidays).

Parameter Name	Parameter Value	Description
	1	(Default) Generates a financial time series that ranges from the first date to the last date in `oldfts` (excludes NYSE nonbusiness days and holidays and weekends based on `AltHolidays` and `Weekend`). If an end-of-quarter date falls on a nonbusiness day or NYSE holiday, returns the last business day of the quarter. NYSE market closures, holidays, and weekends are observed if `AltHolidays` and `Weekend` are not supplied or empty ([]).
`DateFilter`	`Absolute`	(Default) Returns all semiannual dates between the start and end dates of `oldfts`. Some dates may be disregarded if `BusDays = 1`. **Note** The default is to create a time series with every date at the specified periodicity, which is with `DateFilter = Absolute`. If you use `DateFilter = Relative`, the endpoint effects do not apply since only your data defines which dates will appear in the output time series object.
	`Relative`	Returns only semiannual dates that exist in `oldfts`. Some dates may be disregarded if `BusDays = 1`.

Parameter Name	Parameter Value	Description
ED	0	(Default) The end-of-period date is the last day (or last business day) of the semiannual period.
	1 - 31	Specifies a particular end-of-period day. Months that do not contain the specified end-of-period day return the last day of the semiannual period instead (for example, ED = 31 does not exist for February).
EM	1 - 12	End month of the first semiannual period. All subsequent period dates are based on this month. The default end of period months are June (6) and December (12).
EndPtTol	[Begin, End]	Denotes the minimum number of days that constitute an odd semiannual period at the endpoints of the time series (before the first whole period and after the last whole period). Begin and End must be -1 or any positive integer greater than or equal to 0. A single value input for EndPtTol is the same as specifying that single value for Begin and End. -1 Do not include odd period dates and data in calculations. 0 (Default) Include all odd period dates and data in calculations. n Number of days (any positive integer) that constitute an odd period. If there are insufficient days for a complete semiannual period, the odd period dates and data are ignored.

Parameter Name	Parameter Value	Description
The following diagram is a general depiction of the factors involved in the determination of endpoints for this function.		
		
`TimeSpec`	`First`	Returns only the observation that occurs at the first (earliest) time for a specific date.
	`Last`	(Default) Returns only the observation that occurs at the last (latest) time for a specific date.
`AltHolidays`		Vector of dates specifying an alternate set of market closure dates.
	`-1`	Excludes all holidays.
`Weekend`		Vector of length 7 containing 0's and 1's. The value 1 indicates a weekend day. The first element of this vector corresponds to Sunday. For example, when Saturday and Sunday are weekend days (default) then `Weekend = [1 0 0 0 0 0 1]`.

See Also

`convertto`, `toannual`, `todaily`, `tomonthly`, `toquarterly`, `toweekly`

totalreturnprice

Purpose

Total return price time series

Syntax

```
Return = totalreturnprice(Price, Action, Dividend)
```

Arguments

`Price`	Number of observations (`NUMOBS`)-by-`2` matrix of price data. Column 1 contains MATLAB serial date numbers. Column 2 contains price values.
`Action`	`NUMOBS`-by-`2` matrix of price data. Column 1 contains MATLAB serial date numbers. Column 2 contains split ratios.
`Dividend`	`NUMOBS`-by-`2` matrix of price data. Column 1 contains MATLAB serial date numbers. Column 2 contains dividend payouts.

The number of observations (`NUMOBS`) for the three input arguments will differ from each other.

Description

`Return = totalreturnprice(Price, Action, Dividend)` generates a total return price time series given price data, action or split data, and dividend data.

Return is `NUMOBS`-by-`2` array of price data, where `NUMOBS` reflects the number of observations of price data. Column 1 contains MATLAB serial date numbers. Column 2 contains total return price values.

See Also

`periodicreturns`

Purpose

Convert to weekly

Syntax

```
newfts = toweekly(oldfts)
newfts = toweekly(oldfts, ParameterName, ParameterValue, ...)
```

Arguments

`oldfts`	Financial time series object.

Description

`newfts = toweekly(oldfts)` converts a financial time series of any frequency to a weekly frequency. The default weekly days are Fridays or the last business day of the week.

Note If `oldfts` contains time-of-day information, `newfts` displays the time-of-day as `00:00` for those days that did not previously exist in `oldfts`.

Empty (`[ ]`) passed as inputs for parameter pair values for `toweekly` will trigger the use of the defaults.

`newfts = toweekly(oldfts, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input, as specified in the following table.

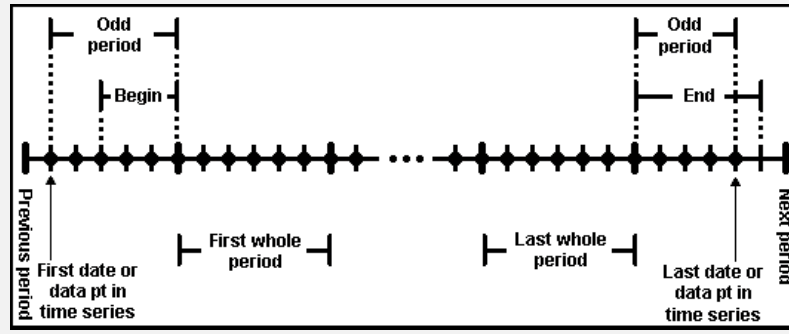
Parameter Name	Parameter Value	Description
`CalcMethod`	`CumSum`	Returns the cumulative sum of the values within each week. Data for missing dates are given the value `0`.

Parameter Name	Parameter Value	Description
	`Exact`	Returns the exact value at the end-of-week dates. No data manipulation occurs.
	`Nearest`	(Default) Returns the values located at the end-of-week dates. If there is missing data, `Nearest` returns the nearest data point preceding the end-of-week date.
	`SimpAvg`	Returns an averaged weekly value that only takes into account dates with data (non`NaN`) within each week.
	`v21x`	This mode is compatible with previous versions of this function (Version 2.1.x and earlier). It returns an averaged end-of-weekly value using a previous `toquarterly` algorithm. This algorithm takes into account all dates and data. For dates that do not contain any data, the data is assumed to be `0`.
	Note If you set `CalcMethod` to `v21x`, settings for all of the following parameter name/parameter value pairs are not supported.	
`BusDays`	`0`	Generates a financial time series that ranges from (or between) the first date to the last date in `oldfts` (includes NYSE nonbusiness days and holidays).

Parameter Name	Parameter Value	Description
	`1`	(Default) Generates a financial time series that ranges from the first date to the last date in `oldfts` (excludes NYSE nonbusiness days and holidays and weekends based on `AltHolidays` and `Weekend`). If an end-of-quarter date falls on a nonbusiness day or NYSE holiday, returns the last business day of the quarter. NYSE market closures, holidays, and weekends are observed if `AltHolidays` and `Weekend` are not supplied or empty ([]).
`DateFilter`	`Absolute`	(Default) Returns all weekly dates between the start and end dates of `oldfts`. Some dates may be disregarded if `BusDays = 1`. **Note** The default is to create a time series with every date at the specified periodicity, which is with `DateFilter = Absolute`. If you use `DateFilter = Relative`, the endpoint effects do not apply since only your data defines which dates will appear in the output time series object.
	`Relative`	Returns only end-of-week dates that exist in `oldfts`. Some dates may be disregarded if `BusDays = 1`.

Parameter Name	Parameter Value	Description
`EndPtTol`	[`Begin`, `End`]	Denotes the minimum number of days that constitute a odd week at the endpoints of the time series (before the first whole period and after the last whole period). `Begin` and `End` must be `-1` or any positive integer greater than or equal to `0`. A single value input for `EndPtTol` is the same as specifying that single value for `Begin` and `End`. `-1` Do not include odd week dates and data in calculations. `0` (Default) Include all odd week dates and data in calculations. `n` Number of days (any positive integer) that constitute an odd week. If there are insufficient days for a complete week, the odd week dates and data are ignored.

The following diagram is a general depiction of the factors involved in the determination of endpoints for this function.



Parameter Name	Parameter Value	Description
EOW	0 - 6	Specifies the end-of-week day: • 0 Friday (default) • 1 Saturday • 2 Sunday • 3 Monday • 4 Tuesday • 5 Wednesday • 6 Thursday
TimeSpec	First	Returns only the observation that occurs at the first (earliest) time for a specific date.
	Last	(Default) Returns only the observation that occurs at the last (latest) time for a specific date.
AltHolidays		Vector of dates specifying an alternate set of market closure dates.
	-1	Excludes all holidays.
Weekend		Vector of length 7 containing 0's and 1's. The value 1 indicates a weekend day. The first element of this vector corresponds to Sunday. For example, when Saturday and Sunday are weekend days (default) then `Weekend = [1 0 0 0 0 0 1]`.

See Also

`convertto`, `toannual`, `todaily`, `tomonthly`, `toquarterly`, `tosemi`

tr2bonds

Purpose

Term-structure parameters given Treasury bond parameters

Syntax

```
[Bonds, Prices, Yields] = tr2bonds(TreasuryMatrix, Settle)
```

Arguments

`TreasuryMatrix`	Treasury bond parameters. An `n`-by-`5` matrix, where each row describes a Treasury bond. Columns are `[CouponRate Maturity Bid Asked AskYield]` where:
`CouponRate`	Coupon rate, as a decimal fraction.
`Maturity`	Maturity date, as a serial date number. Use `datenum` to convert date strings to serial date numbers.
`Bid`	Bid price based on $100 face value.
`Asked`	Asked price based on $100 face value.
`AskYield`	Asked yield to maturity, as a decimal fraction.
`Settle`	(Optional) Date string or serial date number of the settlement date for the analysis.

Description

`[Bonds, Prices, Yields] = tr2bonds(TreasuryMatrix, Settle)` returns term-structure parameters (bond information, prices, and yields) sorted by ascending maturity date, given Treasury bond parameters. The formats of the output matrix and vectors meet requirements for input to the `zbtprice` and `zbtyield` zero-curve bootstrapping functions.

`Bonds`	Coupon bond information. An `n`-by-`6` matrix where each row describes a bond. Columns are `[Maturity CouponRate Face Period Basis EndMonthRule]` where:
`Maturity`	Maturity date of the bond, as a serial date number. Use `datestr` to convert serial date numbers to date strings.
`CouponRate`	Coupon rate of the bond, as a decimal fraction.
`Face`	Redemption or face value of the bond, always 100.
`Period`	Coupons per year of the bond, always 2.
`Basis`	Day-count basis of the bond, possible values include: • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365
`EndMonthRule`	End-of-month flag, always 1, meaning that a bond's coupon payment date is always the last day of the month.

`Prices`	Prices. Column vector containing the price of each bond in `bonds`, respectively. The number of rows (n) matches the number of rows in `bonds`.
`Yields`	Yields. Column vector containing the yield to maturity of each bond in `bonds`, respectively. The number of rows (n) matches the number of rows in `bonds`. If `Settle` is input, `Yields` is computed as a semiannual yield to maturity. If `Settle` is not input, the quoted input yields will be used.

Examples

Given published Treasury bond market parameters for December 22, 1997

```
Matrix =[0.0650 datenum('15-apr-1999')  101.03125 101.09375 0.0564
         0.05125 datenum('17-dec-1998')  99.4375   99.5     0.0563
         0.0625 datenum('30-jul-1998')  100.3125  100.375   0.0560
         0.06125 datenum('26-mar-1998') 100.09375 100.15625 0.0546];
```

Execute the function.

```
[Bonds, Prices, Yields] = tr2bonds(Matrix)

Bonds =

  729840    0.06125    100    2    0    1
  729966    0.0625     100    2    0    1
  730106    0.05125    100    2    0    1
  730225    0.065      100    2    0    1

Prices =

         100.1563
         100.3750
```

```
            99.5000
           101.0938

Yields =

           0.0546
           0.056
           0.0563
           0.0564
```

(Example output has been formatted for readability.)

See Also

`tbl2bond`, `zbtprice`, `zbtyield`, and other functions for "Term Structure of Interest Rates" on page 2-37

tsaccel

Purpose

Acceleration between periods

Syntax

```
acc = tsaccel(data, nperiods, datatype)
accts = tsaccel(tsobj, nperiods, datatype)
```

Arguments

`data`	Data series.
`nperiods`	(Optional) Number of periods. Default = 12.
`datatype`	(Optional) Indicates whether `data` contains the data itself or the momentum of the data: `0` = Data contains the data itself (default). `1` = Data contains the momentum of the data.
`tsobj`	Name of an existing financial time series object.

Description

Acceleration is the difference of two momentums separated by some number of periods.

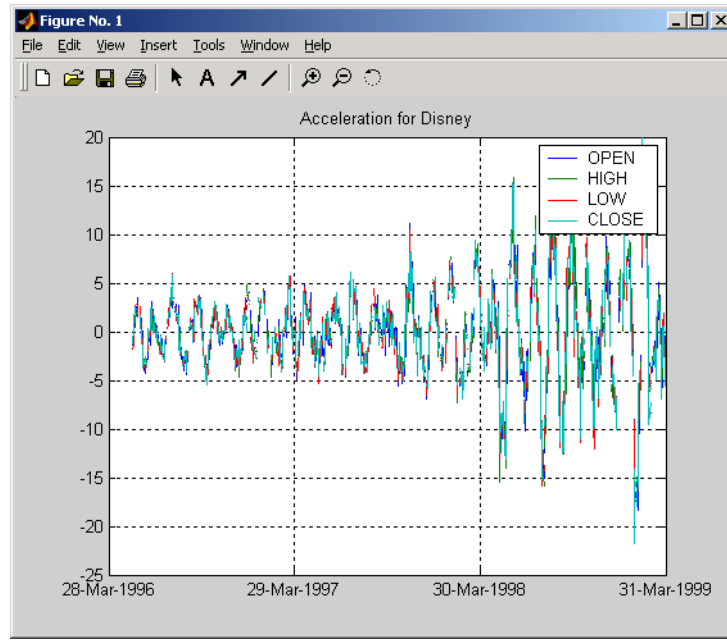
`acc = tsaccel(data, nperiods, datatype)` calculates the acceleration of a data series, essentially the difference of the current momentum with the momentum some number of periods ago. If `nperiods` is specified, `tsaccel` calculates the acceleration of a data series data with time distance of `nperiods` periods.

`accts = tsaccel(tsobj, nperiods, datatype)` calculates the acceleration of the data series in the financial time series object `tsobj`, essentially the difference of the current momentum with the momentum some number of periods ago. Each data series in `tsobj` is treated individually. `accts` is a financial time series object with similar dates and data series names as `tsobj`.

Examples

Compute the acceleration for Disney stock and plot the results:

```
load disney.mat
dis = rmfield(dis,'VOLUME') % remove VOLUME field
dis_Accel = tsaccel(dis);
plot(dis_Accel)
title('Acceleration for Disney')
```



References

Kaufman, P. J., *The New Commodity Trading Systems and Methods*, New York: John Wiley & Sons, 1987.

See Also

`tsmom`

tsmom

Purpose

Momentum between periods

Syntax

```
mom = tsmom(data, nperiods)
momts = tsmom(tsobj, nperiods)
```

Arguments

`data`	Data series. Column-oriented vector or matrix.
`nperiods`	(Optional) Number of periods. Default = 12.
`tsobj`	Financial time series object.

Description

Momentum is the difference between two prices (data points) separated by a number of periods.

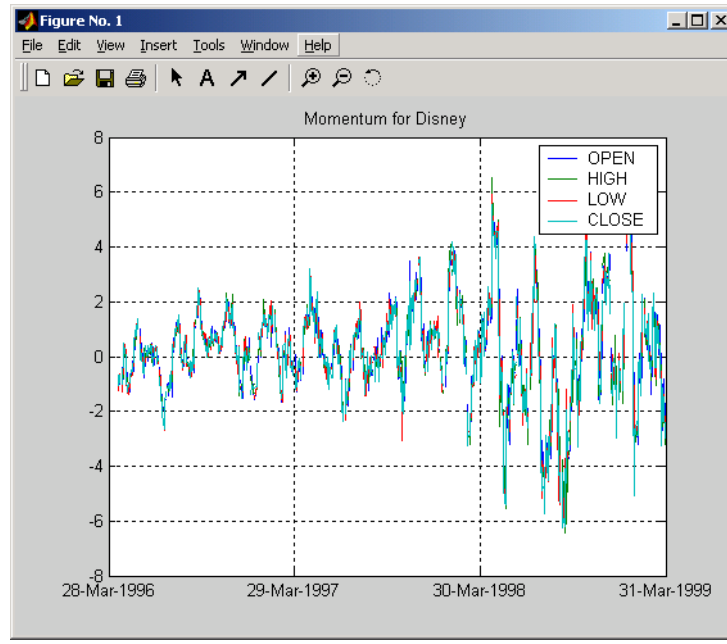
`mom = tsmom(data, nperiods)` calculates the momentum of a data series data. If `nperiods` is specified, `tsmom` uses that value instead of the default 12.

`momts = tsmom(tsobj, nperiods)` calculates the momentum of all data series in the financial time series object `tsobj`. Each data series in `tsobj` is treated individually. `momts` is a financial time series object with similar dates and data series names as `tsobj`. If `nperiods` is specified, `tsmom` uses that value instead of the default 12.

Examples

Compute the momentum for Disney stock and plot the results:

```
load disney.mat
dis = rmfield(dis,'VOLUME') % remove VOLUME field
dis_Mom = tsmom(dis);
plot(dis_Mom)
title('Momentum for Disney')
```



See Also

`tsaccel`

Purpose

Moving average

Syntax

```
output = tsmovavg(tsobj, 's', lag)            (Simple)
output = tsmovavg(vector, 's', lag, dim)
output = tsmovavg(tsobj, 'e', timeperiod)     (Exponential)
output = tsmovavg(vector, 'e', timeperiod, dim)
output = tsmovavg(tsobj, 't', numperiod)      (Triangular)
output = tsmovavg(vector, 't', numperiod, dim)
output = tsmovavg(tsobj, 'w', weights)        (Weighted)
output = tsmovavg(vector, 'w', weights, dim)
output = tsmovavg(tsobj, 'm', numperiod)      (Modified)
output = tsmovavg(vector, 'm', numperiod, dim)
```

Arguments

`tsobj`	Financial time series object.
`lag`	Number of previous data points.
`vector`	Row vector or row-oriented matrix. Each row is a set of observations.
`dim`	(Optional) Specifies dimension when `input` is a vector or matrix. Default = 2 (row-oriented matrix: each row is a variable, and each column is an observation). If `dim = 1`, input is assumed to be a column vector or column-oriented matrix (each column is a variable and each row an observation). `output` is identical in format to `input`.
`timeperiod`	Length of time period.
`numperiod`	Number of periods considered.
`weights`	Weights for each element in the window.

Description

`output = tsmovavg(tsobj, 's', lag)` and `output = tsmovavg(vector, 's', lag, dim)` compute the simple moving average. `lag` indicates the number of previous data points used with the current data point when calculating the moving average.

`output = tsmovavg(tsobj, 'e', timeperiod)` and `output = tsmovavg(vector, 'e', timeperiod, dim)` compute the exponential weighted moving average. The exponential moving average is a weighted moving average, where `timeperiod` specifies the time period. Exponential moving averages reduce the lag by applying more weight to recent prices. For example, a 10-period exponential moving average weights the most recent price by 18.18%. (`2/(timeperiod + 1)`).

`output = tsmovavg(tsobj, 't', numperiod)` and `output = tsmovavg(vector, 't', numperiod, dim)` compute the triangular moving average. The triangular moving average double-smooths the data. `tsmovavg` calculates the first simple moving average with window width of `ceil(numperiod + 1)/2`. Then it calculates a second simple moving average on the first moving average with the same window size.

`output = tsmovavg(tsobj, 'w', weights)` and `output = tsmovavg(vector, 'w', weights, dim)` calculate the weighted moving average by supplying weights for each element in the moving window. The length of the weight vector determines the size of the window. If larger weight factors are used for more recent prices and smaller factors for previous prices, the trend is more responsive to recent changes.

`output = tsmovavg(tsobj, 'm', numperiod)` and `output = tsmovavg(vector, 'm', numperiod, dim)` calculate the modified moving average. The modified moving average is similar to the simple moving average. Consider the argument `numperiod` to be the lag of the simple moving average. The first modified moving average is calculated like a simple moving average. Subsequent values are calculated by adding the new price and subtracting the last average from the resulting sum.

References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 184-192.

See Also

`mean`, `peravg`

Purpose

Typical price

Syntax

```
tprc = typprice(highp, lowp, closep)
tprc = typprice([highp lowp closep])
tprcts = typprice(tsobj)
tprcts = typprice(tsobj, ParameterName, ParameterValue, ...)
```

Arguments

`highp`	High price (vector).
`lowp`	Low price (vector).
`closep`	Closing price (vector).
`tsobj`	Financial time series object.

Description

`tprc = typprice(highp, lowp, closep)` calculates the typical prices `tprc` from the high (`highp`), low (`lowp`), and closing (`closep`) prices. The typical price is the average of the high, low, and closing prices for each period.

`tprc = typprice([highp lowp closep])` accepts a three-column matrix as the input rather than two individual vectors. The columns of the matrix represent the high, low, and closing prices, in that order.

`tprcts = typprice(tsobj)` calculates the typical prices from the stock data contained in the financial time series object `tsobj`. The object must contain, at least, the `High`, `Low`, and `Close` data series. The typical price is the average of the closing price plus the high and low prices. `tprcts` is a financial time series object of the same dates as `tsobj` containing the data series `TypPrice`.

`tprcts = typprice(tsobj, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

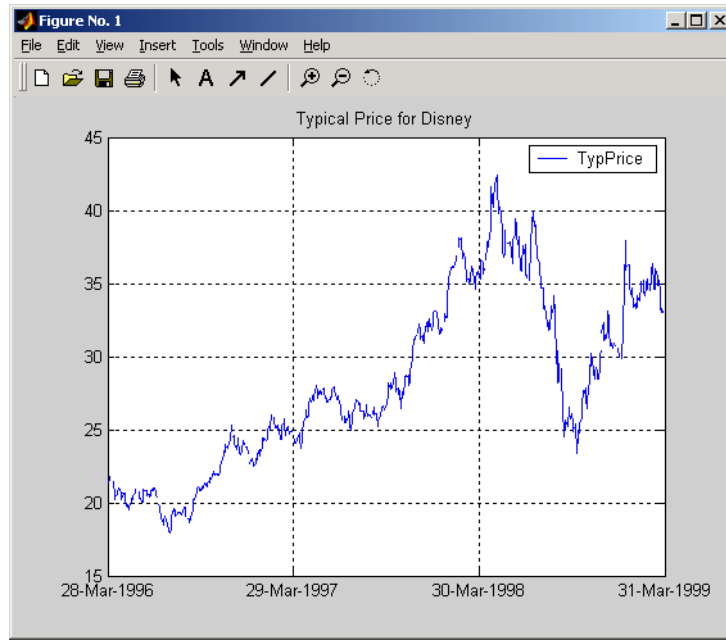
- `HighName`: high prices series name
- `LowName`: low prices series name
- `CloseName`: closing prices series name

Parameter values are the strings that represent the valid parameter names.

Examples

Compute the typical price for Disney stock and plot the results:

```
load disney.mat
dis_Typ = typprice(dis);
plot(dis_Typ)
title('Typical Price for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 291 - 292.

See Also

`medprice`, `wclose`

Purpose

Univariate GARCH(P,Q) parameter estimation with Gaussian innovations

Syntax

```
[Kappa, Alpha, Beta] = ugarch(U, P, Q)
```

Arguments

`U` Single column vector of random disturbances, that is, the residuals or innovations (ε_t), of an econometric model representing a mean-zero, discrete-time stochastic process. The innovations time series `U` is assumed to follow a GARCH(P,Q) process.

Note The latest value of residuals is the last element of vector `U`.

`P` Nonnegative, scalar integer representing a model order of the GARCH process. `P` is the number of lags of the conditional variance. `P` can be zero; when `P = 0`, a GARCH(0,Q) process is actually an ARCH(Q) process.

`Q` Positive, scalar integer representing a model order of the GARCH process. `Q` is the number of lags of the squared innovations.

Description

`[Kappa, Alpha, Beta] = ugarch(U, P, Q)` computes estimated univariate GARCH(P,Q) parameters with Gaussian innovations.

`Kappa` is the estimated scalar constant term ([[KAPPA]]) of the GARCH process.

`Alpha` is a `P`-by-1 vector of estimated coefficients, where `P` is the number of lags of the conditional variance included in the GARCH process.

`Beta` is a `Q`-by-1 vector of estimated coefficients, where `Q` is the number of lags of the squared innovations included in the GARCH process.

The time-conditional variance, σ_t^2, of a GARCH(P,Q) process is modeled as

$$\sigma_t^2 = \kappa + \sum_{i=1}^{P} \alpha_i \sigma_{t-i}^2 + \sum_{j=1}^{Q} \beta_j \varepsilon_{t-j}^2$$

where α represents the argument `Alpha`, ß represents `Beta`, and the GARCH(P, Q) coefficients {[[KAPPA]], α, ß} are subject to the following constraints.

$$\sum_{i=1}^{P} a_i + \sum_{j=1}^{Q} \beta_j < 1$$

$$\kappa > 0$$

$$a_i \geq 0 \quad i = 1, 2, \ldots, P$$

$$\beta_j \geq 0 \quad j = 1, 2, \ldots, Q$$

Note that `U` is a vector of residuals or innovations (ε_t) of an econometric model, representing a mean-zero, discrete-time stochastic process.

Although σ_t^2 is generated using the equation above, ε_t and σ_t^2 are related as

$$\varepsilon_t = \sigma_t v_t$$

where $\{v_t\}$ is an independent, identically distributed (iid) sequence ~ N(0,1).

Note `ugarch` corresponds generally to the Econometrics Toolbox function `garchfit`. The Econometrics Toolbox software provides a comprehensive and integrated computing environment for the analysis of volatility in time series. For information, see the Econometrics Toolbox User's Guide documentation or the financial products Web page at `http://www.mathworks.com/products/finprod/`.

Examples

See `ugarchsim` for an example of a GARCH(P,Q) process.

References

James D. Hamilton, *Time Series Analysis*, Princeton University Press, 1994

See Also

`ugarchpred`, `ugarchsim`, and the Econometrics Toolbox function `garchfit`

Purpose

Log-likelihood objective function of univariate GARCH(P,Q) processes with Gaussian innovations

Syntax

```
LogLikelihood = ugarchllf(Parameters, U, P, Q)
```

Arguments

`Parameters` `(1 + P + Q)`-by-`1` column vector of GARCH(P,Q) process parameters. The first element is the scalar constant term [[KAPPA]] of the GARCH process; the next `P` elements are coefficients associated with the `P` lags of the conditional variance terms; the next `Q` elements are coefficients associated with the `Q` lags of the squared innovations terms.

`U` Single column vector of random disturbances, that is, the residuals or innovations (ε_t), of an econometric model representing a mean-zero, discrete-time stochastic process. The innovations time series `U` is assumed to follow a GARCH(P,Q) process.

Note The latest value of residuals is the last element of vector `U`.

`P` Nonnegative, scalar integer representing a model order of the GARCH process. `P` is the number of lags of the conditional variance. `P` can be zero; when `P = 0`, a GARCH(0,Q) process is actually an ARCH(Q) process.

`Q` Positive, scalar integer representing a model order of the GARCH process. `Q` is the number of lags of the squared innovations.

Description

`LogLikelihood = ugarchllf(Parameters, U, P, Q)` computes the log-likelihood objective function of univariate GARCH(P,Q) processes with Gaussian innovations.

`LogLikelihood` is a scalar value of the GARCH(P,Q) log-likelihood objective function given the input arguments. This function is meant to be optimized via the `fmincon` function of the Optimization Toolbox™ software.

`fmincon` is a minimization routine. To maximize the log-likelihood function, the `LogLikelihood` output parameter is actually the negative of what is formally presented in most time series or econometrics references.

The time-conditional variance, σ_t^2, of a GARCH(P,Q) process is modeled as

$$\sigma_t^2 = \kappa + \sum_{i=1}^{P} \alpha_i \sigma_{t-i}^2 + \sum_{j=1}^{Q} \beta_j \varepsilon_{t-j}^2$$

where α represents the argument `Alpha`, and β represents `Beta`.

`U` is a vector of residuals or innovations (ε_t) representing a mean-zero, discrete time stochastic process. Although σ_t^2 is generated via the equation above, ε_t and σ_t^2 are related as

$$\varepsilon_t = \sigma_t v_t$$

where $\{v_t\}$ is an independent, identically distributed (iid) sequence ~ N(0,1).

Since `ugarchllf` is really just a helper function, no argument checking is performed. This function is not meant to be called directly from the command line.

Note The Econometrics Toolbox software provides a comprehensive and integrated computing environment for the analysis of volatility in time series. For information, see the Econometrics Toolbox User's Guide documentation or the financial products Web page at `http://www.mathworks.com/products/finprod/`.

See Also

`ugarch`, `ugarchpred`, `ugarchsim`

Purpose

Forecast conditional variance of univariate GARCH(P,Q) processes

Syntax

```
[VarianceForecast, H] = ugarchpred(U, Kappa, Alpha, Beta,
NumPeriods)
```

Arguments

`U`

Single column vector of random disturbances, that is, the residuals or innovations (ε_t), of an econometric model representing a mean-zero, discrete-time stochastic process. The innovations time series `U` is assumed to follow a GARCH(P,Q) process.

Note The latest value of residuals is the last element of vector `U`.

`Kappa`

Scalar constant term [[KAPPA]] of the GARCH process.

`Alpha`

`P`-by-1 vector of coefficients, where `P` is the number of lags of the conditional variance included in the GARCH process. `Alpha` can be an empty matrix, in which case `P` is assumed 0; when `P = 0`, a GARCH(0,Q) process is actually an ARCH(Q) process.

`Beta`

`Q`-by-1 vector of coefficients, where `Q` is the number of lags of the squared innovations included in the GARCH process.

`NumPeriods`

Positive, scalar integer representing the forecast horizon of interest, expressed in periods compatible with the sampling frequency of the input innovations column vector `U`.

Description

`[VarianceForecast, H] = ugarchpred(U, Kappa, Alpha, Beta, NumPeriods)` forecasts the conditional variance of univariate GARCH(P,Q) processes.

`VarianceForecast` is a number of periods (`NUMPERIODS`)-by-`1` vector of the minimum mean-square error forecast of the conditional variance of the innovations time series vector `U` (that is, ε_t). The first element contains the 1-period-ahead forecast, the second element contains the 2-period-ahead forecast, and so on. Thus, if a forecast horizon greater than 1 is specified (`NUMPERIODS > 1`), the forecasts of all intermediate horizons are returned as well. In this case, the last element contains the variance forecast of the specified horizon, `NumPeriods` from the most recent observation in `U`.

`H` is a vector of the conditional variances (σ_t^2) corresponding to the innovations vector `U`. It is inferred from the innovations `U`, and is a reconstruction of the "past" conditional variances, whereas the `VarianceForecast` output represents the projection of conditional variances into the "future." This sequence is based on setting pre-sample values of σ_t^2 to the unconditional variance of the $\{\varepsilon_t\}$ process. `H` is a single column vector of the same length as the input innovations vector `U`.

The time-conditional variance, σ_t^2, of a GARCH(P,Q) process is modeled as

$$\sigma_t^2 = \kappa + \sum_{i=1}^{P} \alpha_i \sigma_{t-i}^2 + \sum_{j=1}^{Q} \beta_j \varepsilon_{t-j}^2$$

where α represents the argument `Alpha`, β represents `Beta`, and the GARCH(P,Q) coefficients {[[KAPPA]], α, β} are subject to the following constraints.

$$\sum_{i=1}^{P} a_i + \sum_{j=1}^{Q} \beta_j < 1$$

$$\kappa > 0$$

$$a_i \geq 0 \quad i = 1, 2, \ldots, P$$

$$\beta_j \geq 0 \quad j = 1, 2, \ldots, Q$$

Note that `U` is a vector of residuals or innovations (ε_t) of an econometric model, representing a mean-zero, discrete-time stochastic process.

Although σ_t^2 is generated using the equation above, ε_t and σ_t^2 are related as

$$\varepsilon_t = \sigma_t v_t$$

where $\{v_t\}$ is an independent, identically distributed (iid) sequence ~ N(0,1).

Note `ugarchpred` corresponds generally to the Econometrics Toolbox function `garchpred`. The Econometrics Toolbox software provides a comprehensive and integrated computing environment for the analysis of volatility in time series. For information, see the Econometrics Toolbox User's Guide documentation or the financial products Web page at `http://www.mathworks.com/products/finprod/`.

Examples

See `ugarchsim` for an example of forecasting the conditional variance of a univariate GARCH(P,Q) process.

See Also

`ugarch`, `ugarchsim`, and the Econometrics Toolbox function `garchpred`

Purpose

Simulate univariate GARCH(P,Q) process with Gaussian innovations

Syntax

```
[U, H] = ugarchsim(Kappa, Alpha, Beta, NumSamples)
```

Arguments

`Kappa`	Scalar constant term [[KAPPA]] of the GARCH process.
`Alpha`	`P`-by-`1` vector of coefficients, where `P` is the number of lags of the conditional variance included in the GARCH process. `Alpha` can be an empty matrix, in which case `P` is assumed 0; when `P = 0`, a GARCH(0,Q) process is actually an ARCH(Q) process.
`Beta`	`Q`-by-`1` vector of coefficients, where `Q` is the number of lags of the squared innovations included in the GARCH process.
`NumSamples`	Positive, scalar integer indicating the number of samples of the innovations `U` and conditional variance `H` (see below) to simulate.

Description

`[U, H] = ugarchsim(Kappa, Alpha, Beta, NumSamples)` simulates a univariate GARCH(P,Q) process with Gaussian innovations.

`U` is a number of samples (`NUMSAMPLES`)-by-`1` vector of innovations (ε_t), representing a mean-zero, discrete-time stochastic process. The innovations time series `U` is designed to follow the GARCH(P,Q) process specified by the inputs `Kappa`, `Alpha`, and `Beta`.

`H` is a `NUMSAMPLES`-by-1 vector of the conditional variances (σ_t^2) corresponding to the innovations vector `U`. Note that `U` and `H` are the same length, and form a "matching" pair of vectors. As shown in the following equation, σ_t^2 (that is, `H(t)`) represents the time series inferred from the innovations time series $\{\varepsilon_t\}$ (that is, `U`).

The time-conditional variance, σ_t^2, of a GARCH(P,Q) process is modeled as

$$\sigma_t^2 = \kappa + \sum_{i=1}^{P} \alpha_i \sigma_{t-i}^2 + \sum_{j=1}^{Q} \beta_j \varepsilon_{t-j}^2$$

where α represents the argument `Alpha`, β represents `Beta`, and the GARCH(P,Q) coefficients {[[KAPPA]], α, β} are subject to the following constraints.

$$\sum_{i=1}^{P} a_i + \sum_{j=1}^{Q} \beta_j < 1$$

$$\kappa > 0$$

$$a_i \geq 0 \quad i = 1, 2, \ldots, P$$

$$\beta_j \geq 0 \quad j = 1, 2, \ldots, Q$$

Note that `U` is a vector of residuals or innovations (ε_t) of an econometric model, representing a mean-zero, discrete-time stochastic process.

Although σ_t^2 is generated using the equation above, ε_t and σ_t^2 are related as

$$\varepsilon_t = \sigma_t v_t$$

where $\{v_t\}$ is an independent, identically distributed (iid) sequence ~ N(0,1).

The output vectors `U` and `H` are designed to be steady-state sequences in which transients have arbitrarily small effect. The (arbitrary) metric used by `ugarchsim` strips the first `N` samples of `U` and `H` such that the sum of the GARCH coefficients, excluding `Kappa`, raised to the `N`th power, does not exceed 0.01.

```
0.01 = (sum(Alpha) + sum(Beta))^N
```

Thus

```
N = log(0.01)/log((sum(Alpha) + sum(Beta)))
```

Note `ugarchsim` corresponds generally to the Econometrics Toolbox function `garchsim`. The Econometrics Toolbox software provides a comprehensive and integrated computing environment for the analysis of volatility in time series. For information see the Econometrics Toolbox User's Guide documentation or the financial products Web page at `http://www.mathworks.com/products/finprod/`.

Examples

This example simulates a GARCH(P,Q) process with `P = 2` and `Q = 1`.

```
% Set the random number generator seed for reproducability.

randn('seed', 10)

% Set the simulation parameters of GARCH(P,Q) = GARCH(2,1) process.

Kappa = 0.25;      %a positive scalar.
Alpha = [0.2 0.1]'; %a column vector of nonnegative numbers (P = 2).
Beta = 0.4;        % Q = 1.
NumSamples = 500;  % number of samples to simulate.

% Now simulate the process.

[U , H] = ugarchsim(Kappa, Alpha, Beta, NumSamples);

% Estimate the process parameters.

P = 2;    % Model order P (P = length of Alpha).
Q = 1;    % Model order Q (Q = length of Beta).
[k, a, b] = ugarch(U , P , Q);
disp(' ')
```

```
disp(' Estimated Coefficients:')
disp(' -----------------------')
disp([k; a; b])
disp(' ')

% Forecast the conditional variance using the estimated
%coefficients.

NumPeriods = 10;    % Forecast out to 10 periods.
[VarianceForecast, H1] = ugarchpred(U, k, a, b, NumPeriods);
disp(' Variance Forecasts:')
disp(' ------------------')
disp(VarianceForecast)
disp(' ')
```

When the above code is executed, the screen output looks like the display shown.

```
%%%
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
End diagnostic information
                                        max                        Directional
 Iter   F-count    f(x)   constraint   Step-size     derivative     Procedure
    1      5     699.185      -0.125            1      -2.97e+006
    2     22     658.224     -0.1249     0.000488           -64.6
    3     28     610.181           0            1           -49.4
    4     35     590.888           0          0.5           -38.9
    5     42     583.961    -0.03317          0.5           -29.8
    6     49     583.224    -0.02756          0.5           -31.8
    7     57     582.947    -0.02067         0.25           -7.28
    8     63     578.182           0            1           -2.43
    9     71     578.138    -0.09145         0.25           -0.55
   10     77     577.898    -0.04452            1          -0.148
   11     84     577.882    -0.06128          0.5         -0.0488
   12     90     577.859    -0.07117            1       -0.000758
   13     96     577.858    -0.07033            1       -0.000305    Hessian modified
   14    102     577.858    -0.07042            1      -3.32e-005    Hessian modified
   15    108     577.858     -0.0707            1      -1.29e-006    Hessian modified
   16    114     577.858    -0.07077            1      -1.29e-007    Hessian modified
   17    120     577.858    -0.07081            1      -1.97e-007    Hessian modified

Optimization Converged Successfully
Magnitude of directional derivative in search direction
  less than 2*options.TolFun and maximum constraint violation
  is less than options.TolCon
No Active Constraints

Estimated Coefficients:
----------------------
0.2520
0.0708
0.1623
0.4000

Variance Forecasts:
------------------
```

```
1.3243
0.9594
0.9186
0.8402
0.7966
0.7634
0.7407
0.7246
0.7133
0.7054
```

References

James D. Hamilton, *Time Series Analysis*, Princeton University Press, 1994

See Also

`ugarch`, `ugarchpred`, and the Econometrics Toolbox function `garchsim`

Purpose

Graphical calendar

Syntax

```
uicalendar('PARAM1', VALUE1, 'PARAM2', VALUE2', ...)
```

Arguments

`'BusDays'` Values are:

- 0 — (Default) Standard calendar without nonbusiness day indicators.
- 1 — Marks NYSE nonbusiness days in red.

`'BusDaySelect'` Values are:

- 0 — Only allow selection of business days. Nonbusiness days are determined from the following parameters:
  - `'BusDays'`
  - `'Holiday'`
  - `'Weekend'`
- 1 — (Default) Allows selections of business and nonbusiness days.

`'DateBoxColor'` [date R G B] : Sets the color of the date squares to the specified [R G B] color.

`'DateStrColor'` [date R G B] : Sets the color of the numeric date number in the date square to the specified [R G B] color.

`'DestinationUI'` Values are:

- H — Scalar or vector of the destination object's handles. The default UI property that is populated with the date(s) is 'string'.
- {H, {Prop}} — Cell array of handles and the destination object's UI properties. `H` must be a scalar or vector and `Prop` must be a single property string or a cell array of property strings.

`'Holiday'` Sets the specified holiday dates into the calendar. The corresponding date string of the holiday will appear Red. The Date(s) must be a scalar or vector of datenums.

`'InitDate'` Values are:

- `Datenum` — Numeric date value specifying the initial start date when the calendar is initialized. The default date is `TODAY`.
- `Datestr` — Date string value specifying the initial start date when the calendar is initialized. `Datestr` must include a Year, Month, and Day (for example, 01-Jan-2006).

`'InputDateFormat'` Format — Sets the format of initial start date, `InitDate`. See `'help datestr'` for date format values.

`'OutputDateFormat'` Format — Sets the format of output date string. See `'help datestr'` for date format values.

`'OutputDateStyle'` Values are:

- `0` — (Default) Returns a single date string or a cell array (row) of date string. For example, `{'01-Jan-2001, 02-Jan-2001, ...'}`.
- `1` — Returns a single date string or a cell (column) array of date strings. For example, `{'01-Jan-2001; 02-Jan-2001; ...'}`.
- `2` — Returns a string representation of a row vector of datenums. For example, `'[732758, 732759, 732760, 732761]'`.
- `3` — Returns a string representation of a column vector of datenums. For example, `'[732758; 732759; 732760; 732761]'`.

`'SelectionType'` Values are:

- `0` — (Default) Allows multiple date selections.
- `1` — Allows only a single date selection.

`'Weekend'` `DayOfWeek` — Sets the specified days of the week as weekend days. Weekend days are marked in red. `DayOfWeek` can be a vector containing the following numeric values:

- `1` — Sunday
- `2` — Monday
- `3` — Tuesday
- `4` — Wednesday
- `5` — Thursday
- `6` — Friday

- `7` — Saturday

Also this value can be a vector of length 7 containing 0's and 1's. The value 1 indicates a weekend day. The first element of this vector corresponds to Sunday. For example, when Saturday and Sunday are weekend days then `WEEKEND = [1 0 0 0 0 0 1]`.

`'WindowStyle'` Values are:

- `Normal` — (Default) Standard figure properties.
- `Modal` — Modal figures remain stacked above all normal figures and the MATLAB Command Window.

Description

`uicalendar('PARAM1', VALUE1, 'PARAM2', VALUE2', ...)` supports a customizable graphical calendar that interfaces with uicontrols. `uicalendar` populates uicontrols with user-selected dates.

Examples

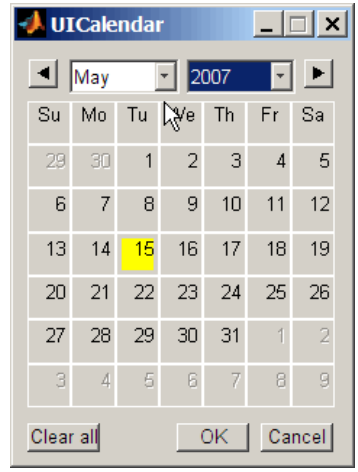
Create a uicontrol:

```
textH1 = uicontrol('style', 'edit', 'position', [10 10 100 20]);
```

Call UICalendar:

```
uicalendar('DestinationUI', {textH1, 'string'})
```

Select a date and click `'OK'`.



For more information on using `uicalendar` with an application, see "Example of Using UICalendar with an Application" on page 11-5.

See Also

`holidays`

uminus

Purpose Unary minus of financial time series object

Syntax `uminus`

Description `uminus` implements unary minus for a financial time series object.

See Also `uplus`

Purpose

Unary plus of financial time series object

Syntax

```
uplus
```

Description

`uplus` implements unary plus for a financial time series object.

See Also

`uminus`

Purpose

Variance

Syntax

```
y = var(X)
y = var(X, 1)
y = var(X, W)
y = var(X, W, DIM)
```

Arguments

X	Financial times series object.
W	Weight vector used in calculating variance.
DIM	Dimension of X used in calculating variance.

Description

var supports financial time series objects based on the MATLAB var function. See var in the MATLAB documentation.

y = var(X), if X is a financial time series object and returns the variance of each series.

var normalizes y by N – 1 if N > 1, where N is the sample size. This is an unbiased estimator of the variance of the population from which X is drawn, as long as X consists of independent, identically distributed samples. For N = 1, y is normalized by N.

y = var(X, 1) normalizes by N and produces the second moment of the sample about its mean. var(X, 0) is the same as var(X).

y = var(X, W) computes the variance using the weight vector W. The length of W must equal the length of the dimension over which var operates, and its elements must be nonnegative. var normalizes W to sum to 1. Use a value of 0 for W to use the default normalization by N – 1, or use a value of 1 to use N.

y = var(X, W, DIM) takes the variance along the dimension DIM of X.

Examples

The variance is the square of the standard deviation. Consider if

```
f = fints((today:today+1)', [4 -2 1; 9  5 7])
```

then

```
var(f, 0, 1)
```

is

```
[12.5 24.5 18.0]
```

and

```
var(f, 0, 2)
```

is

```
[9.0; 4.0]
```

See Also

`corrcoef`, `cov`, `mean`, `std`

Purpose

Concatenate financial time series objects vertically

Description

`vertcat` implements vertical concatenation of financial time series objects. `vertcat` essentially adds data points to a time series object. Objects to be vertically concatenated must not have any duplicate dates and/or times or any overlapping dates and/or times. The description fields are concatenated as well. They are separated by `||`.

Examples

Create two financial time series objects with daily frequencies:

```
myfts   = fints((today:today+4)', (1:5)', 'DataSeries', 'd');
yourfts = fints((today+5:today+9)', (11:15)', 'DataSeries', 'd');
```

Use `vertcat` to concatenate them vertically:

```
newfts1 = [myfts; yourfts]

newfts1 =

    desc:   ||
    freq:  Daily (1)

    'dates:  (10)'    'DataSeries:  (10)'
    '11-Dec-2001'     [                 1]
    '12-Dec-2001'     [                 2]
    '13-Dec-2001'     [                 3]
    '14-Dec-2001'     [                 4]
    '15-Dec-2001'     [                 5]
    '16-Dec-2001'     [                11]
    '17-Dec-2001'     [                12]
    '18-Dec-2001'     [                13]
    '19-Dec-2001'     [                14]
    '20-Dec-2001'     [                15]
```

Create two financial time series objects with different frequencies:

```
myfts   = fints((today:today+4)', (1:5)', 'DataSeries', 'd');
```

```
hisfts  = fints((today+5:7:today+34)', (11:15)', 'DataSeries',...
'w');
```

Concatenate these two objects vertically:

```
newfts2 = [myfts; hisfts]

 newfts2 =

    desc:   ||
    freq:  Unknown (0)

    'dates:  (10)'    'DataSeries:  (10)'
    '11-Dec-2001'     [                 1]
    '12-Dec-2001'     [                 2]
    '13-Dec-2001'     [                 3]
    '14-Dec-2001'     [                 4]
    '15-Dec-2001'     [                 5]
    '16-Dec-2001'     [                11]
    '23-Dec-2001'     [                12]
    '30-Dec-2001'     [                13]
    '06-Jan-2002'     [                14]
    '13-Jan-2002'     [                15]
```

If all frequency indicators are the same, the new object has the same frequency indicator. However, if one of the concatenated objects has a different `freq` from the other(s), the frequency of the resulting object is set to `Unknown (0)`. In these examples, `newfts1` has `Daily` frequency, while `newfts2` has `Unknown (0)` frequency.

See Also

`horzcat`

volarea

Purpose

Price and volume chart

Syntax

```
volarea(X)
```

Arguments

X	M-by-3 matrix where the first column contains date numbers, the second column is the asset price, and the third column is the volume.

Description

`volarea(X)` plots asset date, price, and volume on a single axis.

Examples

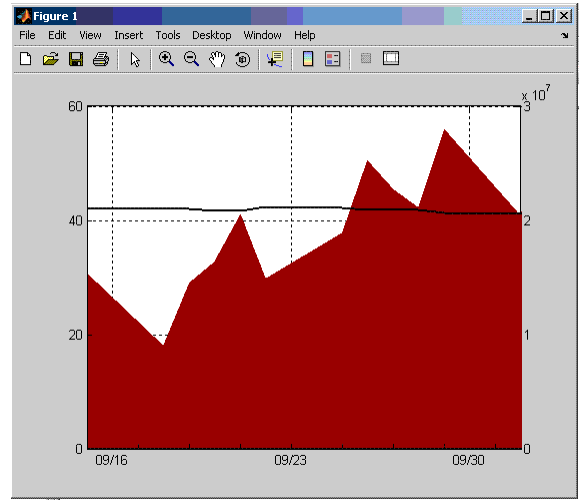
If asset `X` is an `M`-by-`3` matrix of date numbers, asset price, and volume:

```
X = [...

733299.00          41.99   15045445.00;...
733300.00          42.14   15346658.00;...
733303.00          41.93    9034397.00;...
733304.00          41.98   14486275.00;...
733305.00          41.75   16389872.00;...
733306.00          41.61   20475208.00;...
733307.00          42.29   14833200.00;...
733310.00          42.19   18945176.00;...
733311.00          41.82   25188101.00;...
733312.00          41.93   22689878.00;...
733313.00          41.81   21084723.00;...
733314.00          41.37   27963619.00;...
733317.00          41.17   20385033.00;...
733318.00          42.02   27783775.00]
```

then the price volume chart is

```
volarea(X)
```

which plots the asset prices with respect to date and volume as follows.



See Also

`bolling`, `candle`, `highlow`, `kagi`, `linebreak`, `movavg`, `pointfig`, `priceandvol`, `renko`

volroc

Purpose

Volume rate of change

Syntax

```
vroc = volroc(tvolume nperiods)
vrocts = volroc(tsobj, nperiods)
vrocts = volroc(tsobj, nperiods, ParameterName, ParameterValue)
```

Arguments

`tvolume`	Volume traded.
`nperiods`	(Optional) Period difference. Default = 12.
`tsobj`	Financial time series object.

Description

`vroc = volroc(tvolume nperiods)` calculates the volume rate of change, `vroc`, from the volume traded data `tvolume`. If `nperiods` is specified, the volume rate of change is calculated between the current volume and the volume `nperiods` ago.

`vrocts = volroc(tsobj, nperiods)` calculates the volume rate of change, `vrocts`, from the financial time series object `tsobj`. The `vrocts` output is a financial time series object with similar dates as `tsobj` and a data series named `VolumeROC`. If `nperiods` is specified, the volume rate of change is calculated between the current volume and the volume `nperiods` ago.

`vrocts = volroc(tsobj, nperiods, ParameterName, ParameterValue)` specifies the name for the required data series when it is different from the default name. The valid parameter name is

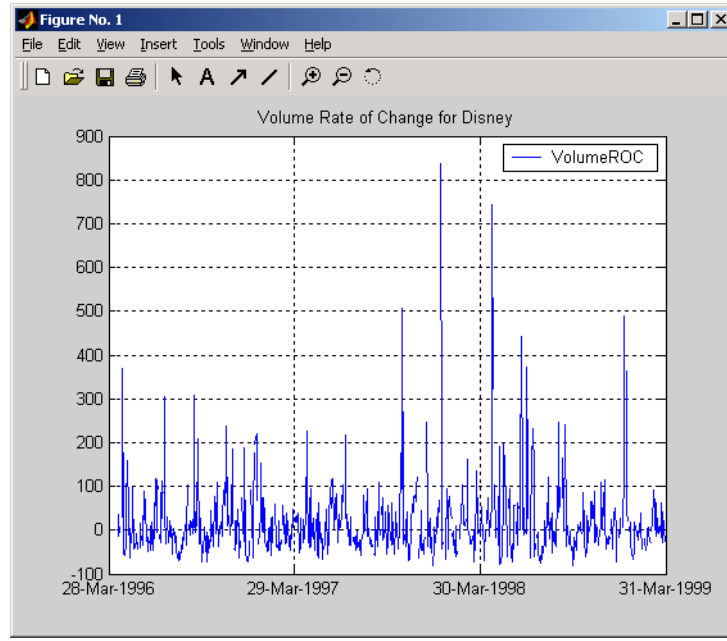
- `VolumeName`: volume traded series name

The parameter value is a string that represents the valid parameter name.

Examples

Compute the volume rate of change for Disney stock and plot the results:

```
load disney.mat
dis_VolRoc = volroc(dis)
plot(dis_VolRoc)
title('Volume Rate of Change for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 310 - 311.

See Also

`prcroc`

wclose

Purpose

Weighted close

Syntax

```
wcls = wclose(highp, lowp, closep)
wcls = wclose([highp lowp closep])
wclsts = wclose(tsobj)
wclsts = wclose(tsobj, ParameterName, ParameterValue, ...)
```

Arguments

`highp`	High price (vector).
`lowp`	Low price (vector).
`closep`	Closing price (vector).
`tsobj`	Financial time series object.

Description

The weighted close price is the average of twice the closing price plus the high and low prices.

`wcls = wclose(highp, lowp, closep)` calculates the weighted close prices `wcls` based on the high (`highp`), low (`lowp`), and closing (`closep`) prices per period.

`wcls = wclose([highp lowp closep])` accepts a three-column matrix consisting of the high, low, and closing prices, in that order.

`wclsts = wclose(tsobj)` computes the weighted close prices for a set of stock price data contained in the financial time series object `tsobj`. The object must contain the high, low, and closing prices needed for this function. The function assumes that the series are named `High`, `Low`, and `Close`. All three are required. `wclsts` is a financial time series object of the same dates as `tsobj` and contains the data series named `WClose`.

`wclsts = wclose(tsobj, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs

specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

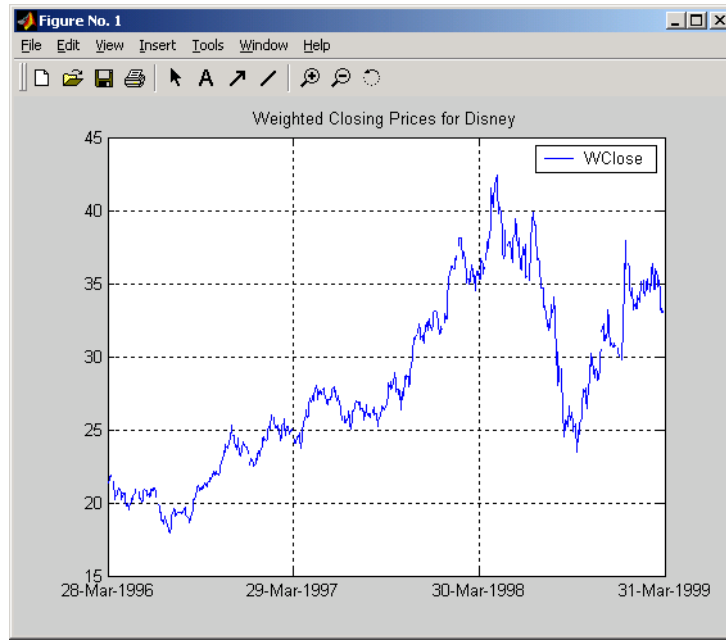
- `HighName`: high prices series name
- `LowName`: low prices series name
- `CloseName`: closing prices series name

Parameter values are the strings that represent the valid parameter names.

Examples

Compute the weighted closing prices for Disney stock and plot the results:

```
load disney.mat
dis_Wclose = wclose(dis)
plot(dis_Wclose)
title('Weighted Closing Prices for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 312 - 313.

See Also

`medprice`, `typprice`

Purpose

Day of week

Syntax

```
[N, S] = weekday(D)
[N, S] = weekday(D, form)
[N, S] = weekday(D, locale)
[N, S] = weekday(D, form, locale)
```

Description

`[N, S] = weekday(D)` returns the day of the week in numeric (`N`) and string (`S`) form for a given serial date number or date string `D`. Input argument `D` can represent more than one date in an array of serial date numbers or a cell array of date strings.

`[N, S] = weekday(D, form)` returns the day of the week in numeric (`N`) and string (`S`) form, where the content of `S` depends on the `form` argument. If `form` is '**`long`**', then `S` contains the full name of the weekday (for example, `Tuesday`). If `form` is '**`short`**', then `S` contains an abbreviated name (for example, `Tues`) from this table.

The days of the week are assigned these numbers and abbreviations.

N	S (short)	S (long)
1	Sun	Sunday
2	Mon	Monday
3	Tue	Tuesday
4	Wed	Wednesday
5	Thu	Thursday
6	Fri	Friday
7	Sat	Saturday

`[N, S] = weekday(D, locale)` returns the day of the week in numeric (`N`) and string (`S`) form, where the format of the output depends on the `locale` argument. If `locale` is '**`local`**', then `weekday` uses local format for its output. If `locale` is '**`en_US`**', then `weekday` uses US English.

`[N, S] = weekday(D, form, locale)` returns the day of the week using the formats described above for `form` and `locale`.

Examples

Either

```
[n, s] = weekday(728647)
```

or

```
[n, s] = weekday('19-Dec-1994')
```

returns `n = 2` and `s = Mon`.

See Also

`datenum`, `datestr`, `datevec`, `day`

Purpose

Week in a year

Syntax

```
[N]= weeknum(D)
[N] = weeknum(D,W)
```

Arguments

D	Serial date number or a date string.
W	(Optional) A numeric representation of the day a week begins. The week start values and their corresponding day are:

- 1 (default) — Sunday
- 2 — Monday
- 3 — Tuesday
- 4 — Wednesday
- 5 — Thursday
- 6 — Friday
- 7 — Staurday

Description

`[N]= weeknum(D)` returns the week of the year given `D`, a serial date number or a date string.

`[N] = weeknum(D,W)` returns the week of the year given `D`, a serial date number or a date string, and `W`, a numeric representation of the day a week begins.

The `weeknum` function considers the week containing January 1 to be the first week of the year.

Examples

You can determine the week of the year using a serial date number

```
N = weeknum(728647)
```

```
N =

    52
```

or a date string

```
N = weeknum('19-Dec-1994')
N =

    52
```

The first week of the year must have at least 4 days in it. For example, January 8, 2004 was a Thursday.

```
weeknum('08-jan-2004')
ans =

     2
```

You can use `weeknum` with `datenum`:

```
weeknum(datenum('01-Jan-2004'):datenum('08-Jan-2004'))

ans =

     1     1     1     2     2     2     2     2
```

The default start day of the week is Sunday. Every day after, and including the first Sunday of the year (04-Jan-2004), returns 2 denoting the second week. In this case, the first of week of the year started before January 1, 2004.

You can also use `weeknum` with `datenum` and specify a `W` value of 5 to indicate that the weeks start on Thursday:

```
weeknum(datenum('01-Jan-2004'):datenum('08-Jan-2004'),5)

ans =
```

```
     1     1     1     1     1     1     1     2
```

The first week of the year that has 4 or more days, based on the specified start day, is considered week one (even if this isn't the first week in the calendar). Any day falling in (or before) this week is given a week number of 1.

See Also

`datenum`, `datestr`, `datevec`, `day`

weights2holdings

Purpose

Portfolio values and weights into holdings

Syntax

```
Holdings = weights2holdings(Values, Weights, Prices)
```

Arguments

`Values`	Scalar or number of portfolios (`NPORTS`) vector containing portfolio values.
`Weights`	`NPORTS` by number of assets (`NASSETS`) matrix with portfolio weights. The weights sum to the value of a `Budget` constraint, which is usually 1. (See `holdings2weights` for information about budget constraints.)
`Prices`	`NASSETS` vector of prices.

Description

`Holdings = weights2holdings(Values, Weights, Prices)` converts portfolio values and weights into portfolio holdings.

`Holdings` is a `NPORTS`-by-`NASSETS` matrix containing the holdings of `NPORTS` portfolios that contain `NASSETS` assets.

Note This function does not create round-lot positions. `Holdings` are floating-point values.

See Also

`holdings2weights`

Purpose

Williams Accumulation/Distribution line

Syntax

```
wadl = willad(highp, lowp, closep)
wadl = willad([highp lowp closep])
wadlts = willad(tsobj)
wadlts = willad(tsobj, ParameterName, ParameterValue, ...)
```

Arguments

`highp`	High price (vector)
`lowp`	Low price (vector)
`closep`	Closing price (vector)
`tsobj`	Time series object

Description

`wadl = willad(highp, lowp, closep)` computes the Williams Accumulation/Distribution line for a set of stock price data. The prices needed for this function are the high (`highp`), low (`lowp`), and closing (`closep`) prices. All three are required.

`wadl = willad([highp lowp closep])` accepts a three-column matrix of prices as input. The first column contains the high prices, the second contains the low prices, and the third contains the closing prices.

`wadlts = willad(tsobj)` computes the Williams Accumulation/Distribution line for a set of stock price data contained in the financial time series object `tsobj`. The object must contain the high, low, and closing prices needed for this function. The function assumes that the series are named `High`, `Low`, and `Close`. All three are required. `wadlts` is a financial time series object with the same dates as `tsobj` and a single data series named `WillAD`.

`wadlts = willad(tsobj, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs

specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

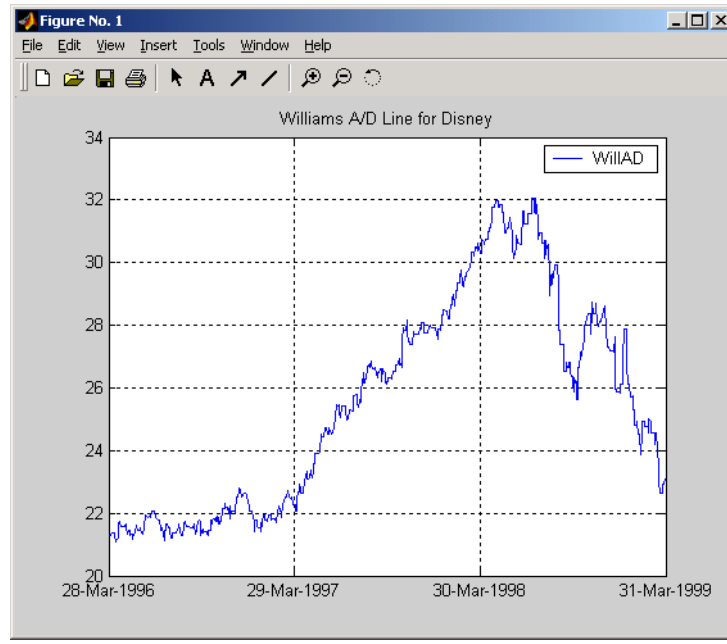
- `HighName`: high prices series name
- `LowName`: low prices series name
- `CloseName`: closing prices series name

Parameter values are the strings that represent the valid parameter names.

Examples

Compute the Williams A/D line for Disney stock and plot the results:

```
load disney.mat
dis_Willad = willad(dis)
plot(dis_Willad)
title('Williams A/D Line for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 314 - 315.

See Also

`adline`, `adosc`, `willpctr`

Purpose

Williams %R

Syntax

```
wpctr = willpctr(highp, lowp, closep, nperiods)
wpctr = willpctr([highp, lowp, closep], nperiods)
wpctrts = willpctr(tsobj)
wpctrts = willpctr(tsobj, nperiods)
wpctrts = willpctr(tsobj, nperiods, ParameterName, ParameterValue,
... )
```

Arguments

`highp`	High price (vector)
`lowp`	Low price (vector)
`closep`	Closing price (vector)
`nperiods`	Number of periods (scalar). Default = 14.
`tsobj`	Financial time series object

Description

`wpctr = willpctr(highp, lowp, closep, nperiods)` calculates the Williams %R values for the given set of stock prices for a specified number of periods `nperiods`. The stock prices needed are the high (`highp`), low (`lowp`), and closing (`closep`) prices. `wpctr` is a vector that represents the Williams %R values from the stock data.

`wpctr = willpctr([highp, lowp, closep], nperiods)` accepts the price input as a three-column matrix representing the high, low, and closing prices, in that order.

`wpctrts = willpctr(tsobj)` calculates the Williams %R values for the financial time series object `tsobj`. The object must contain at least three data series named `High` (high prices), `Low` (low prices), and `Close` (closing prices). `wpctrts` is a financial time series object with the same dates as `tsobj` and a single data series named `WillPctR`.

`wpctrts = willpctr(tsobj, nperiods)` calculates the Williams %R values for the financial time series object `tsobj` for `nperiods` periods.

`wpctrts = willpctr(tsobj, nperiods, ParameterName, ParameterValue, ...)` accepts parameter name/parameter value pairs as input. These pairs specify the name(s) for the required data series if it is different from the expected default name(s). Valid parameter names are

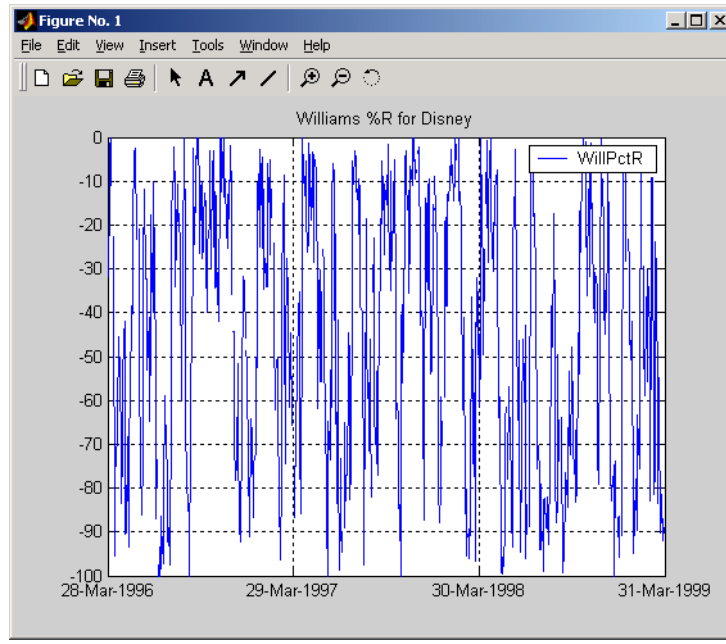
- `HighName`: high prices series name
- `LowName`: low prices series name
- `CloseName`: closing prices series name

Parameter values are the strings that represent the valid parameter names.

Examples

Compute the Williams %R values for Disney stock and plot the results:

```
load disney.mat
dis_Wpctr = willpctr(dis)
plot(dis_Wpctr)
title('Williams %R for Disney')
```



References

Achelis, Steven B., *Technical Analysis from A to Z*, Second printing, McGraw-Hill, 1995, pp. 316 - 317.

See Also

`stochosc`, `willad`

Purpose

Number of working days between dates

Syntax

```
Days = wrkdydif(StartDate, EndDate, Holidays)
```

Arguments

`StartDate`	Enter as serial date numbers or date strings.
`EndDate`	Enter as serial date numbers or date strings.
`Holidays`	A vector containing values for the number of Holidays between the two dates.

Description

`Days = wrkdydif(StartDate, EndDate, Holidays)` returns the number of working days between dates `StartDate` and `EndDate` inclusive. `Holidays` is the number of holidays between the given dates, an integer. Enter dates as serial date numbers or date strings.

Examples

```
Days = wrkdydif('9/1/2000', '9/11/2000', 1)
```

or

```
Days = wrkdydif(730730, 730740, 1)
```

returns

```
Days =
       6
```

See Also

`busdate`, `datewrkdy`, `days360`, `days365`, `daysact`, `daysdif`, `holidays`, `yearfrac`

x2mdate

Purpose

Excel serial date number to MATLAB serial date number

Syntax

```
MATLABDate = x2mdate(ExcelDateNumber, Convention)
```

Arguments

`ExcelDateNumber`	A vector or scalar of Excel serial date numbers.
`Convention`	(Optional) Excel date system. A vector or scalar. When `Convention = 0` (default), the Excel 1900 date system is in effect. When `Convention = 1`, the Excel 1904 date system is used. In the Excel 1900 date system, the Excel serial date number 1 corresponds to January 1, 1900 A.D. In the Excel 1904 date system, date number 0 is January 1, 1904 A.D. Due to a software limitation in Excel software, the year 1900 is considered a leap year. As a result, all DATEVALUEs reported by Excel software between Jan. 1, 1900 and Feb. 28, 1900 (inclusive) differ from the values reported by 1. For example: • In Excel software, Jan. 1, 1900 = 1 • In MATLAB, Jan. 1, 1900 = 2

Vector arguments must have consistent dimensions.

Description

`DateNumber = x2mdate(ExcelDateNumber, Convention)` converts Excel serial date numbers to MATLAB serial date numbers. MATLAB date numbers start with 1 = January 1, 0000 A.D., hence there is a

difference of 693960 relative to the 1900 date system, or 695422 relative to the 1904 date system. This function is useful with Spreadsheet Link EX software.

Examples

Given Excel date numbers in the 1904 system

```
ExDates = [35423  35788  36153];
```

convert them to MATLAB date numbers

```
MATLABDate = x2mdate(ExDates, 1)

MATLABDate =

       730845      731210      731575
```

and then to date strings.

```
datestr(MATLABDate)

ans =

25-Dec-2000
25-Dec-2001
25-Dec-2002
```

See Also

datenum, datestr, m2xdate

Purpose

Internal rate of return for nonperiodic cash flow

Syntax

```
Return = xirr(CashFlow, CashFlowDates, Guess,
MaxIterations, Basis)
```

Arguments

`CashFlow`	Vector of nonperiodic cash flows. Include the initial investment as the initial cash flow value (a negative number).
`CashFlowDates`	Vector of dates on which the cash flows occur. Enter dates as serial date numbers or date strings.
`Guess`	(Optional) Initial estimate of the expected return. Default = 0.1 (10%).
`MaxIterations`	(Optional) Number of iterations used by Newton's method to solve for `Return`. Default = 50.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA)

- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Description

`Return = xirr(CashFlow, CashFlowDates, Guess, MaxIterations, Basis)` returns the internal rate of return for a schedule of nonperiodic cash flows.

Examples

An investment of $10,000 returns this nonperiodic cash flow. The original investment and its date are included.

Cash Flow	Dates
($10000)	January 12, 2007
$2500	February 14, 2008
$2000	March 3, 2008
$3000	June 14, 2008
$4000	December 1, 2008

To calculate the internal rate of return for this nonperiodic cash flow

```
CashFlow = [-10000, 2500, 2000, 3000, 4000];
CashFlowDates = ['01/12/2007'
                 '02/14/2008'
                 '03/03/2008'
                 '06/14/2008'
                 '12/01/2008'];
Return = xirr(CashFlow, CashFlowDates)
```

returns

```
Return =
         0.1006 (or 10.0644% per annum)
```

References

Sharpe and Alexander, *Investments*, 4th edition, page 463.

See Also

`fvvar`, `irr`, `mirr`, `pvvar`

Purpose

Year of date

Syntax

```
Year = year(Date)
```

Description

`Year = year(Date)` returns the year of a serial date number or a date string.

Examples

```
Year = year(731798.776)
```

or

```
Year = year('05-Aug-2003')
```

returns

```
Year =

        2003
```

See Also

`datevec`, `day`, `month`, `yeardays`

yeardays

Purpose

Number of days in year

Syntax

```
Days = yeardays(Year, Basis)
```

Arguments

`Year`	Enter as a four-digit integer.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Description

`Days = yeardays(Year, Basis)` returns the number of days in the given year, based upon the day-count basis.

Examples

```
Days = yeardays(2000)

Days =

       366
Days = yeardays(2000, 1)

Days =

   360
```

See Also

days360, days365, daysact, year, yearfrac

Purpose

Fraction of year between dates

Syntax

```
YearFraction = yearfrac(StartDate, EndDate, Basis)
```

Arguments

`StartDate`	Enter as serial date numbers or date strings.
`EndDate`	Enter as serial date numbers or date strings.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

All specified arguments must be number of instruments (`NUMINST`)-by-`1` or `1`-by-`NUMINST` conforming vectors or scalar arguments.

Description

`YearFraction = yearfrac(StartDate, EndDate, Basis)` returns a fraction based on the number of days between dates `StartDate` and `EndDate` using the given day-count basis. If `EndDate` is earlier than `StartDate`, `Fraction` is negative.

Examples

```
YearFraction = yearfrac('14 mar 01', '14 sep 01', 0)

YearFraction =

    0.5041

YearFraction = yearfrac('14 mar 01', '14 sep 01', 1)

YearFraction =

    0.5000
```

See Also

`days360`, `days365`, `daysact`, `daysdif`, `months`, `wrkdydif`, `year`, `yeardays`

ylddisc

Purpose

Yield of discounted security

Syntax

```
Yield = ylddisc(Settle, Maturity, Face, Price, Basis)
```

Arguments

`Settle`	Settlement date. Enter as serial date number or date string. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. Enter as serial date number or date string.
`Face`	Redemption (par, face) value.
`Price`	Discounted price of the security.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA) • 11 = 30/360E (ISMA)

- 12 = actual/365 (ISDA)

Description

`Yield = ylddisc(Settle, Maturity, Face, Price, Basis)` finds the yield of a discounted security.

Examples

Using the data

```
Settle = '10/14/2000';
Maturity = '03/17/2001';
Face = 100;
Price = 96.28;
Basis = 2;

Yield = ylddisc(Settle, Maturity, Face, Price, Basis)
```

returns

```
Yield =

        0.0903 (or 9.03%)
```

References

Mayle, *Standard Securities Calculation Methods*, Volumes I-II, 3rd edition. Formula 1.

See Also

`acrudisc`, `bndprice`, `bndyield`, `prdisc`, `yldmat`, `yldtbill`

yldmat

Purpose

Yield with interest at maturity

Syntax

```
Yield = yldmat(Settle, Maturity, Issue, Face, Price,
CouponRate, Basis)
```

Arguments

`Settle`	Settlement date. Enter as serial date number or date string. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. Enter as serial date number or date string.
`Issue`	Issue date. Enter as serial date number or date string.
`Face`	Redemption (par, face) value.
`Price`	Price of the security.
`CouponRate`	Coupon rate. Enter as decimal fraction.
`Basis`	(Optional) Day-count basis of the instrument. A vector of integers. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA)

- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

Description

`Yield = yldmat(Settle, Maturity, Issue, Face, Price, CouponRate, Basis)` returns the yield of a security paying interest at maturity.

Examples

Using the data

```
Settle = '02/07/2000';
Maturity = '04/13/2000';
Issue = '10/11/1999';
Face = 100;
Price = 99.98;
CouponRate = 0.0608;
Basis = 1;

Yield = yldmat(Settle, Maturity, Issue, Face, Price,...
CouponRate, Basis)
```

returns

```
Yield =
        0.0607 (or 6.07%)
```

References

Mayle, *Standard Securities Calculation Methods*, Volumes I-II, 3rd edition. Formula 3.

See Also

`acrubond`, `bndprice`, `bndyield`, `prmat`, `ylddisc`, `yldtbill`

yldtbill

Purpose

Yield of Treasury bill

Syntax

```
Yield = yldtbill(Settle, Maturity, Face, Price)
```

Arguments

`Settle`	Settlement date. Enter as serial date number or date string. `Settle` must be earlier than or equal to `Maturity`.
`Maturity`	Maturity date. Enter as serial date number or date string.
`Face`	Redemption (par, face) value.
`Price`	Price of the Treasury bill.

Description

`Yield = yldtbill(Settle, Maturity, Face, Price)` returns the yield for a Treasury bill.

Examples

The settlement date of a Treasury bill is February 10, 2000, the maturity date is August 6, 2000, the par value is $1000, and the price is $981.36. Using this data

```
Yield = yldtbill('2/10/2000', '8/6/2000', 1000, 981.36)
```

returns

```
Yield =

         0.0384 (or 3.84%)
```

References

Bodie, Kane, and Marcus, *Investments*, pages 41-43.

See Also

`beytbill`, `bndyield`, `prtbill`, `yldmat`

Purpose

Zero curve bootstrapping from coupon bond data given price

Syntax

```
[ZeroRates, CurveDates] = zbtprice(Bonds, Prices, Settle,
OutputCompounding)
```

Arguments

`Bonds`

Coupon bond information used to generate the zero curve. An `n`-by-`2` to `n`-by-`6` matrix where each row describes a bond. The first two columns are required; the rest are optional but must be added in order. All rows in `Bonds` must have the same number of columns.

Columns are `[Maturity CouponRate Face Period Basis EndMonthRule]` where

`Maturity`	Maturity date of the bond, as a serial date number. Use `datenum` to convert date strings to serial date numbers.
`CouponRate`	Coupon rate of the bond, as a decimal fraction.
`Face`	(Optional) Redemption or face value of the bond. Default = 100.
`Period`	(Optional) Coupons per year of the bond, as an integer. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.

`Basis` (Optional) Day-count basis of the bond:

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month flag. This flag applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore flag, meaning that a bond's coupon payment date is always the same day of the month. 1 = set flag (default), meaning that a bond's coupon payment date is always the last day of the month.

`Prices`	Column vector containing the clean price (price without accrued interest) of each bond in `Bonds`, respectively. The number of rows (n) must match the number of rows in `Bonds`.
`Settle`	Settlement date, as a scalar serial date number. This represents time zero for deriving the zero curve, and it is normally the common settlement date for all the bonds.
`OutputCompounding`	(Optional) Scalar that sets the compounding frequency per year for the output zero rates in `ZeroRates`. Allowed values are:

`1`	Annual compounding
`2`	Semiannual compounding (default)
`3`	Compounding three times per year
`4`	Quarterly compounding
`6`	Bimonthly compounding
`12`	Monthly compounding
`-1`	Continuous compounding

Description

`[ZeroRates, CurveDates] = zbtprice(Bonds, Prices, Settle, OutputCompounding)` uses the bootstrap method to return a zero curve given a portfolio of coupon bonds and their prices. A zero curve consists of the yields to maturity for a portfolio of theoretical zero-coupon bonds that are derived from the input `Bonds` portfolio. The bootstrap method that this function uses does *not* require alignment among the cash-flow dates of the bonds in the input portfolio. It uses theoretical par bond arbitrage and yield interpolation to derive all zero rates. For best results, use a portfolio of at least 30 bonds evenly spaced across the investment horizon.

`ZeroRates` An `m`-by-`1` vector of decimal fractions that are the implied zero rates for each point along the investment horizon represented by `CurveDates`; m is the number of bonds of unique maturity dates. In aggregate, the rates in `ZeroRates` constitute a zero curve.

If more than one bond has the same maturity date, `zbtprice` returns the mean zero rate for that maturity.

`CurveDates` An `m`-by-`1` vector of unique maturity dates (as serial date numbers) that correspond to the zero rates in `ZeroRates`; m is the number of bonds of different maturity dates. These dates begin with the earliest maturity date and end with the latest maturity date `Maturity` in the `Bonds` matrix.

Examples

Given data and prices for 12 coupon bonds, two with the same maturity date; and given the common settlement date

```
Bonds = [datenum('6/1/1998')   0.0475   100  2  0  0;
         datenum('7/1/2000')   0.06     100  2  0  0;
         datenum('7/1/2000')   0.09375  100  6  1  0;
         datenum('6/30/2001')  0.05125  100  1  3  1;
         datenum('4/15/2002')  0.07125  100  4  1  0;
         datenum('1/15/2000')  0.065    100  2  0  0;
         datenum('9/1/1999')   0.08     100  3  3  0;
         datenum('4/30/2001')  0.05875  100  2  0  0;
         datenum('11/15/1999') 0.07125  100  2  0  0;
         datenum('6/30/2000')  0.07     100  2  3  1;
         datenum('7/1/2001')   0.0525   100  2  3  0;
         datenum('4/30/2002')  0.07     100  2  0  0];
```

```
Prices = [99.375;
          99.875;
         105.75 ;
          96.875;
         103.625;
         101.125;
         103.125;
          99.375;
         101.0  ;
         101.25 ;
          96.375;
         102.75 ];

Settle = datenum('12/18/1997');
```

Set semiannual compounding for the zero curve.

```
OutputCompounding = 2;
```

Execute the function

```
[ZeroRates, CurveDates] = zbtprice(Bonds, Prices, Settle,...
OutputCompounding)
```

which returns the zero curve at the maturity dates. Note the mean zero rate for the two bonds with the same maturity date.

```
ZeroRates =

            0.0616
            0.0609
            0.0658
            0.0590
            0.0648
            0.0655*
            0.0606
            0.0601
```

```
              0.0642
              0.0621
              0.0627

CurveDates =

              729907  (serial date number for 01-Jun-1998)
              730364  (01-Sep-1999)
              730439  (15-Nov-1999)
              730500  (15-Jan-2000)
              730667  (30-Jun-2000)
              730668  (01-Jul-2000)*
              730971  (30-Apr-2001)
              731032  (30-Jun-2001)
              731033  (01-Jul-2001)
              731321  (15-Apr-2002)
              731336  (30-Apr-2002)
```

References

Fabozzi, Frank J. "The Structure of Interest Rates." Ch. 6 in Fabozzi, Frank J. and T. Dessa Fabozzi, eds. *The Handbook of Fixed Income Securities*. 4th ed. New York: Irwin Professional Publishing. 1995.

McEnally, Richard W. and James V. Jordan. "The Term Structure of Interest Rates." Ch. 37 in Fabozzi and Fabozzi, ibid.

Das, Satyajit. "Calculating Zero Coupon Rates." *Swap and Derivative Financing*. Appendix to Ch. 8, pp. 219-225. New York: Irwin Professional Publishing. 1994.

See Also

`zbtyield` and other functions for Term Structure of Interest Rates

Purpose

Zero curve bootstrapping from coupon bond data given yield

Syntax

```
[ZeroRates, CurveDates] = zbtyield(Bonds, Yields, Settle,
OutputCompounding)
```

Arguments

`Bonds`

Coupon bond information used to generate the zero curve. An `n`-by-`2` to `n`-by-`6` matrix where each row describes a bond. The first two columns are required; the rest are optional but must be added in order. All rows in `Bonds` must have the same number of columns. Columns are `[Maturity CouponRate Face Period Basis EndMonthRule]` where

`Maturity`	Maturity date of the bond, as a serial date number. Use `datenum` to convert date strings to serial date numbers.
`CouponRate`	Coupon rate of the bond, as a decimal fraction.
`Face`	(Optional) Redemption or face value of the bond. Default = 100.
`Period`	(Optional) Coupons per year of the bond, as an integer. Allowed values are 0, 1, 2 (default), 3, 4, 6, and 12.

`Basis` (Optional) Day-count basis of the bond.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`EndMonthRule` (Optional) End-of-month flag. This flag applies only when `Maturity` is an end-of-month date for a month having 30 or fewer days. 0 = ignore flag, meaning that a bond's coupon payment date is always the same day of the month. 1 = set flag (default), meaning that a bond's coupon payment date is always the last day of the month.

`Yields`	Column vector containing the yield to maturity of each bond in `Bonds`, respectively. The number of rows (n) must match the number of rows in `Bonds`. Yield to maturity must be compounded semiannually.
`Settle`	Settlement date, as a scalar serial date number. This represents time zero for deriving the zero curve, and it is normally the common settlement date for all the bonds.
`OutputCompounding`	(Optional) Scalar that sets the compounding frequency per year for the output zero rates in `ZeroRates`. Allowed values are:

`1`	Annual compounding
`2`	Semiannual compounding (default)
`3`	Compounding three times per year
`4`	Quarterly compounding
`6`	Bimonthly compounding
`12`	Monthly compounding
`-1`	Continuous compounding

Description

`[ZeroRates, CurveDates] = zbtyield(Bonds, Yields, Settle, OutputCompounding)` uses the bootstrap method to return a zero curve given a portfolio of coupon bonds and their yields. A zero curve consists of the yields to maturity for a portfolio of theoretical zero-coupon bonds that are derived from the input `Bonds` portfolio. The bootstrap method that this function uses does *not* require alignment among the cash-flow dates of the bonds in the input portfolio. It uses theoretical par bond arbitrage and yield interpolation to derive all zero rates. For best

results, use a portfolio of at least 30 bonds evenly spaced across the investment horizon.

`ZeroRates`	An `m`-by-`1` vector of decimal fractions that are the implied zero rates for each point along the investment horizon represented by `CurveDates`; m is the number of bonds of different maturity dates. In aggregate, the rates in `ZeroRates` constitute a zero curve. If more than one bond has the same maturity date, `zbtyield` returns the mean zero rate for that maturity.
`CurveDates`	An `m`-by-`1` vector of unique maturity dates (as serial date numbers) that correspond to the zero rates in `ZeroRates`; m is the number of bonds of different maturity dates. These dates begin with the earliest maturity date and end with the latest maturity date `Maturity` in the `Bonds` matrix. Use `datestr` to convert serial date numbers to date strings.

Examples

Given data and yields to maturity for 12 coupon bonds, two with the same maturity date; and given the common settlement date

```
Bonds = [datenum('6/1/1998')   0.0475   100  2  0  0;
         datenum('7/1/2000')   0.06     100  2  0  0;
         datenum('7/1/2000')   0.09375  100  6  1  0;
         datenum('6/30/2001')  0.05125  100  1  3  1;
         datenum('4/15/2002')  0.07125  100  4  1  0;
         datenum('1/15/2000')  0.065    100  2  0  0;
         datenum('9/1/1999')   0.08     100  3  3  0;
         datenum('4/30/2001')  0.05875  100  2  0  0;
         datenum('11/15/1999') 0.07125  100  2  0  0;
```

```
            datenum('6/30/2000')  0.07     100  2  3  1;
            datenum('7/1/2001')   0.0525   100  2  3  0;
            datenum('4/30/2002')  0.07     100  2  0  0];

Yields = [0.0616
          0.0605
          0.0687
          0.0612
          0.0615
          0.0591
          0.0603
          0.0608
          0.0655
          0.0646
          0.0641
          0.0627];

Settle = datenum('12/18/1997');
```

Set semiannual compounding for the zero curve.

```
OutputCompounding = 2;
```

Execute the function

```
[ZeroRates, CurveDates] = zbtyield(Bonds, Yields, Settle,...
OutputCompounding)
```

which returns the zero curve at the maturity dates. Note the mean zero rate for the two bonds with the same maturity date.

```
ZeroRates =

    0.0616
    0.0603
    0.0657
    0.0590
```

```
    0.0649
    0.0650
    0.0606
    0.0611
    0.0643
    0.0614
    0.0627

CurveDates =

     729907  (serial date number for 01-Jun-1998)
     730364  (01-Sep-1999)
     730439  (15-Nov-1999)
     730500  (15-Jan-2000)
     730667  (30-Jun-2000)
     730668  (01-Jul-2000)
     730971  (30-Apr-2001)
     731032  (30-Jun-2001)
     731033  (01-Jul-2001)
     731321  (15-Apr-2002)
     731336  (30-Apr-2002)
```

References

Fabozzi, Frank J. "The Structure of Interest Rates." Ch. 6 in Fabozzi, Frank J. and T. Dessa Fabozzi, eds. *The Handbook of Fixed Income Securities*. 4th ed. New York: Irwin Professional Publishing. 1995.

McEnally, Richard W. and James V. Jordan. "The Term Structure of Interest Rates." Ch. 37 in Fabozzi and Fabozzi, ibid.

Das, Satyajit. "Calculating Zero Coupon Rates." *Swap and Derivative Financing*. Appendix to Ch. 8, pp. 219-225. New York: Irwin Professional Publishing. 1994.

See Also

`zbtprice` and other functions for "Term Structure of Interest Rates" on page 2-37

Purpose

Discount curve given zero curve

Syntax

```
[DiscRates, CurveDates] = zero2disc(ZeroRates, CurveDates, Settle,
Compounding, Basis)
```

Arguments

`ZeroRates`	Number of bonds (`NUMBONDS`)-by-`1` vector of annualized zero rates, as decimal fractions. In aggregate, the rates constitute an implied zero curve for the investment horizon represented by `CurveDates`.
`CurveDates`	`NUMBONDS`-by-`1` vector of maturity dates (as serial date numbers) that correspond to the zero rates.
`Settle`	Serial date number that is the common settlement date for the zero rates; that is, the settlement date for the bonds from which the zero curve was bootstrapped.
`Compounding`	(Optional) Scalar that indicates the compounding frequency per year used for annualizing the input zero rates in `ZeroRates`. Allowed values are:

`1`	Annual compounding
`2`	Semiannual compounding (default)
`3`	Compounding three times per year
`4`	Quarterly compounding
`6`	Bimonthly compounding
`12`	Monthly compounding
`365`	Daily compounding

	`-1` Continuous compounding
`Basis`	(Optional) Day-count basis used for annualizing the input zero rates. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA) • 11 = 30/360E (ISMA) • 12 = actual/365 (ISDA)

Description

`[DiscRates, CurveDates] = zero2disc(ZeroRates, CurveDates, Settle, Compounding, Basis)` returns a discount curve given a zero curve and its maturity dates.

`DiscRates`	A `NUMBONDS`-by-`1` vector of discount factors, as decimal fractions. In aggregate, the factors in constitute a discount curve for the investment horizon represented by `CurveDates`.
`CurveDates`	A `NUMBONDS`-by-`1` vector of maturity dates (as serial date numbers) that correspond to the discount rates. This vector is the same as the input vector `CurveDates`.

Examples

Given a zero curve over a set of maturity dates and a settlement date

```
ZeroRates = [0.0464
             0.0509
             0.0524
             0.0525
             0.0531
             0.0525
             0.0530
             0.0531
             0.0549
             0.0536];

CurveDates = [datenum('06-Nov-2000')
              datenum('11-Dec-2000')
              datenum('15-Jan-2001')
              datenum('05-Feb-2001')
              datenum('04-Mar-2001')
              datenum('02-Apr-2001')
              datenum('30-Apr-2001')
              datenum('25-Jun-2001')
              datenum('04-Sep-2001')
              datenum('12-Nov-2001')];

Settle = datenum('03-Nov-2000');
```

The zero curve was compounded daily on an actual/365 basis.

```
Compounding = 365;
Basis = 3;
```

Execute the function

```
[DiscRates, CurveDates] = zero2disc(ZeroRates, CurveDates,...
Settle, Compounding, Basis)
```

which returns the discount curve `DiscRates` at the maturity dates `CurveDates`.

```
DiscRates =

      0.9996
      0.9947
      0.9896
      0.9866
      0.9826
      0.9787
      0.9745
      0.9665
      0.9552
      0.9466

CurveDates =

      730796
      730831
      730866
      730887
      730914
      730943
      730971
      731027
      731098
      731167
```

For readability, `ZeroRates` and `DiscRates` are shown here only to the basis point. However, MATLAB software computed them at full precision. If you enter `ZeroRates` as shown, `DiscRates` may differ due to rounding.

See Also

`disc2zero` and other functions for "Term Structure of Interest Rates" on page 2-37

Purpose

Forward curve given zero curve

Syntax

```
[ForwardRates, CurveDates] = zero2fwd(ZeroRates, CurveDates,
Settle, Compounding, Basis)
```

Arguments

`ZeroRates`	Number of bonds (`NUMBONDS`)-by-`1` vector of annualized zero rates, as decimal fractions. In aggregate, the rates constitute an implied zero curve for the investment horizon represented by `CurveDates`. The first element pertains to forward rates from the settlement date to the first curve date.
`CurveDates`	`NUMBONDS`-by-`1` vector of maturity dates (as serial date numbers) that correspond to the zero rates.
`Settle`	Serial date number that is the common settlement date for the zero rates.
`Compounding`	(Optional) Scalar that sets the compounding frequency per year used to annualize the input zero rates and the output implied forward rates. Allowed values are:

`1`	Annual compounding
`2`	Semiannual compounding (default)
`3`	Compounding three times per year
`4`	Quarterly compounding
`6`	Bimonthly compounding
`12`	Monthly compounding
`365`	Daily compounding

	`-1` Continuous compounding
`Basis`	(Optional) Day-count basis used to construct the input zero and output implied forward rate curves. • 0 = actual/actual (default) • 1 = 30/360 (SIA) • 2 = actual/360 • 3 = actual/365 • 4 = 30/360 (PSA) • 5 = 30/360 (ISDA) • 6 = 30/360 (European) • 7 = actual/365 (Japanese) • 8 = actual/actual (ISMA) • 9 = actual/360 (ISMA) • 10 = actual/365 (ISMA) • 11 = 30/360E (ISMA) • 12 = actual/365 (ISDA)

Description

`[ForwardRates, CurveDates] = zero2fwd(ZeroRates, CurveDates, Settle, Compounding, Basis)` returns an implied forward rate curve given a zero curve and its maturity dates.

`ForwardRates`	A `NUMBONDS`-by-1 vector of decimal fractions. In aggregate, the rates in `ForwardRates` constitute a forward curve over the dates in `CurveDates`.
`CurveDates`	A `NUMBONDS`-by-1 vector of maturity dates (as serial date numbers) that correspond to the forward rates in. This vector is the same as the input vector `CurveDates`.

Examples

Given a zero curve over a set of maturity dates, a settlement date, and a compounding rate, compute the forward rate curve.

```
ZeroRates = [0.0458
             0.0502
             0.0518
             0.0519
             0.0524
             0.0519
             0.0523
             0.0525
             0.0541
             0.0529];

CurveDates = [datenum('06-Nov-2000')
              datenum('11-Dec-2000')
              datenum('15-Jan-2001')
              datenum('05-Feb-2001')
              datenum('04-Mar-2001')
              datenum('02-Apr-2001')
              datenum('30-Apr-2001')
              datenum('25-Jun-2001')
              datenum('04-Sep-2001')
              datenum('12-Nov-2001')];

Settle = datenum('03-Nov-2000');
Compounding = 1;
```

Execute the function

```
[ForwardRates, CurveDates] = zero2fwd(ZeroRates, CurveDates,...
Settle, Compounding)
```

which returns the forward rate curve ForwardRates at the maturity dates `CurveDates`.

```
ForwardRates =

    0.0458
    0.0506
    0.0535
    0.0522
    0.0541
    0.0498
    0.0544
    0.0531
    0.0594
    0.0476

CurveDates =

      730796
      730831
      730866
      730887
      730914
      730943
      730971
      731027
      731098
      731167
```

For readability, `ZeroRates` and `ForwardRates` are shown here only to the basis point. However, MATLAB software computed them at full

precision. If you enter `ZeroRates` as shown, `ForwardRates` may differ due to rounding.

See Also

`fwd2zero` and other functions for "Term Structure of Interest Rates" on page 2-37

Purpose

Par yield curve given zero curve

Syntax

```
[ParRates, CurveDates] = zero2pyld(ZeroRates, CurveDates, Settle,
Compounding, Basis, InputCompounding)
```

Arguments

`ZeroRates`	A number of bonds (`NUMBONDS`)-by-`1` vector of annualized zero rates, as decimal fractions. In aggregate, the rates constitute an implied zero curve for the investment horizon represented by `CurveDates`.
`CurveDates`	A `NUMBONDS`-by-`1` vector of maturity dates (as serial date numbers) that correspond to the zero rates.
`Settle`	A serial date number that is the common settlement date for the zero rates.
`Compounding`	(Optional) Scalar value representing the periodicity in which the output par rates are compounded when annualized. Allowed values are:

`1`	Annual compounding
`2`	Semiannual compounding (default)
`3`	Compounding three times per year
`4`	Quarterly compounding
`6`	Bimonthly compounding
`12`	Monthly compounding
`365`	Daily compounding

`Basis` (Optional) Day-count basis used to annualize the implied zero rates.

- 0 = actual/actual (default)
- 1 = 30/360 (SIA)
- 2 = actual/360
- 3 = actual/365
- 4 = 30/360 (PSA)
- 5 = 30/360 (ISDA)
- 6 = 30/360 (European)
- 7 = actual/365 (Japanese)
- 8 = actual/actual (ISMA)
- 9 = actual/360 (ISMA)
- 10 = actual/365 (ISMA)
- 11 = 30/360E (ISMA)
- 12 = actual/365 (ISDA)

`InputCompounding` (Optional) Scalar value representing the periodicity in which the input zero rates were compounded when annualized. The default is the value for `Compounding`.

Description

`[ParRates, CurveDates] = zero2pyld(ZeroRates, CurveDates, Settle, Compounding, Basis, InputCompounding)` returns a par yield curve given a zero curve and its maturity dates.

`ParRates`	A `NUMBONDS`-by-`1` vector of annualized par yields, as decimal fractions. (Par yields = coupon rates.) In aggregate, the yield rates in `ParRates` constitute a par yield curve for the investment horizon represented by `CurveDates`.
`CurveDates`	A `NUMBONDS`-by-`1` vector of maturity dates (as serial date numbers) that correspond to the par yield rates. This vector is the same as the input vector `CurveDates`.

Examples

Given

- A zero curve over a set of maturity dates and
- A settlement date
- Annual compounding for the input zero curve and monthly compounding for the output par rates

compute a par yield curve.

```
ZeroRates = [0.0457
             0.0487
             0.0506
             0.0507
             0.0505
             0.0504
             0.0506
             0.0516
             0.0539
             0.0530];

CurveDates = [datenum('06-Nov-2000')
              datenum('11-Dec-2000')
              datenum('15-Jan-2001')
              datenum('05-Feb-2001')
```

```
               datenum('04-Mar-2001')
               datenum('02-Apr-2001')
               datenum('30-Apr-2001')
               datenum('25-Jun-2001')
               datenum('04-Sep-2001')
               datenum('12-Nov-2001')];

Settle = datenum('03-Nov-2000');
InputCompounding = 1;
Compounding = 12;

[ParRates, CurveDates] = zero2pyld(ZeroRates, CurveDates,...
Settle, Compounding, [] , InputCompounding)

ParRates =

    0.0479
    0.0511
    0.0530
    0.0531
    0.0526
    0.0524
    0.0525
    0.0534
    0.0555
    0.0543

CurveDates =

      730796
      730831
      730866
      730887
      730914
      730943
      730971
      731027
```

```
731098
731167
```

For readability, `ZeroRates` and `ParRates` are shown only to the basis point. However, MATLAB software computed them at full precision. If you enter `ZeroRates` as shown, `ParRates` may differ due to rounding.

See Also

`pyld2zero` and other functions for "Term Structure of Interest Rates" on page 2-37

A

Bibliography

- "Bond Pricing and Yields" on page A-2
- "Term Structure of Interest Rates" on page A-3
- "Derivatives Pricing and Yields" on page A-4
- "Portfolio Analysis" on page A-5
- "Investment Performance Metrics" on page A-6
- "Financial Statistics" on page A-8
- "Other References" on page A-9

Note For the well-known algorithms and formulas used in Financial Toolbox software (such as how to compute a loan payment given principal, interest rate, and length of the loan), no references are given here. The references here pertain to less common formulas.

Bond Pricing and Yields

The pricing and yield formulas for fixed-income securities come from:

[1] Golub, B.W. and L.M. Tilman, *Risk Management: Approaches for Fixed Income Markets* Wiley, 2000.

[2] Martellini, L., P. Priaulet, and S. Priaulet *Fixed Income Securities* Wiley, 2003.

[3] Mayle, Jan, *Standard Securities Calculation Methods* New York: Securities Industry Association, Inc. Vol. 1, 3rd ed., 1993, ISBN 1-882936-01-9. Vol. 2, 1994, ISBN 1-882936-02-7.

[4] Tuckman, B. *Fixed Income Securities: Tools for Today's Markets* Wiley, 2002.

In many cases these formulas compute the price of a security given yield, dates, rates, and other data. These formulas are nonlinear, however; so when solving for an independent variable within a formula, Financial Toolbox software uses Newton's method. See any elementary numerical methods textbook for the mathematics underlying Newton's method.

Term Structure of Interest Rates

The formulas and methodology for term structure functions come from:

[5] Fabozzi, Frank J., "The Structure of Interest Rates." Ch. 6 in Fabozzi, Frank J. and T. Dessa Fabozzi, eds. *The Handbook of Fixed Income Securities.* 4th ed. New York: Irwin Professional Publishing, 1995, ISBN 0-7863-0001-9.

[6] McEnally, Richard W. and James V. Jordan, "The Term Structure of Interest Rates." Ch. 37 in Fabozzi and Fabozzi, ibid.

[7] Das, Satyajit, "Calculating Zero Coupon Rates." *Swap and Derivative Financing.* Appendix to Ch. 8, pp. 219-225, New York: Irwin Professional Publishing., 1994, ISBN 1-55738-542-4.

Derivatives Pricing and Yields

The pricing and yield formulas for derivative securities come from:

[8] Chriss, Neil A., "Black-Scholes and Beyond: Option Pricing Models," Chicago: Irwin Professional Publishing, 1997, ISBN 0-7863-1025-1.

[9] Cox, J., S. Ross, and M. Rubenstein, "Option Pricing: A Simplified Approach", *Journal of Financial Economics 7*, Sept. 1979, pp. 229 - 263.

[10] Hull, John C., *Options, Futures, and Other Derivatives*, Prentice Hall, 5th edition, 2003, ISBN 0-13-009056-5.

Portfolio Analysis

The Markowitz model is used for portfolio analysis computations. For a discussion of this model see Chapter 7 of:

[11] Bodie, Zvi, Alex Kane, and Alan J. Marcus, *Investments*, Burr Ridge, IL: Irwin. 2nd. ed., 1993, ISBN 0-256-08342-8.

To solve the quadratic minimization problem associated with finding the efficient frontier, the toolbox uses the `fmincon` function (finds the constrained minimum of a function of several variables) in the Optimization Toolbox documentation. See that toolbox documentation for more details.

Investment Performance Metrics

The risk and ratio formulas for investment performance metrics come from:

[12] Daniel Bernoulli, "Exposition of a New Theory on the Measurement of Risk," *Econometrica*, Vol. 22, No 1, January 1954, pp. 23-36 (English translation of "Specimen Theoriae Novae de Mensura Sortis," *Commentarii Academiae Scientiarum Imperialis Petropolitanae*, Tomus V, 1738, pp. 175-192).

[13] Martin Eling and Frank Schuhmacher, *Does the Choice of Performance Measure Influence the Evaluation of Hedge Funds?*, Working Paper, November 2005.

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[15] Malik Magdon-Ismail, Amir F. Atiya, Amrit Pratap, and Yaser S. Abu-Mostafa, "On the Maximum Drawdown of a Brownian Motion," *Journal of Applied Probability*, Volume 41, Number 1, March 2004, pp. 147-161.

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[25] Sexton, Joe and Anders Rygh Swensen, "ECM Algorithms That Converge at the Rate of EM," *Biometrika*, Vol. 87, No. 3, 2000, pp. 651-662.

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Other References

Other references include:

[27] Addendum to Securities Industry Association, *Standard Securities Calculation Methods: Fixed Income Securities Formulas for Analytic Measures,* Vol. 2, Spring 1995. This addendum explains and clarifies the end-of-month rule.

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[30] *A Dictionary of Finance.* Oxford: Oxford University Press., 1993, ISBN 0-19-285279-5.

[31] Fabozzi, Frank J. and T. Dessa Fabozzi, eds. *The Handbook of Fixed-Income Securities.* Burr Ridge, IL: Irwin. 4th ed., 1995, ISBN 0-7863-0001-9.

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[36] Sharpe, William F., *Macro-Investment Analysis*. An "electronic work-in-progress" published on the World Wide Web, 1995, at http://www.stanford.edu/~wfsharpe/mia/mia.htm.

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B

Examples

Use this list to find examples in the documentation.

Bond Examples

"Single Bond Example" on page 2-28
"Bond Portfolio Example" on page 2-29

Portfolio Examples

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Glossary

active return
Amount of return achieved in excess of the return produced by an appropriate benchmark (for example, an index portfolio).

active risk
Standard deviation of the active return. Also known as the **tracking error** on page Glossary-12.

American option
An option that can be exercised any time until its expiration date. Contrast with European option.

amortization
Reduction in value of an asset over some period for accounting purposes. Generally used with intangible assets. Depreciation is the term used with fixed or tangible assets.

annuity
A series of payments over a period of time. The payments are usually in equal amounts and usually at regular intervals such as quarterly, semiannually, or annually.

arbitrage
The purchase of securities on one market for immediate resale on another market to profit from a price or currency discrepancy.

basis point
One hundredth of one percentage point, or 0.0001.

beta
The price volatility of a financial instrument relative to the price volatility of a market or index as a whole. Beta is most commonly used with respect to equities. A high-beta instrument is riskier than a low-beta instrument.

binomial model
A method of pricing options or other equity derivatives in which the probability over time of each possible price follows a binomial

distribution. The basic assumption is that prices can move to only two values (one higher and one lower) over any short time period.

Black-Scholes model

The first complete mathematical model for pricing options, developed by Fischer Black and Myron Scholes. It examines market price, strike price, volatility, time to expiration, and interest rates. It is limited to only certain kinds of options.

Bollinger band chart

A financial chart that plots actual asset data along with three other bands of data: the upper band is two standard deviations above a user-specified moving average; the lower band is two standard deviations below that moving average; and the middle band is the moving average itself.

bootstrapping, bootstrap method

An arithmetic method for backing an implied zero curve out of the par yield curve.

building a binomial tree

For a binomial option model: plotting the two possible short-term price-changes values, and then the subsequent two values each, and then the subsequent two values each, and so on over time, is known as "building a binomial tree." See also **binomial model** on page Glossary-1.

call

a. An option to buy a certain quantity of a stock or commodity for a specified price within a specified time. See also **put** on page Glossary-10. **b.** A demand to submit bonds to the issuer for redemption before the maturity date. **c.** A demand for payment of a debt. **d.** A demand for payment due on stock bought on margin.

callable bond

A bond that allows the issuer to buy back the bond at a predetermined price at specified future dates. The bond contains an embedded call option; that is, the holder has sold a call option to the issuer. See also **puttable bond** on page Glossary-10.

candlestick chart

A financial chart usually used to plot the high, low, open, and close price of a security over time. The body of the "candle" is the region between the open and close price of the security. Thin vertical lines extend up to the high and down to the low, respectively. If the open price is greater than the close price, the body is empty. If the close price is greater than the open price, the body is filled. See also **high-low-close chart** on page Glossary-6.

cap

Interest-rate option that guarantees that the rate on a floating-rate loan will not exceed a certain level.

cash flow

Cash received and paid over time.

collar

Interest-rate option that guarantees that the rate on a floating-rate loan will not exceed a certain upper level nor fall below a lower level. It is designed to protect an investor against wide fluctuations in interest rates.

convexity

A measure of the rate of change in duration; measured in time. The greater the rate of change, the more the duration changes as yield changes.

correlation

The simultaneous change in value of two random numeric variables.

correlation coefficient

A statistic in which the covariance is scaled to a value between minus one (perfect negative correlation) and plus one (perfect positive correlation).

coupon

Detachable certificate attached to a bond that shows the amount of interest payable at regular intervals, usually semiannually. Originally coupons were actually attached to the bonds and had to be cut off or "clipped" to redeem them and receive the interest payment.

coupon dates
The dates when the coupons are paid. Typically a bond pays coupons annually or semiannually.

coupon rate
The nominal interest rate that the issuer promises to pay the buyer of a bond.

covariance
A measure of the degree to which returns on two assets move in tandem. A positive covariance means that asset returns move together; a negative covariance means they vary inversely.

delta
The rate of change of the price of a derivative security relative to the price of the underlying asset; that is, the first derivative of the curve that relates the price of the derivative to the price of the underlying security.

depreciation
Reduction in value of fixed or tangible assets over some period for accounting purposes. See also **amortization** on page Glossary-1.

derivative
A financial instrument that is based on some underlying asset. For example, an option is a derivative instrument based on the right to buy or sell an underlying instrument.

discount curve
The curve of discount rates versus maturity dates for bonds.

drawdown
The peak to trough decline during a specific record period of an investment or fund.

duration
The expected life of a fixed-income security considering its coupon yield, interest payments, maturity, and call features. As market interest rates rise, the duration of a financial instrument decreases. See also **Macaulay duration** on page Glossary-7.

efficient frontier
A graph representing a set of portfolios that maximizes expected return at each level of portfolio risk. See also **Markowitz model** on page Glossary-8.

elasticity
See **Lambda** on page Glossary-7.

European option
An option that can be exercised only on its expiration date. Contrast with American option.

ex-ante
Referring to future events, such as the future price of a stock.

ex-post
Referring to past events, when uncertainty of the result has been eliminated.

exercise price
The price set for buying an asset (call) or selling an asset (put). The strike price.

face value
The maturity value of a security. Also known as par value, principal value, or redemption value.

fixed-income security
A security that pays a specified cash flow over a specific period. Bonds are typical fixed-income securities.

floor
Interest-rate option that guarantees that the rate on a floating-rate loan will not fall below a certain level.

forward curve
The curve of forward interest rates versus maturity dates for bonds.

forward rate

The future interest rate of a bond inferred from the term structure, especially from the yield curve of zero-coupon bonds, calculated from the growth factor of an investment in a zero held until maturity.

future value

The value that a sum of money (the present value) earning compound interest will have in the future.

gamma

The rate of change of delta for a derivative security relative to the price of the underlying asset; that is, the second derivative of the option price relative to the security price.

greeks

Collectively, "greeks" refer to the financial measures beta, delta, gamma, lambda, rho, theta, and vega, which are sensitivity measures used in evaluating derivatives.

hedge

A securities transaction that reduces or offsets the risk on an existing investment position.

high-low-close chart

A financial chart usually used to plot the high, low, open, and close price of a security over time. Plots are vertical lines whose top is the high, bottom is the low, open is a short horizontal tick to the left, and close is a short horizontal tick to the right.

implied volatility

For an option, the variance that makes a call option price equal to the market price. Given the option price, strike price, and other factors, the Black-Scholes model computes implied volatility.

information ratio

The ratio of relative return to relative risk.

internal rate of return

a. The average annual yield earned by an investment during the period held. **b.** The effective rate of interest on a loan. **c.** The discount rate

in discounted cash flow analysis. **d.** The rate that adjusts the value of future cash receipts earned by an investment so that interest earned equals the original cost. See also **yield** on page Glossary-13.

issue date

The date a security is first offered for sale. That date usually determines when interest payments, known as coupons, are made.

Ito process

Statistical assumptions about the behavior of security prices. For details, see the book by Hull in "Derivatives Pricing and Yields" on page A-4.

key rate duration

Key rate duration measures the sensitivity of a portfolio's (or security's) value in relation to changes in specific maturities of the zero or spot curve.

Lambda

The percentage change in the price of an option relative to a 1% change in the price of the underlying security. Also known as elasticity.

long position

Outright ownership of a security or financial instrument. The owner expects the price to rise in order to make a profit on some future sale.

long rate

The yield on a zero-coupon Treasury bond.

lower partial moment

A model for the moments of asset returns that fall below a minimum acceptable level of return.

Macaulay duration

A widely used measure of price sensitivity to yield changes developed by Frederick Macaulay in 1938. It is measured in years and is a weighted average-time-to-maturity of an instrument. The Macaulay duration of an income stream, such as a coupon bond, measures how long, on average, the owner waits before receiving a payment. It is the weighted

average of the times payments are made, with the weights at time T equal to the present value of the money received at time T.

Markowitz model

A model for selecting an optimum investment portfolio, devised by H. M. Markowitz. It uses a discrete-time, continuous-outcome approach for modeling investment problems, often called the mean-variance paradigm. See also **efficient frontier** on page Glossary-5.

maturity date

The date when the issuer returns the final face value of a bond to the buyer.

mean

a. A number that typifies a set of numbers, such as a geometric mean or an arithmetic mean. **b.** The average value of a set of numbers.

modified duration

The Macaulay duration discounted by the per-period interest rate; that is, divided by (1+rate/frequency).

Monte-Carlo simulation

A mathematical modeling process. For a model that has several parameters with statistical properties, pick a set of random values for the parameters and run a simulation. Then pick another set of values, and run it again. Run it many times (often 10,000 times) and build up a statistical distribution of outcomes of the simulation. This distribution of outcomes is then used to answer whatever question you are asking.

moving average

A price average that is adjusted by adding other parametrically determined prices over some time period.

moving-averages chart

A financial chart that plots leading and lagging moving averages for prices or values of an asset.

normal (bell-shaped) distribution

In statistics, a theoretical frequency distribution for a set of variable data, usually represented by a bell-shaped curve symmetrical about the mean.

odd first or last period

Fixed-income securities may be purchased on dates that do not coincide with coupon or payment dates. The length of the first and last periods may differ from the regular period between coupons, and thus the bond owner is not entitled to the full value of the coupon for that period. Instead, the coupon is prorated according to how long the bond is held during that period.

on-the-run treasury bonds

The most recently auctioned issue of a U.S. Treasury bond or note of a particular maturity.

option

A right to buy or sell specific securities or commodities at a stated price (exercise or strike price) within a specified time. An option is a type of derivative.

par value

The maturity or face value of a security or other financial instrument.

par yield curve

The yield curve of bonds selling at par, or face, value.

point and figure chart

A financial chart usually used to plot asset price data. Upward price movements are plotted as X's and downward price movements are plotted as O's.

present value

Today's value of an investment that yields some future value when invested to earn compounded interest at a known interest rate; that is, the future value at a known period in time discounted by the interest rate over that time period.

principal value
See **par value** on page Glossary-9.

purchase price
Price actually paid for a security. Typically the purchase price of a bond is not the same as the redemption value.

put
An option to sell a stipulated amount of stock or securities within a specified time and at a fixed exercise price. See also **call** on page Glossary-2.

puttable bond
A bond that allows the holder to redeem the bond at a predetermined price at specified future dates. The bond contains an embedded put option; that is, the holder has bought a put option. See also **callable bond** on page Glossary-2.

Quant
A quantitative analyst; someone who does numerical analysis of financial information in order to detect relationships, disparities, or patterns that can lead to making money.

redemption value
See **par value** on page Glossary-9.

regression analysis
Statistical analysis techniques that quantify the relationship between two or more variables. The intent is quantitative prediction or forecasting, particularly using a small population to forecast the behavior of a large population.

rho
The rate of change in a derivative's price relative to the underlying security's risk-free interest rate.

sensitivity
The "what if" relationship between variables; the degree to which changes in one variable cause changes in another variable. A specific synonym is volatility.

settlement date
The date when money first changes hands; that is, when a buyer actually pays for a security. It need not coincide with the issue date.

Sharpe ratio
The ratio of the excess return of an asset divided by the asset's standard deviation of returns.

short rate
The annualized one-period interest rate.

short sale, short position
The sale of a security or financial instrument not owned, in anticipation of a price decline and making a profit by purchasing the instrument later at a lower price, and then delivering the instrument to complete the sale. See also **long position** on page Glossary-7.

spot curve, spot yield curve
See **zero curve, zero-coupon yield curve** on page Glossary-13.

spot rate
The current interest rate appropriate for discounting a cash flow of some given maturity.

spread
For options, a combination of call or put options on the same stock with differing exercise prices or maturity dates.

standard deviation
A measure of the variation in a distribution, equal to the square root of the arithmetic mean of the squares of the deviations from the arithmetic mean; the square root of the variance.

stochastic
Involving or containing a random variable or variables; involving chance or probability.

straddle
A strategy used in trading options or futures. It involves simultaneously purchasing put and call options with the same exercise price and

expiration date, and it is most profitable when the price of the underlying security is very volatile.

strike
Exercise a put or call option.

strike price
See **exercise price** on page Glossary-5.

swap
A contract between two parties to exchange cash flows in the future according to some formula.

swaption
A swap option; an option on an interest-rate swap. The option gives the holder the right to enter into a contracted interest-rate swap at a specified future date. See also **swap** on page Glossary-12.

term structure
The relationship between the yields on fixed-interest securities and their maturity dates. Expectation of changes in interest rates affects term structure, as do liquidity preferences and hedging pressure. A yield curve is one representation in the term structure.

theta
The rate of change in the price of a derivative security relative to time. Theta is usually very small or negative since the value of an option tends to drop as it approaches maturity.

tracking error
See **active risk** on page Glossary-1.

Treasury bill
Short-term U.S. government security issued at a discount from the face value and paying the face value at maturity.

Treasury bond
Long-term debt obligation of the U.S. government that makes coupon payments semiannually and is sold at or near par value in $1000 denominations or higher. Face value is paid at maturity.

variance

The dispersion of a variable. The square of the standard deviation.

vega

The rate of change in the price of a derivative security relative to the volatility of the underlying security. When vega is large, the security is sensitive to small changes in volatility.

volatility

a. Another general term for sensitivity. **b.** The standard deviation of the annualized continuously compounded rate of return of an asset. **c.** A measure of uncertainty or risk.

yield

a. Measure of return on an investment, stated as a percentage of price. Yield can be computed by dividing return by purchase price, current market value, or other measure of value. **b.** Income from a bond expressed as an annualized percentage rate. **c.** The nominal annual interest rate that gives a future value of the purchase price equal to the redemption value of the security. Any coupon payments determine part of that yield.

yield curve

Graph of yields (vertical axis) of a particular type of security versus the time to maturity (horizontal axis). This curve usually slopes upward, indicating that investors usually expect to receive a premium for securities that have a longer time to maturity. The benchmark yield curve is for U.S. Treasury securities with maturities ranging from three months to 30 years. See also **term structure** on page Glossary-12.

yield to maturity

A measure of the average rate of return that will be earned on a bond if held to maturity.

zero curve, zero-coupon yield curve

A yield curve for zero-coupon bonds; zero rates versus maturity dates. Since the maturity and duration (Macaulay duration) are identical for zeros, the zero curve is a pure depiction of supply/demand conditions for loanable funds across a continuum of durations and maturities. Also known as spot curve or spot yield curve.

zero-coupon bond, or zero

A bond that, instead of carrying a coupon, is sold at a discount from its face value, pays no interest during its life, and pays the principal only at maturity.

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