# HiQ™

# Reference Manual

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*The Software is the Instrument®*

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# Important Information

# Contents

# About This Manual

The *HiQ Reference Manual* contains reference information about different HiQ features, including ActiveX automation, the Command Window, graphics, HiQ objects, HiQ-Script reference, and built-in HiQ functions.

If you are new to HiQ, read *Getting Results with HiQ*, an introductory manual designed to teach you HiQ basics.

## Organization of This Manual

The *HiQ Reference Manual* is organized as follows:

- Chapter 1, *ActiveX Connectivity*, describes ActiveX connectivity and how you can use that technology in HiQ to communicate with other applications, embed objects from other applications in HiQ, embed HiQ Notebooks in other applications, control other applications from HiQ, control HiQ from other applications, and use ActiveX controls in HiQ.
- Chapter 2, *HiQ Command Window*, explains how you can customize the HiQ Command Window, take advantage of Command Window shortcuts, and navigate the Command Window using custom commands for both HiQ and MATLAB modes. This chapter concludes with a description of the HiQ Log Window.
- Chapter 3, *Using HiQ Graphics*, provides information about using 2D and 3D graphics in HiQ and procedures for working with graphs interactively and programmatically.
- Chapter 4, *HiQ Objects and Object Properties*, explains HiQ objects in general, describes each HiQ object specifically, and provides all properties and property descriptions for each object.
- Chapter 5, *HiQ-Script Basics*, introduces HiQ-Script, the built-in scripting language that you can use to build algorithms you need to solve your problems.
- Chapter 6, *HiQ-Script Reference*, contains an alphabetical reference of HiQ-Script elements, including expressions and statements.
- Chapter 7, *Function Reference*, contains an alphabetical list and description of every HiQ built-in function.
- Appendix A, *HiQ Functions Listed by Category*, lists all HiQ built-in functions by category: Analysis, File I/O, Graphics, and Utilities. The analysis functions are divided into subcategories: approximation, basic

math, derivatives, differential equations, integral equations, integration, linear algebra, nonlinear systems, optimization, polynomials, special functions, statistics, structures, trigonometric, and utility functions.

- Appendix B, *HiQ Constants*, lists and describes the HiQ property constants, HiQ-Script language constants, and built-in function constants.
- Appendix C, *Customer Communication*, contains forms you can use to request help from National Instruments or to comment on our products and manuals.
- The *Glossary* contains an alphabetical list and description of terms used in this manual, including abbreviations, acronyms, metric prefixes, mnemonics, and symbols.
- The *Index* contains an alphabetical list of key terms and topics in this manual, including the page where you can find each one.

## Conventions Used in This Manual

The following conventions are used in this manual:

| | |
|---|---|
| <> | Angle brackets enclose the name of a key on the keyboard—for example, <shift>. In HiQ-Script, angle brackets denote a HiQ-Script constant. |
| - | A hyphen between two or more key names enclosed in angle brackets denotes that you should simultaneously press the named keys—for example, <Control-Alt-Delete>. |
| » | The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **Help»HiQ Help Topics** directs you to pull down the **Help** menu and select the **HiQ Help Topics** item. This symbol also represents the MATLAB prompt. |
| ☞ | This icon to the left of bold italicized text denotes a note, which alerts you to important information. |
| **bold** | Bold text denotes the names of menus, menu items, dialog box buttons or options, icons, and windows. |
| ***bold italic*** | Bold italic text denotes a note. |
| <Control> | Key names are capitalized. |
| *italic* | Italic text denotes a cross reference or an introduction to a key concept. |

| | |
|---|---|
| `monospace` | Text in this font denotes text or characters that you should literally enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, parameters, functions, variables, filenames and extensions, and for statements and comments taken from programs. |
| *`monospace italic`* | Italic text in this font denotes optional parameters or indicates that you must enter the appropriate words or values in the place of these items. |
| paths | Paths in this manual are denoted using backslashes (\) to separate drive names, directories, folders, and files. |

## Related Documentation

The following documents contain information you might find helpful as you read this manual:

- *Getting Results with HiQ*
- The HiQ online help, which you can access with the **Help»HiQ Help Topics** command.

## Customer Communication

National Instruments wants to receive your comments on our products and manuals. We are interested in the applications you develop with our products, and we want to help if you have problems with them. To make it easy for you to contact us, this manual contains comment and configuration forms for you to complete. These forms are in Appendix C, *Customer Communication*, at the end of this manual.

1

# ActiveX Connectivity

This chapter describes ActiveX connectivity and how you can use that technology in HiQ to communicate with other applications, embed objects from other applications in HiQ, embed HiQ Notebooks in other applications, control other applications from HiQ, control HiQ from other applications, and use ActiveX controls in HiQ.

## ActiveX Technology

ActiveX is a Microsoft standard technology that allows programs to communicate with each other and share data. ActiveX technology encompasses five major areas: document containers, document servers, automation clients, automation servers, and controls containers. Because HiQ supports all five areas of ActiveX technology, you have maximum flexibility in sharing HiQ with your other software tools.

### HiQ Is an ActiveX Document Container

As an ActiveX document container, HiQ allows you to embed documents and objects from other applications directly into your HiQ Notebook. For example, you can embed a Microsoft Word file, an Excel spreadsheet, or a PowerPoint presentation directly in your HiQ Notebook. These embedded objects are editable within the HiQ environment and can be stored within a HiQ Notebook or linked to an external file on disk. For more information about embedding objects in HiQ, see *Embedding Objects from Other Applications in HiQ* later in this chapter.

### HiQ Is an ActiveX Document Server

As an ActiveX document server, HiQ allows you to embed a HiQ Notebook into any other application that is an ActiveX document container. For example, you can embed a HiQ Notebook directly into a Microsoft Word document, an Excel spreadsheet, or a PowerPoint presentation. The embedded HiQ Notebook is editable within the other application and can be stored within the container document. For more information about embedding a HiQ Notebook in another application, see *Embedding HiQ Notebooks in Other Applications* later in this chapter.

## HiQ Is an ActiveX Automation Client

As an ActiveX automation client, HiQ allows you to run and control other applications from the HiQ environment. For example, you can create a HiQ Notebook that automatically launches Microsoft Word or Excel and then shares HiQ data with the Word document or Excel spreadsheet to produce an automated report. For more information about controlling another application from HiQ, see *Controlling Other Applications from HiQ* later in this chapter.

## HiQ Is an ActiveX Automation Server

As an ActiveX automation server, HiQ allows you to run and control a HiQ Notebook from within any other application that is an ActiveX automation client. For example, you can create a program in another application, such as Microsoft Visual Basic, LabVIEW, or LabWindows/CVI, that automatically launches HiQ, opens a HiQ Notebook, and sends data to HiQ for automated analysis, visualization, and report generation. For more information about controlling a HiQ Notebook from another application, see *Controlling HiQ from Other Applications* later in this chapter.

## HiQ Is an ActiveX Controls Container

As an ActiveX controls container, HiQ allows you to embed ActiveX controls directly into your HiQ Notebook. These embedded controls can be accessed both interactively and programmatically from within the HiQ environment. For example, you can embed a Microsoft Web Browser or National Instruments ComponentWorks control directly into your HiQ Notebook and then access that control to automatically gather data from the Internet or a physical measurement device. You then can store that data in your HiQ Notebook for analysis. For more information about embedding an ActiveX control in a HiQ Notebook, see *Using ActiveX Controls in HiQ* later in this chapter.

## Communicating with ActiveX Servers, Objects, and Controls

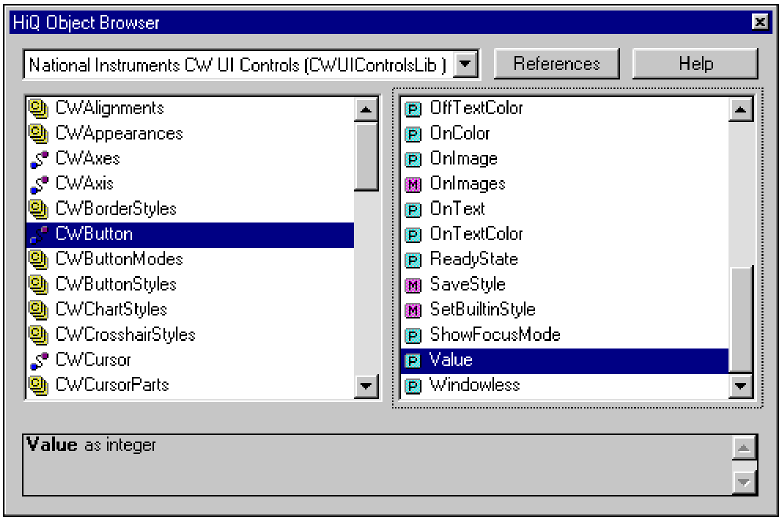
You can connect HiQ to other applications (ActiveX servers), share data with embedded documents (ActiveX objects), and operate embedded controls (ActiveX controls). By displaying the methods and properties available to these servers, objects, and controls, the HiQ ActiveX Object Browser makes it easy to communicate with other ActiveX components.

The HiQ ActiveX Object Browser is a browser window that lets you view all the interfaces for ActiveX servers, objects, and controls installed on your computer. From these interfaces, you can access the properties and methods from HiQ-Script to manipulate the other ActiveX component.

## Displaying the HiQ ActiveX Object Browser

You can invoke the HiQ ActiveX Object Browser in one of three ways from the HiQ environment:

- Select **ActiveX Object Browser** from the **View** menu.
- Right click on an embedded object or control, and select **Browse**.
- Use the `browse` command in the HiQ Command Window. For more information about the `browse` command, see *Command Window Commands* in Chapter 2, *The HiQ Command Window*.



**Value** as integer

**Figure 1-1.** HiQ ActiveX Object Browser

The HiQ ActiveX Object Browser, as shown in Figure 1-1, appears at the top of the HiQ window by default.

The HiQ ActiveX Object Browser consists of four windows:

- The top pulldown window is a selection list that allows you to choose which ActiveX server, object, or control you want to browse.
- The left window displays the ActiveX interfaces to the currently selected ActiveX server, object, or control.
- The right window displays all the properties and methods for the currently selected ActiveX interface.
- The bottom window displays the syntax help for the currently selected property or method. This help text is provided by the selected ActiveX component.

There are two buttons on the HiQ ActiveX Object Browser:

- **References**—This button brings up the References dialog box where you choose which of the currently installed ActiveX servers, objects, and controls on your computer are to be displayed in the ActiveX Object Browser selection list.
- **Help**—This button brings up the online help for the currently selected item in the ActiveX Object Browser.

**Note** ***Not all ActiveX servers, objects, and controls have online help. As a result, help might not be available for some items.***

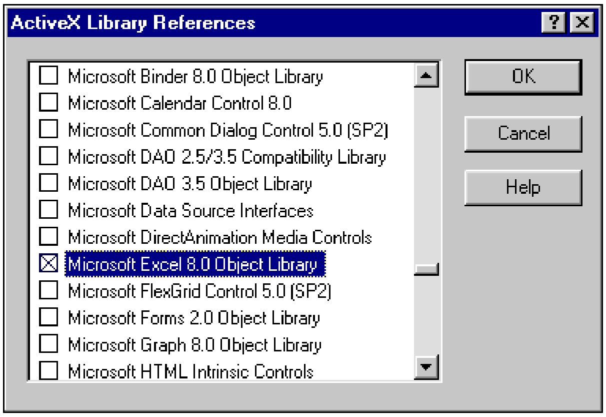
## Using the HiQ ActiveX Object Browser

The HiQ ActiveX Object Browser (Figure 1-1) displays ActiveX interfaces to servers, objects, and controls in the left window. Methods and properties for these interfaces are displayed in the right window.

Use the following procedure to browse the ActiveX interface to Microsoft Excel. You can use this procedure to browse other applications as well.

**Note** ***You need Microsoft Excel 97 installed on your computer to complete this example.***

1. Invoke the ActiveX Object Browser.
2. Click on **References** to display a list of all available ActiveX servers, objects, and controls in the ActiveX Library References dialog box. From this dialog, you can select which servers, objects, and controls appear in the ActiveX Object Browser list.
3. Select Microsoft Excel Object Library from the selection list, and click on **OK**.



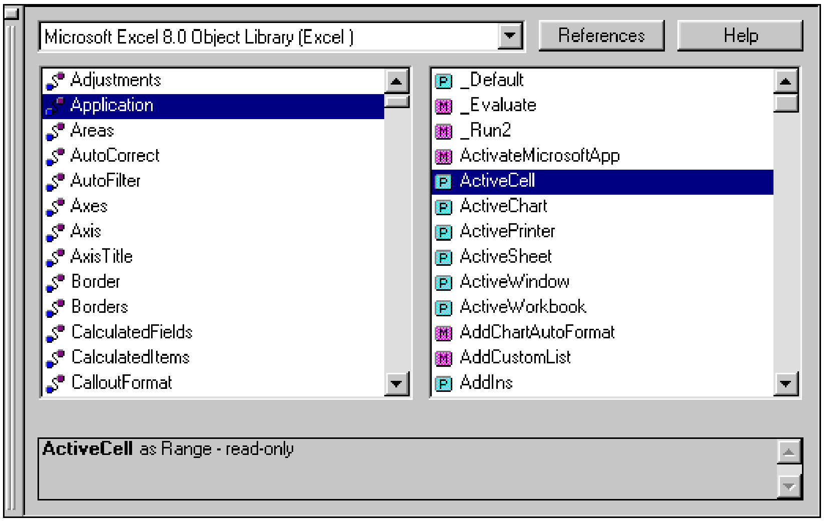
- [ ] Microsoft Binder 8.0 Object Library
- [ ] Microsoft Calendar Control 8.0
- [ ] Microsoft Common Dialog Control 5.0 (SP2)
- [ ] Microsoft DAO 2.5/3.5 Compatibility Library
- [ ] Microsoft DAO 3.5 Object Library
- [ ] Microsoft Data Source Interfaces
- [ ] Microsoft DirectAnimation Media Controls
- [x] Microsoft Excel 8.0 Object Library
- [ ] Microsoft FlexGrid Control 5.0 (SP2)
- [ ] Microsoft Forms 2.0 Object Library
- [ ] Microsoft Graph 8.0 Object Library
- [ ] Microsoft HTML Intrinsic Controls

**Figure 1-2.** ActiveX Library References

In the left window of the ActiveX Object Browser, the available interfaces for Microsoft Excel are now listed.

4. Click on the Application interface in the left widow. Notice that the properties and methods for the Application interface are immediately displayed in the right window of the ActiveX Object Browser.

5. Click on the ActiveCell property in the right window. Notice the syntax help for the ActiveCell property is immediately displayed in the window below.



**ActiveCell** as Range - read-only

**Figure 1-3.** Microsoft Excel 8.0 Object Library

**Note** ***To view the syntax help for a particular property or method of an ActiveX interface, select the interface from the left window of the ActiveX Object Browser. Then, select the appropriate property or method from the right window. The syntax help for that item is displayed in the bottom window of the ActiveX Object Browser.***

6. To access some of the properties and methods of Excel, enter the following commands in the HiQ Command Window.

**Note** ***You can use the HiQ ActiveX Object Browser to verify the syntax of the following commands. Click on the*** **Help** ***button to view the online help for a selected item.***

```
excel = CreateInterface("excel.application");
excel.visible = true;
excel.workbooks.add;
sheet = excel.activesheet;
sheet.range("A1:C3") = CreateMatrix(3, 3, <random>);
v = sheet.range("B1:B3").value;
```

In this example, `excel` is an ActiveX interface to the Excel automation server application created by the `CreateInterface` function call, and `sheet` is an ActiveX interface to the currently active Excel sheet. You use an ActiveX interface in HiQ-Script to access the properties and methods of an ActiveX object. Once you have a sheet interface, you can modify the sheet using its properties and methods.

For more information about the `createInterface` function, see *createInterface*, in Chapter 7, *Function Reference*.

In the above example, you are setting the range of Excel cells A1 to C3 to random numbers that are generated from HiQ. You then read the Excel sheet to create a vector in HiQ containing the values from cells B1 to B3.

This example shows how you can use the HiQ ActiveX Object Browser to view the ActiveX interfaces for various application servers, objects, and controls. Using this information, you can easily communicate with other software tools by sending and receiving data from HiQ.

For more information about controlling other applications from HiQ, see *Controlling Other Applications from HiQ* later in this chapter.

## Embedding Objects from Other Applications in HiQ

You can embed objects from other applications directly in a HiQ Notebook, which is especially useful when you want to annotate your HiQ Notebook with pictures, charts, images, and text from other applications you already own. Embedded objects are editable within the HiQ environment and can be stored within the HiQ Notebook or linked to an external file on disk.

Use the following procedure to embed an object into a HiQ Notebook.

1. Select **Insert Object** from the **Edit** menu. A list box appears showing you all of the currently registered object servers on your computer.
2. Choose the object from the list that you would like to embed in your HiQ Notebook. For example, select Microsoft Word Document if you want to include a Word document in your HiQ Notebook.
3. Click on **Create New** to create a new embedded object, or click on **Create from File** to embed a file from disk.

**Note** ***When you select*** **Create New*****, the newly created object is stored in the HiQ Notebook. When you select*** **Create from File*****, you can embed a copy of the entire file or link to the file on disk. Choose the*** **Link** ***option if you want to link to the file on disk. If you want the entire object embedded and saved, rather than linked, do not choose the*** **Link** ***option.***

You now have an embedded object in your HiQ Notebook. Notice that the HiQ menu bar and HiQ toolbars change to reflect the merging of HiQ with the embedded object's application. Figure 1-4 shows an example of a Microsoft Word document embedded and active in a HiQ Notebook.

4. Edit the embedded object directly in HiQ with the natural tools available to the embedded object.

   When you finish editing the embedded object, click outside the object somewhere on the Notebook page to terminate your editing. Notice that the HiQ menu bars and toolbars return to their original state, indicating that you are no longer editing the embedded object.

   To edit the embedded object again, double click on the embedded object view on the HiQ Notebook page. Notice that the HiQ menu bar and toolbars change to merge with the embedded object's application.

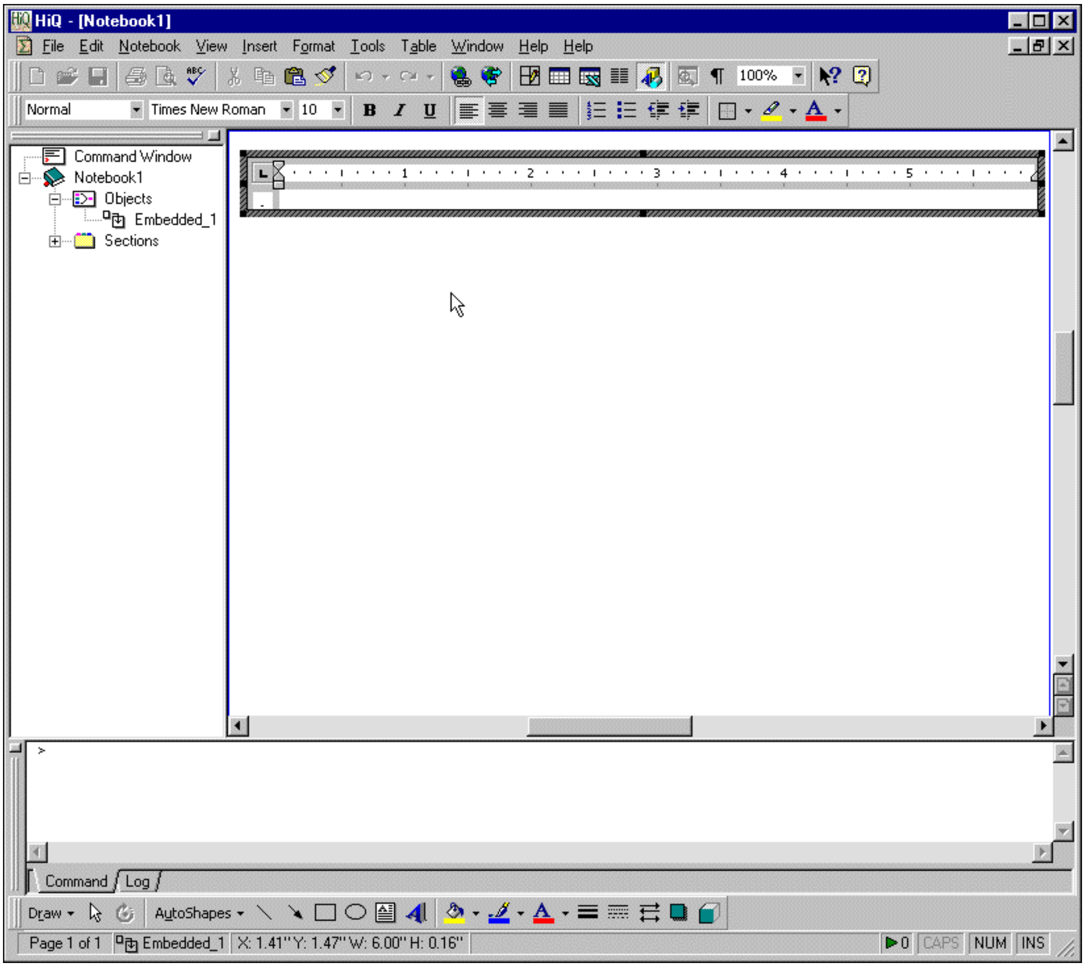


**Figure 1-4.** Microsoft Word Document Embedded in a HiQ Notebook

After embedding an object in a HiQ Notebook, you can manipulate it in one of two ways:

- Interactively edit an embedded object directly on the HiQ Notebook page by double clicking on it.
- Programmatically control an embedded object with HiQ-Script, which gives you the power to access the properties and methods for embedded objects. For example, you can programmatically change the text within an embedded Microsoft Word document in HiQ, as described in the following example.

## Programmatically Modifying An Embedded Microsoft Word Document

With the following steps, you can programmatically modify an embedded Microsoft Word object within a HiQ Notebook.

**Note** ***You need Microsoft Word 97 or greater installed on your computer to complete this example.***

1. In a new HiQ Notebook, select **Insert Object** from the **Edit** menu.
2. Choose Microsoft Word Document from the **Object Type** list, and click on **OK** to embed the Microsoft Word Document in your HiQ Notebook. The default name of the new embedded Word object is `ActiveXObject_1`.
3. Type text into the embedded Word object, and then click outside the new embedded Word object on the Notebook page to terminate editing.
4. Right click on the embedded Word object, select **Rename**, and rename `ActiveXObject_1` to `myWordDoc`.
5. Right click on the embedded Word object and select **Browse** to browse all the properties and methods for this embedded object in the HiQ ActiveX Object Browser. Notice that the **Document** interface is highlighted in the left window of the ActiveX Object Browser, indicating that the embedded object is a Microsoft Word Document interface.

**Note** ***To browse the methods and properties available for embedded objects, use the procedures described in*** *Communicating with ActiveX Servers, Objects, and Controls* ***earlier in this chapter.***

6. Click on the Application property in the right window of the ActiveX Object Browser.

   This property returns an Application interface to the Microsoft Word application. You can learn more about the Application interface by selecting it and then clicking on the **Help** button in the ActiveX Object Browser.
7. Click on the Application interface in the left window of the ActiveX Object Browser to view the properties and methods associated with the Application interface. Scroll through the right window of the ActiveX Object Browser to view the properties and methods available for the Application interface. Select the Selection property and click on the **Help** button. Notice that this property returns a Selection object.

8. Click on the Selection interface in the left window of the ActiveX Object Browser to view the properties and methods available for a Selection object. Scroll through the right window of the ActiveX Object Browser to view the properties and methods available for the Selection object. Select the Text property and click on the **Help** button. Notice that this property can be used to set the text within the embedded ActiveX object.

After browsing the embedded Word object, you have determined which methods and properties you need to access to modify the text.

9. From the HiQ Command Window, enter the following HiQ-Script code to programmatically add text to the embedded Word object and press <Enter>.

```
myWordDoc.application.selection.text=“Hello Word”;
```

You have programmatically modified the embedded Word object from the HiQ environment. You can change an embedded object using any of the available properties and methods for that object as shown in the HiQ ActiveX Object Browser. In this case, most tasks you can do in Microsoft Word, you also can control programmatically from within the HiQ environment.

## Embedding HiQ Notebooks in Other Applications

You can embed a HiQ Notebook in any application that is an ActiveX document container, which is especially useful when you want to include a HiQ Notebook as part of a document you are creating in another application. The embedded HiQ Notebook is editable within the environment of the container application and can be stored in the container application.

Use the following procedure to embed a HiQ Notebook in another application.

**Note** ***The application you are using must be an ActiveX container.***

1. Select **Insert Object** in the container application. The exact command name and location varies from application to application. For example, in Microsoft Word, select **Object...** from the **Insert** menu.

   In the Object dialog box, a list box displays all of the currently registered ActiveX object servers on your machine.

2. To embed a new HiQ Notebook, select HiQ Notebook from the list of currently registered ActiveX object servers. When you select **Create**

**New**, the new Notebook is stored within the container application's document.

**Note** ***HiQ does not support the*** **Create from File** ***option when embedding a HiQ Notebook into another application.***

3. Edit the embedded HiQ Notebook. You can edit the Notebook at any time by double clicking on it in the container application. Notice that the embedded HiQ Notebook comes up in HiQ for you to edit.
4. When you finish editing the embedded HiQ Notebook, select **Close and Return...** from the HiQ **File** menu. The changes to your HiQ Notebook are automatically saved to the container application file.

## Controlling Other Applications from HiQ

As an ActiveX automation client, HiQ allows you to run and control other applications from within the HiQ environment. Using this technology, you can create a HiQ Notebook that automatically launches another application such as Microsoft Word, Microsoft Excel, or MATLAB. You can control that application and share data to add automated analysis to your existing applications.

This capability is available in HiQ via a new built-in function designed specifically for supporting ActiveX client capability: `CreateInterface`.

### Launching and Controlling Microsoft Excel from HiQ

The following HiQ-Script code launches Microsoft Excel, creates a new Excel Worksheet, sets a range of cells, reads the numeric values of the selected cells into a HiQ matrix, and finally graphs the data in a HiQ 3D graph:

```
excel = CreateInterface(“Excel.Application”);
excel.workbooks.add;
sheet = excel.activesheet;
sheet.range(“a1:c3”) = createMatrix(3,3,<random>);
m = sheet.range(“a1:c3”).value;
g = createGraph(m);
createView(g);
```

You can use the HiQ ActiveX Object Browser to view the Excel properties and methods used in this example.

For more information about using these new functions to control other applications from HiQ, see *createInterface* in Chapter 7, *Function Reference*.

## Controlling HiQ from Other Applications

As an ActiveX automation server, HiQ allows you to run and control a HiQ Notebook from any application that is an ActiveX automation client. The HiQ ActiveX automation interface enables applications such as Excel, Word, Visual Basic, LabWindows/CVI, and LabVIEW to control HiQ for advanced data visualization, analysis, and report generation. This interface exposes a collection of class objects—the Application object and the Notebook object—that contain methods and properties you can use to directly manipulate HiQ.

The Application object represents an instance of HiQ, which you can use to load notebooks and control various HiQ properties. Use the Notebook object to set and get data; run scripts; and print, save, and close notebooks.

If you are using ActiveX-enabled scripting environments such as Excel and Visual Basic, use the `HiQ.olb` type library file in the HiQ `Programs` folder to browse the HiQ automation interface.

If you are using LabVIEW, use the VI library `HiQ.llb`, which is installed in the `vi.lib` folder, to control HiQ. You can access the VI library from the Communications functions palette. Refer to the LabVIEW documentation and online reference for complete information about using these VIs. You also can find a collection of example VIs in the `LabVIEW Examples\Comm\HiQ` folder.

The descriptions of the following methods and properties include examples of accessing them using Visual Basic for Applications (VBA).

### Application Object

The Application object represents a currently executing instance of HiQ.

Use the Visual Basic function `CreateObject` to launch HiQ and return an instance of an Application object. If HiQ is already running, use the Visual Basic function `GetObject` to return an instance of an Application object. The class name for the HiQ Application object is `HiQ.Application`.

For example, the following Visual Basic code launches HiQ and makes it visible.

```
Dim HiQApp as Object
Set HiQApp = CreateObject("HiQ.Application")
HiQApp.Visible = true
```

## Application Object Properties

### CurrentDirectory

Gets or sets the current directory for HiQ.

```
Application.CurrentDirectory As String
```

The following Visual Basic code launches HiQ, sets the current directory to `c:\Temp`, and loads a Notebook from that directory.

```
Dim HiQApp as Object
Dim Notebook as Object
Set HiQApp = CreateObject("HiQ.Application")
HiQApp.CurrentDirectory = "c:\Temp"
Set Notebook = HiQApp.open("Automation.HiQ")
```

### Visible

Shows or hides HiQ.

```
Application.Visible As Boolean
```

For example, the following Visual Basic code launches HiQ and makes it visible.

```
Dim HiQApp as Object
Set HiQApp = CreateObject("HiQ.Application")
HiQApp.Visible = true
```

## Application Object Methods

### Exit

Exits the HiQ application.

```
Application.Exit()
```

For example, the following Visual Basic code launches HiQ, loads and prints the `Automation.HiQ` Notebook, and exits HiQ.

```
Dim HiQApp as Object
Dim Notebook as Object
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.PrintOut
HiQApp.Exit
```

### Open

Opens a HiQ Notebook and returns an object representing the notebook.

```
Set oNotebook = Application.Open(NotebookName As String)
                As Notebook
```

`NotebookName` is the name of the notebook to open. `oNotebook` is the returned notebook object representing the open notebook.

For example, the following Visual Basic code launches HiQ and loads and prints the `Automation.HiQ` Notebook.

```
Dim HiQApp as Object
Dim Notebook as Object
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.PrintOut
```

## Notebook Object

The Notebook object represents an instance of an open HiQ Notebook.

Use the `Open` method of the Application object to open a HiQ Notebook and return an instance of this Notebook object.

For example, the following Visual Basic code launches HiQ and loads and prints the `Automation.HiQ` Notebook.

```
Dim HiQApp as Object
Dim Notebook as Object
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.PrintOut
```

## Notebook Object Properties

### LastError

Gets the most recent HiQ ActiveX Automation error. This property is read only. Table 1-1, *Automation Errors*, lists the HiQ automation errors.

```
Notebook.LastError As Long
```

For example, the following Visual Basic code launches HiQ, loads the `Automation.HiQ` Notebook, and checks for an error.

```
Dim HiQApp as Object
Dim Notebook as Object
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
If Notebook.LastError <> HiQSuccess then
   Msgbox "Error: " & Notebook.LastError
End If
```

## Notebook Object Methods

### Close

Closes a HiQ Notebook. Once closed, the Notebook object is no longer valid.

```
Status = Notebook.Close() As Long
```

`Status` is the result of the operation. If `Status` is not equal to zero, an error occurred. Refer to Table 1-1, *Automation Errors*, later in this chapter for a list of HiQ automation errors.

For example, the following Visual Basic code launches HiQ, loads and prints the `Automation.HiQ` Notebook, closes the Notebook, and exits HiQ.

```
Dim HiQApp as Object
Dim Notebook as Object
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.PrintOut
Notebook.Close
HiQApp.Exit
```

## GetData

Gets an object's data value.

```
Value = Notebook.GetData(ObjectName As String) as Variant
```

`ObjectName` is the name of the HiQ object to query, and `Value` is the current value of the object.

Use the `LastError` property to determine the status of this operation. If `ObjectName` is a complex scalar object, `Value` is returned as a two-element 1D array with `Value(0)` containing the real part and `Value(1)` containing the imaginary part of the complex number. If `ObjectName` is a complex vector object, `Value` is returned as a two-column 2D array with the first column containing the real part and the second column containing the imaginary part of the complex vector. If `ObjectName` is a complex matrix object, `Value` is returned as a 2D array with twice the number of columns as the matrix object. The even numbered columns (0, 2, 4, ...) contain the real parts, and the odd numbered columns (1, 3, 5, ...) contain the imaginary parts of the complex matrix.

For example, the following Visual Basic code launches HiQ, loads the `Automation.HiQ` Notebook, and gets the value of the matrix object `Answer`.

```
Dim HiQApp as Object
Dim Notebook as Object
Dim Answer as Variant
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Answer = Notebook.GetData("Answer")
```

## PrintOut

Prints a HiQ Notebook.

```
Status = Notebook.PrintOut(DisplaySetupDialog As Boolean
= False, DisplayCancelDialog As Boolean = True) As Long
```

`DisplaySetupDialog` specifies whether the print setup dialog is displayed. `DisplayCancelDialog` specifies whether the print cancel dialog is displayed. `Status` is the result of the operation. If `Status` is not equal to zero, an error occurred. Refer to Table 1-1, *Automation Errors*, later in this chapter for a list of HiQ automation errors.

For example, the following Visual Basic code launches HiQ and loads and prints the `Automation.HiQ` Notebook.

```
Dim HiQApp as Object
Dim Notebook as Object
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.PrintOut
```

## RunScript

Runs a script.

```
Status = Notebook.RunScript(ScriptName As String)
         As Long
```

`ScriptName` is the name of the script to execute, and `Status` is the result of the operation. If `Status` is not equal to zero, an error occurred. Refer to Table 1-1, *Automation Errors*, later in this chapter for a list of HiQ automation errors.

For example, the following Visual Basic code launches HiQ, loads the `Automation.HiQ` Notebook, sets the value of two vector objects, sets the value of the script object `newScript`, runs the script, and saves the notebook.

```
Dim HiQApp as Object
Dim Notebook as Object
Dim x(10) as Double
Dim y(10) as Double
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.SetData("x", x)
Notebook.SetData("y", y)
Notebook.SetScript("newScript",
                   "addPlot(myGraph,x,y);")
Notebook.RunScript("newScript")
Notebook.Save
```

## Save

Saves a HiQ Notebook. If `NotebookPath` is omitted, the Notebook is saved with the same name.

```
Status = Notebook.Save(NotebookPath As String = "")
         As Long
```

`NotebookPath` is the complete path name of the Notebook file to save. `Status` is the result of the operation. If `Status` is not equal to zero, an error occurred. Refer to Table 1-1, *Automation Errors*, later in this chapter for a list of HiQ automation errors.

For example, the following Visual Basic code launches HiQ, loads the `Automation.HiQ` Notebook, sets the value of a Matrix object, and saves the notebook twice.

```
Dim HiQApp as Object
Dim Notebook as Object
Dim data(10,10) as Double
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.SetData("newMatrix", data)
Notebook.Save    'Save the Notebook in the same file.
Notebook.Save("Newfile.HiQ")  'Save to a new file.
```

## SetComplexData

Sets a complex object's data value.

```
Status = Notebook.SetComplexData(ObjectName As String,
RealValue as Variant, ImaginaryValue as Variant) As Long
```

`ObjectName` is the name of the HiQ object to modify. `RealValue` contains the real values of the resulting complex object. `ImaginaryValue` contains the imaginary values of the resulting complex object.

`Status` is the result of the operation. If `Status` is not equal to zero, an error occurred. Refer to Table 1-1, *Automation Errors*, later in this chapter for a list of HiQ automation errors.

If the specified object exists in HiQ but has a different data type, the object is converted to complex. If the specified HiQ object does not currently exist in the notebook, it is created based on the data type of `Value` according to the following table.

| Visual Basic Data Type | HiQ Data Type |
|---|---|
| Double | Complex Scalar |
| Double 1D Array | Complex Vector |
| Double 2D Array | Complex Matrix |

For example, the following Visual Basic code launches HiQ, loads the `Automation.HiQ` Notebook, sets the value of the complex vector object `newVector`, and saves the notebook.

```
Dim HiQApp as Object
Dim Notebook as Object
Dim realData(10) as Double
Dim imagData(10) as Double
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.SetComplexData("newMatrix", realData, imagData)
Notebook.Save
```

## Set Data

Sets an object's data value.

```
Status = Notebook.SetData(ObjectName As String,
                          Value As Variant) As Long
```

`ObjectName` is the name of the HiQ object to modify, `Value` is the new value of the HiQ object, and `Status` is the result of the operation. If `Status` is not equal to zero, an error occurred. Refer to Table 1-1, *Automation Errors*, later in this chapter for a list of HiQ automation errors.

If the specified object exists in HiQ but has a different data type, the object is converted to the data type of `Value`. If the specified HiQ object does not currently exist in the notebook, it is created based on the data type of `Value` according to the following table.

| Visual Basic Data Type | HiQ Data Type |
|---|---|
| Long | Integer Scalar |
| Long 1D Array | Integer Vector |
| Long 2D Array | Integer Matrix |
| Double | Real Scalar |
| Double 1D Array | Real Vector |
| Double 2D Array | Real Matrix |
| String | Text |

For example, the following Visual Basic code launches HiQ, loads the `Automation.HiQ` Notebook, sets the value of the real matrix object `newMatrix`, and saves the notebook.

```
Dim HiQApp as Object
Dim Notebook as Object
Dim Data(10,10) as Double
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.SetData("newMatrix", Data)
Notebook.Save
```

## SetScript

Sets the text of a script. If the Script object does not exist, this method creates a new object.

```
Status = Notebook.SetScript(ScriptName As String,
         ScriptText As String) As Long
```

`ScriptName` is the name of the script object to modify, `ScriptText` is the text used to modify the script object, and `Status` is the result of the operation. If `Status` is not equal to zero, an error occurred. Refer to *Automation Errors* later in this chapter for more information.

For example, the following Visual Basic code launches HiQ, loads the `Automation.HiQ` Notebook, sets the value of two vector objects, sets the value of the script object `newScript`, runs the script, and saves the notebook.

```
Dim HiQApp as Object
Dim Notebook as Object
Dim x(10) as Double
Dim y(10) as Double
Set HiQApp = CreateObject("HiQ.Application")
Set Notebook = HiQApp.Open("Automation.HiQ")
Notebook.SetData("x", x)
Notebook.SetData("y", y)
Notebook.SetScript("newScript", "addPlot(myGraph,x,y);")
Notebook.RunScript("newScript")
Notebook.Save
```

## Automation Errors

The following errors can be generated by the HiQ ActiveX automation methods.

**Table 1-1.** Automation Errors

| Error Code | Description |
|---|---|
| `HiQSuccess` | Successful operation. (No Error) |
| `HiQObjectLocked` | Attempt to modify a HiQ object that is currently in use. |
| `HiQObjectNonexistant` | Specified object does not exist in the HiQ Notebook. |
| `HiQDataTypeLocked` | Specified HiQ object has its data type locked and cannot be modified. |
| `HiQDataTypeMismatch` | Data type of the specified HiQ object does not match the requested data type. |
| `HiQOperationUnsupported` | Specified HiQ object does not support the requested operation. For example, you cannot set the value of a HiQ Graph object or run a Matrix object. |
| `HiQScriptCompileError` | Compile error was encountered while trying to run a script. |
| `HiQScriptRuntimeError` | Runtime error was encountered while trying to run a script. |
| `HiQArrayEmpty` | Attempt to pass an empty array to HiQ. |
| `HiQOutOfMemory` | Insufficient memory for requested operation. Try closing open applications to create more memory. |
| `HiQUnspecifiedException` | Unspecified OLE or HiQ error occurred. |
| `HiQInternalError` | Internal error has been detected. Please contact National Instruments. |
| `HiQSaveError` | Error occurred (such as out of disk space) while saving a notebook. |
| `HiQPrintError` | Error occurred during printing or the print job was canceled by the user. |
| `HiQDataTypeUnsupported` | Data type of a value passed to `SetData` or `SetComplexData` is not supported. |

**Table 1-1.** Automation Errors (Continued)

| Error Code | Description |
|---|---|
| `HiQArrayDimension Mismatch` | Real and imaginary array values passed to `SetComplexData` have different dimensions. |
| `HiQInvalidObjectName` | Specified object name is not a valid HiQ object name. |

## Using ActiveX Controls in HiQ

You can embed ActiveX controls directly in your HiQ Notebook. You can access these embedded controls both interactively and programmatically from the HiQ environment. Use the following procedure to insert an ActiveX control in a HiQ Notebook.

1. Select **Insert Control** from the **Edit** menu. The Insert Control dialog box lists all of the available ActiveX controls currently installed on your computer.
2. For this example, select the ActiveMovie Control Object and click on **OK**. The ActiveMovie control object becomes embedded in the HiQ Notebook.
3. Resize the control to make it larger on your Notebook page so you can see the entire movie when it runs.
4. Right click on the embedded control and select **Browse** to browse the list of available properties and methods for this control.
5. Click on the ActiveMovie interface in the left window, then click on the FileName property in the right window. Notice that a description for this property appears at the bottom of the ActiveX Object Browser, telling us that the FileName property is a text property.
6. Now select the Run method in the right window of the ActiveX Object Browser. Notice that this method is a function you can call for an ActiveMovie interface and that it takes no parameters.
7. To programmatically control this ActiveX control from HiQ, type the following HiQ-Script in the Command Window to load a movie into this control and run it.

```
ActiveXControl_1.FileName =
  "C:\Program Files\National Instruments\HiQ
     \Examples\Data\Sample.mpg";
ActiveXControl_1.Run;
```

You also can operate this control interactively from the HiQ Notebook page. To run the movie interactively, click on the run button within the control.

# 2 HiQ Command Window

This chapter explains how you can customize the HiQ Command Window, take advantage of Command Window shortcuts, and navigate the Command Window using custom commands for both HiQ and MATLAB modes. This chapter concludes with a description of the HiQ Log Window.

For more information about navigating the Command Window, getting help from the Command Window, creating and modifying notebooks from the Command Window, and getting immediate results using the Command Window, see Chapter 3, *Getting Results with the Command Window*, in *Getting Results with HiQ*.

## Customizing the Command Window

You can customize the Command Window to fit your needs. Right click in the Command Window to change most of these options.

### Attached/Detached Mode

When you enter a command that creates an object, that object is always placed in the Object List of the active notebook. To perform operations without adding objects to the Object List of the current notebook, use the detached mode. Detached mode places all new objects created from the Command Window in its own Object List and makes accessible all current objects in the Command Window Object List. You can find objects created in detached mode in the Notebook Explorer, under the Command Window entry.

To enter detached mode, type `detach` in the Command Window, or select **Detach** from the right-click popup menu. To attach the Command Window to the current notebook, type `attach` in the Command Window, or select **Attach** from the right-click popup menu.

## Terse/Verbose Mode

When you execute a command that changes the value of an object, the Command Window displays the new value to you while in verbose mode. In terse mode, the Command Window does not display results on the command line.

To enter terse mode, type `terse` in the Command Window, or right click on the Command Window and select **Terse** from the popup menu. To exit terse mode, type `verbose` on the command line, or select **Verbose** from the right-click popup menu.

In verbose mode, a semicolon at the end of a command optionally suppresses the results for that command only. You can turn off this option in the property page.

## Syntax Highlighting and Font Options

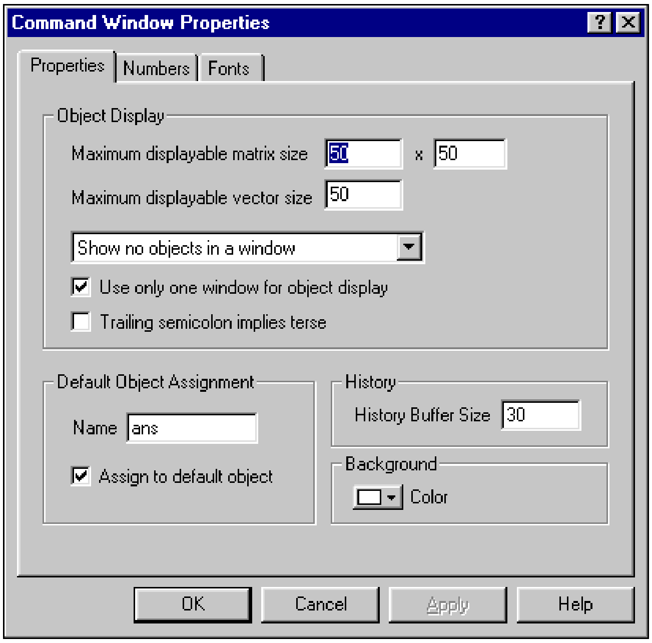
Like Script objects, the command window performs syntax highlighting. You can select your syntax highlighting font options from the Command Window property pages (right click in the Command Window, select **Properties...** from the popup menu, and click on the **Fonts** tab).

## Object Views

With the Command Window, you can view the result of an expression without having a view of the object on the notebook page. The Command Window automatically displays the result of any object that you change from the Command Window (if the Command Window is not in terse mode). However, some objects do not have a text version or have an extremely large text version, such as a very large matrix. To accommodate these situations, the Command Window offers three options for viewing objects.

- Show large or graphical objects in a window—A popup window is created and a new view of the object is placed in the window. The Command Window continues to display other objects in the Command Window.
- Show all objects in a window—If you prefer having popup windows display the new value of all objects, you can display all objects in individual windows.
- Show no objects in a window—(Default) If the Command Window cannot show the changed object on the command line, it does not show you the object at all.

Figure 2-1, *Command Window Properties*, shows other properties that you can customize, including the largest matrix and vector you want displayed in the Command Window and formatting options for displaying numeric objects.



Object Display

Maximum displayable matrix size 50 x 50

Maximum displayable vector size 50

Show no objects in a window

☑ Use only one window for object display

☐ Trailing semicolon implies terse

Default Object Assignment

Name ans

☑ Assign to default object

History

History Buffer Size 30

Background

Color

**Figure 2-1.** Command Window Properties

## History

The Command Window remembers the most recently executed commands and stores them in a history list. You can specify the length of the history list from the Command Window property page in the History Buffer Size field (see Figure 2-1).

### Recalling Commands from an Empty Command Line

When the current command line is empty, press the up arrow key to recall the last command you executed. You can modify the command, if needed, and execute it again. You can recall previous commands by continuing to press the up arrow key. Press the down arrow key to cycle through the commands in reverse order. If the current command has multiple lines, use the arrow keys to move between the lines of the command. If you are at the first line of a multiple command, the up arrow key recalls the previous command. If you are at the last line of the current command, the down arrow key recalls the next command. To move to another command when not on the first or last line of a multiple command, hold down the <Ctrl> key while using the arrow keys.

### Recalling Commands with a Match String

If you type in text before pressing an arrow key, the text is used as a match string. Only commands beginning with the text are shown. For example, if you type `x =` and then press the up arrow key, you see only commands that start with `x =`. HiQ preserves the command history for successive invocations of HiQ.

### HiQ/MATLAB Mode

When you first launch HiQ, the Command Window opens in the HiQ mode. If you have MATLAB 5.0 or greater installed on your computer, HiQ can communicate with MATLAB and you can transfer data between the two when you enter MATLAB mode. To enter MATLAB mode, type `matlab` at the prompt. To return to HiQ mode, type `hiq` at the prompt.

While in MATLAB mode, you can execute any valid MATLAB command. You also can use the four HiQ data transfer commands: `get`, `put`, `getAll`, and `putAll`. For a complete description of these commands, see *MATLAB Mode Commands* later in this chapter. For more information about using MATLAB from the HiQ Command Window, see Chapter 9, *Getting Results as a MATLAB User,* in *Getting Results with HiQ*.

## Command Window Shortcuts

Because it is designed to give you quick results, the Command Window offers several built-in shortcuts, such as the optional trailing semicolon, default variable assignment, and multiple statements and block statement support.

### Optional Trailing Semicolon

Although HiQ-Script statements require trailing semicolons in the script editor, you can omit the trailing semicolon of the last statement in the Command Window. Rather than typing

```
x = 4;
```

you can type

```
x = 4
```

When the Command Window is in verbose mode, the trailing semicolon optionally suppresses results if you select the **Trailing semicolon implies terse** option from the Command Window property page.

### Default Object Assignment

With default object assignment, the Command Window assigns the result of an expression you type to the default object. If you type `sin(1)`, the Command Window returns `ans = 0.841471`.

Because the Command Window recognizes when you enter an expression and not a complete assignment statement, it assigns the result of the expression to the default object. In this case, the object `ans` is given the result of the expression. You can change the name of the default object or disable this feature from the Command Window property page.

### Multiple Statements and Block Statement Support

The Command Window supports multiple statements and block statements. In the following example, the Command Window executes both statements and displays the new `x` and `y` values.

```
x = 4; y = sin(x);
```

You also can enter block statements, such as For and While loops, similar to the following block of code.

```
for x = 1 to 20 do
      v[x] = sin(x);
end for;
```

The Command Window does not execute the first line because it is an incomplete statement. Instead, it waits until you type `end for;`, thus completing the for statement, to execute the command.

## Terminating Commands

The Command Window displays a spinning cursor to indicate that a command is still executing. Most commands execute so quickly that HiQ does not display this cursor.

If you want to terminate a command while it is executing, press the <Esc> or <Ctrl-Break> keys or select **Terminate** from the right-click popup menu.

## Command Window Commands

The Command Window evaluates any valid HiQ-Script statement or expression and special Command Window commands. Table 2-1 lists the Command Window commands. You can type an object name at the command line to display its value. For more information about HiQ-Script syntax, refer to Chapter 6, *HiQ-Script Reference*.

**Note** ***If a Command Window command and an object share the same name and you type the name at the command line, the object is displayed, and the command does not execute. To execute the command in this situation, prefix the command with the pound sign (#). For example, type*** `#clear`***, instead of*** `clear`**.**

**Table 2-1.** Command Window Commands

| Command | Explanation |
|---|---|
| `clear` | Clears the contents of the Command Window. |
| `clearHistory` | Clears the contents of the history. |
| `quit` | Quits HiQ, which is the same as selecting **Exit** from the **File** menu. |
| `help` *`keyword`* | Displays the online help topic for the word you specify. |
| `delete` *`object_name`* | Removes *`object_name`* from the Object List. |
| `openNotebook` *`name`* | Opens the HiQ Notebook *`name`*. |
| `whatChanged` | Lists all objects that changed as a result of executing the previous command. |
| `objects` | Lists the names of all objects in the Object List. |
| `place` *`object_name`* | Places a view of *`object_name`* on the active page of the current notebook. |

**Table 2-1.** Command Window Commands (Continued)

| Command | Explanation |
|---|---|
| `terse` | Enters terse mode. Results are not echoed on the Command Window. |
| `verbose` | Exits terse mode. Results are echoed on the Command Window. |
| `detach` | Enters detached mode. Results are not placed or saved in any Notebook. |
| `attach` | Attaches the Command Window to the currently active Notebook. Subsequent objects created using the Command Window are placed in the Object List. |
| `whatis` *`object_name`* | Displays type information about *`object_name`*. |
| `cd` *`path`* | Changes the current directory to *`path`*. *`path`* can be a relative pathname or an absolute path name. *`path`* also can specify a network computer and share name. If you do not specify *`path`*, the current directory is displayed. |
| `pwd` | Displays the current directory. |
| `dir` | Lists the names of the files in the current directory. |
| `ls` | Lists the names of the files in the current directory. |
| `run` *`file_name`* | Runs the HiQ-Script contained in *`file_name`*. You can omit the `.hqs` extension. |
| `view` *`object_name`* | Places a view of *`object_name`* in an individual window. |
| `browse` *`object_name`* | Displays the ActiveX information for *`object_name`* in the ActiveX Object Browser. *`object_name`* must be an ActiveX object. |
| `matlab` | Enters MATLAB mode. |

## MATLAB Mode Commands

If you have MATLAB 5.0 or greater installed on you computer, you can enter MATLAB mode by typing `Matlab` in the Command Window. The Command Window enters MATLAB mode and displays the » prompt. While you are in MATLAB mode, you can invoke any MATLAB file command and call any MATLAB file you have. Results are displayed in the Command Window in the familiar MATLAB manner. Table 2-2 lists the additional commands available in MATLAB mode that you can use to exchange data between HiQ and MATLAB.

**Table 2-2.** MATLAB Mode Commands

| Column Head Needed | Column Head Needed |
|---|---|
| `get` *`MATLABname HiQname`* | Gets the MATLAB object *`MATLABname`*, names it *`HiQname`*, and places it in the current Object List. If *`HiQname`* is omitted, *`MATLABname`* is used for the *`HiQname`*. |
| `getAll` | Gets all MATLAB objects and places them in the current Object List. |
| `put` *`HiQname MATLABname`* | Sends the object *`HiQname`* to MATLAB and names it *`MATLABname`*. If *`MATLABname`* is omitted, the object is named *`HiQname`*. |
| `putAll` | Sends all objects in the current Object List to MATLAB. |

To return to HiQ mode, type `hiq` in the Command Window. Although this command returns you to HiQ mode, the MATLAB session is not terminated. Type `matlab` to return to the same session. Type `quit` to quit the MATLAB session and return to HiQ mode.

## HiQ Log Window

Use the Log Window to post status messages from HiQ-Script. You can access the Log Window through three built-in functions: `clearLog`, `logMessage`, and `saveLog`. `clearLog` clears the Log Window. `logMessage` adds a message to the Log Window. `saveLog` saves the contents of the Log Window to a file. Right click on the Log Window to display the popup menu of operations you can perform interactively to the Log Window.

For more information about these built-in functions, see Chapter 7, *Function Reference*.

3

# Using HiQ Graphics

This chapter provides information about using 2D and 3D graphics in HiQ and procedures for working with graphs interactively and programmatically.

You can further explore graphics capabilities in the following sources:

- Chapter 5, *Visualizing Data with 2D and 3D Graphs*, in *Getting Results with HiQ*
- Chapter 4, *HiQ Objects and Object Properties*, in this manual
- Online and Context help
- HiQ Example Notebooks, which you can find in the `\Examples\Data Visualization` folder.

## Two-Dimensional Graphs

### Two-Dimensional Graph Features

Two-dimensional graphs support the following features:

- Multiple Plot Style
  - Point
  - Line
  - Line-point
  - Bar
- Multiple Plots
- Multiple Y Axes
- Auto Scaling
- Configurable Axes
- Legends
- Cartesian and Polar Coordinate Systems

## Creating a 2D Graph

To create a 2D graph interactively, use the following procedure:

1. Select the 2D graph tool from the Tools toolbar (or select **Notebook»Create»2D Graph**).
2. Click and drag a region on the Notebook page.

To create a 2D graph programmatically, use the `createGraph` function:

```
graph = CreateGraph(<Graph2D>);
```

where <`Graph2D`> is a HiQ constant that specifies a 2D graph, and `graph` is the new Graph object.

After creating a graph, you can perform the following tasks, either interactively or programmatically:

- Add one or more plots to the graph
- Set and get graph and plot properties
- Change the data associated with a specific plot
- Remove plots from the graph

## Adding a Plot to an Existing 2D Graph

To add a plot to an existing 2D graph interactively, use the following procedure:

1. Right click on the graph and select **New Plot** to display the New 2D Plot dialog box.
2. Specify the range and domain for the plot and select **OK**. You also can select the desired plot type and coordinate system.
3. Repeat steps 1 and 2 to add multiple plots to the graph.

To add a plot to an existing 2D graph programmatically, use the `addPlot` function. This function has a variety of usages for creating Y, X-Y, and function plots.

- To plot a vector of data against its indices

  ```
  plotID = addPlot(graph,y);
  ```

  where `graph` is the graph to modify, and `y` is the vector to plot. `plotID` contains a unique negative integer value that represents the plot. Use this ID to refer to the plot in subsequent operations.

- To plot one vector versus another

  ```
  plotID = addPlot(graph,x,y);
  ```

  where `x` is a vector of domain values, and `y` is a vector of range values.
- To plot a function over a domain of values

  ```
  plotID = addPlot(graph,x,yFct);
  ```

  where `x` is a vector of domain values, and `yFct` is a single-valued function. `yFct` can be a HiQ or user-defined function. For example, you can plot the sin function evaluated from 0 to π:

  ```
  //Generate a sequence from 0 to pi in steps of 0.1
  x = seq(0,<pi>,0.1);

  //Add the plot to 'myGraph'
  addPlot(myGraph,x,sin);
  ```
- To create a plot using a specific plot ID, use one of the following forms:

  ```
  addPlot(graph,plotID,y);
  addPlot(graph,plotID,x,y);
  addPlot(graph,plotID,x,yFct);
  ```

  where `plotID` is a positive integer value of your choice, unique to all other plot IDs in the graph.

## Creating 2D Plot Objects

With the `createPlot` function, you can create 2D plots as independent objects:

```
plot = createPlot(y);
plot = createPlot(x,y);
plot = createPlot(x,yFct);
```

where `plot` is the new plot object. The semantics of the `createPlot` forms are identical to those of the `addPlot` function.

To add a plot object to a graph, use the `addPlot` function:

```
addPlot(graph,plot);
```

where `graph` is the graph to modify, and `plot` is the plot object to add. When you add the plot, you create a link between the plot and the graph. You can add the same Plot object to multiple graphs. When the data or properties change, all graphs linked to the plot are updated to reflect the change.

**Note** ***Plot objects cannot be created interactively.***

## Changing the Data of a 2D Plot

After creating a plot, you can change the underlying data without affecting the properties of the plot.

To change the data of a plot interactively, use the following procedure.

1. Select the plot you want to change by clicking on it.
2. Right click to display the plot popup and select **Change**, which displays the Change 2D Plot dialog box.
3. Specify the new range and domain for the plot and select **OK**. If the plot was created interactively, the domain and range information reflects the original settings used to generate the plot. Otherwise, the domain and range fields are blank.

   The graph updates to reflect the new plot data.

To change the data of an embedded plot programmatically, use the `changePlotData` function with one of the following forms:

```
changePlotData(graph,plotID,y);
changePlotData(graph,plotID,x,y);
changePlotData(graph,plotID,x,yFct);
```

where `graph` is the graph to modify, and `plotID` is the ID of the plot to change. You also can use the `addPlot` function, in one of the following forms, to change the data of a plot:

```
addPlot(graph,plotID,y);
addPlot(graph,plotID,x,y);
addPlot(graph,plotID,x,yFct);
```

where `plotID` specifies the ID of the plot to change. If the specified ID does not match an existing plot, a new embedded plot is created and assigned the specified ID.

To change the data of a Plot object programmatically, use the `changePlotData` function in one of the following forms:

```
changePlotData(plot,y);
changePlotData(plot,x,y);
changePlotData(plot,x,yFct);
```

where `plot` is the Plot object to change.

## Creating a Graph and Plot Simultaneously

If you want to create a 2D graph with a plot in a single step, use the `createGraph` function in one of the following forms:

```
[graph, plotID] = createGraph(y);
[graph, plotID] = createGraph(x,y);
[graph, plotID] = createGraph(x,yFct);
```

where `graph` is the new Graph object, and `plotID` is the ID assigned to the new plot.

## Adding Multiple Y Axes to a 2D Graph

Two-dimensional graphs support up to eight Y axes, each with its own set of properties. You can associate individual plots with a particular Y axis. By default, all plots are associated with the primary Y axis. Because visibility of all secondary axes is set to automatic mode, a secondary axis becomes visible when you associate a plot with it.

Use the following procedure to interactively associate a plot with a different Y axis.

1. Select the plot.
2. Right click and select **Properties**.
3. Select the axis in the Associated Y Axis control on the **General** subpage and press **OK**.

To associate a plot with a different Y axis programmatically, set the `yAxis` property of the plot. Refer to *Setting Graph Properties* later in this chapter for information about the `yAxis` plot property.

# Three-Dimensional Graphs

## Three-Dimensional Graph Features

Three-dimensional graphs support the following features:

- Multiple Plot Styles
  - Point
  - Line
  - Line-Point
  - Hidden-Line
  - Contour
  - Surface
  - Surface-Line
  - Surface-Contour
  - Surface-Normal
- Multiple Plots
- Auto Scaling
- Configurable Axes
- Legends
- Cartesian, Cylindrical, and Spherical Coordinate Systems
- Color Maps
- Transparency
- Plane Projections
- Orthographic and Perspective Viewing
- Lighting
- Rotation, Zooming, and Panning

## Creating a 3D Graph

To create a 3D graph interactively, use the following procedure:

1. Select the 3D graph tool (or select **Notebook»Create»3D Graph**).
2. Click and drag a region on the Notebook page.

To create a 3D graph programmatically, use the `createGraph` function:

```
graph = CreateGraph(<Graph3D>);
```

where <`Graph3D`> is a HiQ constant that specifies a 3D graph, and `graph` is the new Graph object.

After creating a graph, you can perform the following tasks, either interactively or programmatically:

- Add one or more plots to the graph
- Set and get graph and plot properties
- Change the data associated with a specific plot
- Remove plots from the graph

## Adding a Plot to an Existing 3D Graph

To add a plot to an existing 3D graph interactively, use the following procedure.

1. Right click on the graph and select **New Plot** to display the New 3D Plot dialog box.
2. Specify the range and domain for the plot and select **OK**. You also can select the desired plot type and coordinate system.

To programmatically add a plot to an existing 3D graph, use the `addPlot` function. This function has a variety of usages for creating parametric curve plots, surface plots, and parametric surface plots.

- To create a simple surface plot

  ```
  plotID = addPlot(graph,Z);
  ```

  where `graph` is the graph to modify, and `Z` is the matrix of range values to plot. The indices of the matrix are used for the x and y domain values. `plotID` contains a unique negative integer value that represents the plot. Use this ID to refer to the plot in subsequent operations.
- To create a surface plot

  ```
  plotID = addPlot(graph,x,y,Z);
  ```

  where `x` and `y` are vectors of domain values, and `Z` is a matrix of range values.

- To create a surface plot of a function over a domain of values

  ```
  plotID = addPlot(graph,x,y,zFct);
  ```

  where `x` and `y` are vectors of domain values and `zFct` is a double-valued function. `zFct` can be a HiQ or user-defined function. For example, you can plot the pow function evaluated from 0 to π.

  ```
  //Generate a sequence from 0 to pi in steps of 0.1
  v = seq(0,<pi>,0.1);
  ```

  ```
  //Add the plot to the graph object named 'myGraph'
  addPlot(myGraph,v,v,pow);
  ```

- To create a parametric surface plot

  ```
  plotID = addPlot(graph,X,Y,Z);
  ```

  where `X`, `Y`, and `Z` are matrices.

- To create a parametric surface plot of a set of functions over a domain of values

  ```
  plotID = addPlot(graph,u,v,xFct,yFct,zFct);
  ```

  where `u` and `v` are vectors of domain values and `xFct`, `yFct`, and `zFct` are double-valued functions. Each function is evaluated over the u and v domains to produce a matrix. Then, this collection of matrices is plotted as a parametric surface.

- To create a parametric curve plot

  ```
  plotID = addPlot(graph,x,y,z);
  ```

  where `x`, `y`, and `z` are vectors representing the points of the curve.

- To create a parametric curve plot of a set of functions over a domain of values

  ```
  plotID = addPlot(graph,t,xFct,yFct,zFct);
  ```

  where `t` is a vector of domain values and `xFct`, `yFct`, and `zFct` are single-valued functions. Each function is evaluated over the `t` domain to produce a vector. Then, this collection of vectors is plotted as a parametric curve.

- To create a plot using a specific plot ID, use one of the following forms:

  ```
  addPlot(graph,plotID,Z);
  addPlot(graph,plotID,x,y,Z);
  addPlot(graph,plotID,x,y,zFct);
  addPlot(graph,plotID,X,Y,Z);
  addPlot(graph,plotID,u,v,xFct,yFct,zFct);
  addPlot(graph,plotID,x,y,z);
  addPlot(graph,plotID,t,xFct,yFct,zFct);
  ```

where `plotID` is a positive integer value of your choice, unique to all other plot IDs in the graph.

## Creating 3D Plot Objects

With the `createPlot` function, you also can create 3D plots as independent objects:

```
plot = createPlot(Z);
plot = createPlot(x,y,Z);
plot = createPlot(x,y,zFct);
plot = createPlot(X,Y,Z);
plot = createPlot(u,v,xFct,yFct,zFct);
plot = createPlot(x,y,z);
plot = createPlot(t,xFct,yFct,zFct);
```

where `plot` is the new Plot object. The semantics of the `createPlot` forms are identical to those of the `addPlot` function.

To add a Plot object to a graph, use the `addPlot` function:

```
addPlot(graph,plot);
```

where `graph` is the graph to modify, and `plot` is the Plot object to add. When you add the plot, you create a link between the plot and the graph. You can add the same Plot object to multiple graphs. When the data or properties change, all graphs linked to the plot are updated to reflect the change.

**Note** ***Plot objects cannot be created interactively.***

## Changing the Data of a 3D Plot

After creating a plot, you can change the underlying data without affecting the properties of the plot.

To change the data of a plot interactively, use the following procedure.

1. Select the plot you want to change.
2. Right click to display the plot popup and select **Change**, which displays the Change 3D Plot dialog box.
3. Specify the new range and domain for the plot and select **OK**. If the plot was created interactively, the domain and range information reflect the original settings used to generate the plot. Otherwise, the domain and range fields are blank.

   The graph updates to reflect the new plot data.

To programmatically change the data of an embedded plot, use the `changePlotData` function in one of the following forms:

```
changePlotData(graph,plotID,Z);
changePlotData(graph,plotID,x,y,Z);
changePlotData(graph,plotID,x,y,zFct);
changePlotData(graph,plotID,X,Y,Z);
changePlotData(graph,plotID,u,v,xFct,yFct,zFct);
changePlotData(graph,plotID,x,y,z);
changePlotData(graph,plotID,t,xFct,yFct,zFct);
```

where `graph` is the graph to modify, and `plotID` is the ID of the plot to change. You also can use the `addPlot` function, in one of the following forms, to change the data of a plot:

```
addPlot(graph,plotID,Z);
addPlot(graph,plotID,x,y,Z);
addPlot(graph,plotID,x,y,zFct);
addPlot(graph,plotID,X,Y,Z);
addPlot(graph,plotID,u,v,xFct,yFct,zFct);
addPlot(graph,plotID,x,y,z);
addPlot(graph,plotID,t,xFct,yFct,zFct);
```

where `plotID` specifies the ID of the plot to change. If the specified ID does not match an existing plot, a new embedded plot is created and assigned the specified ID.

To programmatically change the data of a plot object, use the `changePlotData` function in one of the following forms:

```
changePlotData(plot,Z);
changePlotData(plot,x,y,Z);
changePlotData(plot,x,y,zFct);
changePlotData(plot,X,Y,Z);
changePlotData(plot,u,v,xFct,yFct,zFct);
changePlotData(plot,x,y,z);
changePlotData(plot,t,xFct,yFct,zFct);
```

where `plot` is the plot object to change.

## Creating a Graph and Plot Simultaneously

Use the `createGraph` function, in one of the following forms, to create a 3D graph with a plot in a single step:

```
[graph,plotID] = createGraph(Z);
[graph,plotID] = createGraph(x,y,Z);
[graph,plotID] = createGraph(x,y,zFct);
[graph,plotID] = createGraph(X,Y,Z);
[graph,plotID] = createGraph(u,v,xFct,yFct,zFct);
[graph,plotID] = createGraph(x,y,z);
[graph,plotID] = createGraph(t,xFct,yFct,zFct);
```

where `graph` is the new Graph object, and `plotID` is the ID assigned to the new plot.

## Creating 4D Plots

Four-dimensional plots are three-dimensional surface or curve plots with additional information to control the color assignment for each point in the plot. Color is assigned based on the value of the color map style property for the plot. If the color map style is set to none, all points in the plot use the same color. If the color map style is set to shaded, spectrum, or grayscale, the color for each point is calculated by linearly scaling the point's magnitude onto a range of color values defined by the color map. The magnitude of the point is either its Z value or the corresponding element in the optional magnitude data supplied when the plot was created.

The `createGraph`, `createPlot`, `addPlot`, and `changePlotData` functions support an optional last parameter that defines the magnitude data for the plot. For example, you can create a 3D surface plot of sin(x) * cos(y) with a random matrix as the magnitude data:

```
//Create a sequence from 0 to pi in steps of 0.1
v = seq(0,<pi>,0.1);

//Create a function for sin(x) * cos(y)
fct = {func: x,y: "sin(x) * cos(y)"};

//Create a mesh of sin(x) * cos(y) over 0 to pi
Z = eval(fct,v,v,<mesh>);

//Create a mesh of random numbers over 0 to pi
w = eval(random,v,v,<mesh>);

//Create the plot with separate magnitude data
addPlot(graph,Z,w);
```

## Interacting with 3D Graphs

You can rotate, zoom, and pan a 3D graph using your mouse.

- To rotate a graph, press and hold the left mouse button while it is positioned over the graph, and move the mouse to rotate the graph.
- To zoom in or out on a graph, use the same procedure for rotating the graph while pressing the <Alt> key. When you move the mouse down, you zoom in, and when you move up, you zoom out. You also can use the mouse wheel to zoom the graph.
- To pan a graph, use the same procedure for rotating a graph while pressing the <Shift> key.

To terminate the operation, release the mouse button. To set the graph to its default viewing position, select **Default View** from the right popup.

By default, HiQ draws a reduced representation of the graph and its plots when rotating, zooming, or panning. You can force HiQ to draw the entire graph by deselecting the **Fast Draw for the Zoom/Pan/Rotate** option on the **3D** tab of the **Graph** property page.

## Using Lights

Use lights to enhance the appearance of a graph. You can use up to four lights at one time. Each light has a variety of properties such as color, position, and attenuation mode. In addition to setting individual lights, you can specify the ambient light color for the graph.

To configure the lighting interactively, use the **Lighting** tab on the **Graph** property page. Specify the position of a light as a longitude/latitude pair (in degrees) along with the distance from the center of the unit cube.

To configure the lighting programmatically, use the light properties for the graph. Refer to the section entitled *Light Properties* later in this chapter for a complete list of light properties.

## Using Accelerated OpenGL Graphics Adapters

If you have a graphics adapter that supports OpenGL hardware acceleration, you can enable the **Use 3D Hardware Acceleration** option in the **File»Preferences** dialog. Enabling this option forces HiQ to render 3D graphs directly to the display adapter, which maximizes rendering performance.

Disabling this option forces HiQ to render 3D graphs to an off-screen frame buffer, which is then copied to the screen. HiQ caches this frame buffer and updates it only when the graph needs to be rendered (such as adding a plot or changing the view position). For complex 3D graphs, the time to render the image into the frame buffer greatly exceeds the time to copy the frame buffer to the screen. As a result, simple screen updates that do not require the graph to re-render (such as scrolling the page) execute very quickly.

The following table summarizes the advantages and disadvantages of enabling and disabling this option.

**Table 3-1.** Advantages and Disadvantages of Using 3D Hardware Acceleration

| 3D Hardware Acceleration | Advantages | Disadvantages |
|---|---|---|
| Enabled | • Faster rendering<br>• Uses less memory | • Always renders the graph, even for simple screen updates |
| Disabled | • Fast redraw for simple screen updates | • Uses more memory<br>• Slower rendering |

**Note** ***Changing the*** **Use 3D Hardware Acceleration** ***option does not affect the behavior of existing graphs.***

## Common Graph Operations

This section contains common graph operations and properties that pertain to both 2D and 3D graphs, except where noted.

### Setting Graph Properties

Graphs contain many properties that control their appearance and behavior. You can set properties interactively through the **Graph** property page or programmatically using the property notation syntax in HiQ-Script.

**Note** ***For the following examples, assume that you have a Graph object*** `g` ***that contains a single embedded plot, which has an ID of 1.***

To programmatically set a graph property, use the following form:

```
graph.property = value;
```

where `graph` specifies the graph to modify, `property` is the name of the graph property to set, and `value` is the new property value. For example, you can set the title of a graph with the following syntax:

```
g.title = "My Graph";
```

Table 3-2 summarizes the graph properties.

**Table 3-2.** Graph Properties

| Property | | Data Type | Description |
|---|---|---|---|
| background. | border.color | HiQ Color | Defines the border color of the background area. |
| | border.style | HiQ Constant[a] | Defines the border style of the background area. |
| | color | HiQ Color | Defines the background color of the graph. |
| border. | color | HiQ Color | Defines the color of the graph border. |
| | style | HiQ Constant[a] | Defines the style of the graph border. |
| frame. | color | HiQ Color | Defines the color of the frame area. |
| | visible | Boolean | Displays the frame area of the graph when set to `true`. The frame area includes the area of the graph, which is filled with the frame color and the graph title. |
| legend. | backColor | HiQ Color | Defines the background color of the legend. |
| | border.color | HiQ Color | Defines the border color of the legend. |
| | border.style | HiQ Constant[a] | Defines the border style of the legend. |
| | font | HiQ Font | Defines the font of the legend. |
| | includeUntitled | Boolean | Defines which plots are included in the legend.<br>`true`—Shows all plots in the legend.<br>`false`—Shows only plots that have a title currently defined. |
| | textColor | HiQ Color | Defines the text color of the legend. |
| | visible | Boolean | Displays the legend when set to `true`. |
| title | | Text | Defines the title of the graph. |
| title. | color | HiQ Color | Defines the text color of the graph title. |
| | visible | Boolean | Displays the graph title when set to `true`. |
| type | | HiQ Constant[b] | Returns the type of the object. (Read Only) |

**Table 3-2.** Graph Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| **3D Properties (Valid for 3D Graphs)** | | | |
| dither | | Boolean | Defines the dither mode of the graph.<br><br>`true`—Dithering is enabled. Combinations of colors are used to approximate selected colors that cannot be directly displayed because of a limited number of display colors on the system.<br><br>`false`—Dithering is disabled.<br><br>Note: This property is valid on 256 color displays only. |
| fastDraw | | Boolean | Defines how the graph is drawn during interactive operations such as rotating, zooming, and panning.<br><br>`true`—Draws a reduced representation of the graph and its plots.<br><br>`false`—Draws the entire graph and its plots. Using this mode can create unresponsive interaction for complex graphs. |
| grid. | frameColor | HiQ Color | Defines the color of the grid frame. |
| | smoothing | Boolean | Defines the smoothing mode for grid lines.<br><br>`true`—Uses a technique called *anti-aliasing* to create smoother grid lines.<br><br>`false`—Draws grid lines without smoothing. |
| | xy | Boolean | Draws the X-Y grid plane when `true`. |
| | xz | Boolean | Draws the X-Z grid plane when `true`. |
| | yz | Boolean | Draws the Y-Z grid plane when `true`. |
| lighting. | ambientColor | HiQ Color | Defines the ambient light color for the graph when lighting is enabled. |
| | enable | Boolean | Enables graph lighting when `true`. |

**Table 3-2.** Graph Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| projectionStyle | | HiQ Constant | Defines the projection style of the graph. Valid values include<br>`<orthographic>`<br>`<perspective>` |
| smoothing | | Boolean | Defines the smoothing mode for drawing plots on the graph.<br>`true`—Uses a technique called *anti-aliasing* to create smoother lines and polygons when drawing plots.<br>`false`—Draws plots without smoothing. |
| view. | autoDistance | Boolean | Defines how the viewing distance is set.<br>`true`—Viewing distance is automatically calculated.<br>`false`—Viewing distance is defined by the `view.distance` property. |
| | distance | Real | Specifies the distance of the viewing position from the origin. |
| | latitude | Real | Defines the latitude of the viewing position when the `view.mode` property is `<viewUserDefined>`. |
| | longitude | Real | Defines the longitude of the viewing position when the `view.mode` property is `<viewUserDefined>`. |
| | mode | HiQ Constant | Defines the viewing position of the graph. Valid values include<br>`<viewXYPlane>`<br>`<viewxzPlane>`<br>`<viewyZPlane>`<br>`<viewUserDefined>` |

a. For a complete list of HiQ Constants for borders, see Table B-2, *Border Style Constants*, in Appendix B, *HiQ Constants*.

b. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Plot Properties

To set a property of an embedded plot, use the following syntax:

```
graph.Plot(plotID).property = value;
```

where `graph` specifies the graph to modify, `plotID` specifies the ID of the plot to modify, `property` is the name of the plot property to set, and `value` is the new property value to apply. `plotId` can be a scalar constant or scalar object.

To set a property for all plots in the graph, use the following form:

```
graph.Plots.property = value;
```

To set a property of a Plot object, use the following form:

```
plot.property = value;
```

where `plot` specifies the Plot object to modify, `property` is the name of the plot property to set, and `value` is the new property value to apply.

Table 3-3 summarizes the plot properties.

**Table 3-3.** Plot Properties

| Property | Data Type | Description |
|---|---|---|
| coordinateSystem | HiQ Constant | Defines the coordinate system of the plot. Valid values for 2D plots include<br>`<cartesian>`<br>`<polar>`<br><br>Valid values for 3D plots include<br>`<cartesian>`<br>`<cylindrical>`<br>`<spherical>` |
| fill.color | HiQ Color | Defines the fill color of the plot if you define the style as a filled plot. Filled plot styles include<br>`<verticalBar>`<br>`<horizontalBar>`<br>`<surface>`<br>`<surfaceLine>`<br>`<surfaceNormal>`<br>`<surfaceContour>` |

**Table 3-3.** Plot Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| line. | color | HiQ Color | Defines the line color of the plot. |
| | style | HiQ Constant | Defines the line style of the plot. Valid values include `<solidLine>` `<dotLine>` `<dashLine>` `<dotDashLine>`<br><br>If you set this property to anything other than `<solidLine>`, the line width is set to zero. |
| | width | Real | Defines the width of the line in points. If the value is greater than zero, the line style is set to `<solidLine>`. If you specify a zero line width, the line appears as narrow as possible while still remaining visible. (Valid Range: 0–100) |
| numGraphs | | Integer | Returns the number of graphs displaying the plot. (Read Only) |
| point. | color | HiQ Color | Defines the color of the points of the plot. |
| | frequency | Integer | Defines the frequency of points in the plot. For example, a frequency of one indicates that all points should be drawn. A frequency of two indicates that every other point should be drawn. This value must be greater than zero. |
| | size | Real | Defines the size of the plot points in points. (Valid range: 0–100) |

**Table 3-3.** Plot Properties (Continued)

| **Property** | | **Data Type** | **Description** |
|---|---|---|---|
| point. (*continued*) | style | HiQ Constant | Defines the style of the point. Valid values include<br>`<emptySquare>`<br>`<solidSquare>`<br>`<emptyCircle>`<br>`<solidCircle>`<br>`<diamond>`<br>`<asterisk>`<br>`<boldX>`<br>`<noPoint>`<br>The following values are valid for 3D plots:<br>`<wireframeSphere>`<br>`<solidSphere>`<br>`<wireframeCube>`<br>`<solidCube>` |
| style | | HiQ Constant | Defines the style of the plot. Valid values for 2D plots include<br>`<point>`<br>`<line>`<br>`<linePoint>`<br>`<verticalBar>`<br>`<horizontalBar>`<br>Valid values for 3D surface plots include<br>`<point>`<br>`<line>`<br>`<hiddenLine>`<br>`<contour>`<br>`<surface>`<br>`<surfaceLine>`<br>`<surfaceNormal>`<br>`<surfaceContour>`<br>Valid values for 3D curve plots include<br>`<point>`<br>`<line>` |
| title | | Text | Defines the plot title. This title appears in the legend and on the graph. |

**Table 3-3.** Plot Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| title. | color | HiQ Color | Defines the color of the title displayed on the graph, not in the legend. |
| | font | HiQ Font | Defines the font of the plot title displayed on the graph, not in the legend. |
| | visible | Boolean | Displays the title on the graph when `true`. |
| type | | HiQ Constant[a] | Returns the type of the object. (Read Only) This property is valid for Plot objects only. |
| visible | | Boolean | Displays the plot on its graphs when set to `true`. |
| **2D Properties (Valid for 2D Plots)** | | | |
| line.interpolation | | HiQ Constant | Specifies the interpolation style used to draw the line of the plot. Valid values include<br><`linear`>—Draws the plot point-to-point.<br><`cubicSpline`>—Draws the plot with bezier curves that pass through each point. |
| yAxis | | Integer | Defines the index of the y-axis with which the plot is associated. (Valid range: 1–8) |
| **3D Properties (Valid for 3D Plots)** | | | |
| cacheData | | Boolean | Improves drawing performance by caching intermediate calculations when set to `true`. However, you use more memory in the process. When `false`, the plot does not cache intermediate calculations, which reduces memory usage. |
| colorMap.style | | HiQ Constant | Defines the color map used by the plot. Valid values include<br><`none`><br><`shaded`><br><`grayscale`><br><`spectrum`> |

**Table 3-3.** Plot Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| contour. | anchor.enable | Boolean | Enables the contour anchor if `true`. The anchor defines a value that a contour is guaranteed to pass through. |
| | anchor.value | Real | Defines the value of the contour anchor. |
| | basis | HiQ Constant | Defines the basis of the plots contours. Valid values include<br><`magnitude`>—Contours based on the magnitude data, if specified. Otherwise, based on Z data.<br><`x`>—Contours based on X data.<br><`y`>—Contours based on Y data.<br><`z`>—Contours based on Z data. |
| | interval | Integer | Defines the distance between each level of the contour. When you set this value, the number of levels adjusts to accommodate the new interval. |
| | levelList | Real Vector | Defines the contour levels of the plot. Each element of the vector contains the position of a contour. |
| | levels | Integer | Defines the number of contour levels for the plot. |
| fill.style | | HiQ Constant | Defines the fill style of the plot. Valid values include<br><`smooth`><br><`flat`> |
| projection. | xy | Boolean | Draws the X-Y plane projection of the plot when `true`. |
| | xz | Boolean | Draws the X-Z plane projection of the plot when `true`. |
| | yz | Boolean | Draws the Y-Z plane projection of the plot when `true`. |

**Table 3-3.** Plot Properties (Continued)

| Property | Data Type | Description |
|---|---|---|
| showProjectionsOnly | Boolean | Defines the show projections only mode.<br>`true`—Draws all projections that are currently enabled but does not draw the plot.<br>`false`—Draws all projections that are currently enabled and draws the plot. |
| transparency | Integer | Indicates the percentage of transparency, where a value of 0 specifies opaque and 100 specifies completely transparent. |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Contour Properties

To set a property of a particular contour in a plot, use the following form:

```
graph.plot(plotID).contour(n).property = value;
```

where `graph` specifies the graph to modify, `plotID` specifies the ID of the plot to modify, `n` is the one-based index of the contour to modify, `property` is the name of the property to set, and `value` is the new property value to apply.

To set a property for all contours in a plot, use the following form:

```
graph.plot(plotID).contours.property = value;
```

Table 3-4 summarizes the contour properties.

**Table 3-4.** Contour Properties

| Property | | Data Type | Description |
|---|---|---|---|
| color | | HiQ Color | Defines the color of the contour line. |
| label | | Text | Labels the contour. If the text contains a `%value`, the value of the level is substituted for the `%value` tag. If the text contains a `%level`, the level number is substituted for the `%level` tag. |
| label. | color | HiQ Color | Defines the color of the contour label. |
| | decimalPlaces | Integer | Defines the number of decimal places used to format the contour label. |
| | font | HiQ Font | Defines the font of the contour label. |
| | format | HiQ Constant | Defines the contour label format. Valid values include `<decimal>` `<scientific>` `<engineering>` |
| | visible | Boolean | Draws the contour label when `true`. |
| level | | Real | Defines the position of the plot. |
| style | | HiQ Constant | Defines the line style of the contour line. Valid values include `<solidLine>` `<dotLine>` `<dashLine>` `<dotDashLine>` |
| width | | Real | Defines the width of the contour line in points. (Valid range: 0–100) |

Table 3-5 contains plot property examples.

**Table 3-5.** Examples: Setting Plot Properties

| HiQ-Script | Description |
|---|---|
| `g.plot(1).title = "Rainfall";` | Sets the title of the embedded plot with an ID of 1 to `Rainfall`. |
| `g.plot(voltagePlot).line.color = <blue>;` | Sets the line color of the embedded plot with an ID of `voltagePlot` to blue. |
| `myPlot.coordinateSystem = <polar>;` | Sets the coordinate system of the `myPlot` Plot object to polar. |
| `g.plots.style = <LinePoint>;` | Sets the style of all plots in the graph to line-point. |
| `g.plot(1).contour(2).label="Sea Level";` | Sets the label of the second contour level of the embedded plot with an ID of 1 to `Sea Level`. |
| `g.plot(1).contours.label.color = <red>;` | Sets the label color of all contours of the embedded plot with an ID of 1 to red. |

## Axis Properties

To set an axis property, use the following form:

```
graph.axis.axisType.property = value;
```

where `graph` specifies the graph to modify, `axisType` specifies the axis to modify, `property` is the name of the axis property to set, and `value` is the new property value to apply.

To set a property for all axes, use the following form:

```
graph.axes.property = value;
```

Table 3-6 summarizes the valid values for `axisType`.

**Table 3-6.** Valid Values for axisType

| axisType | Description |
|---|---|
| **2D Graphs** | |
| `x` | X axis only. |
| `y` | Primary Y axis only. |
| `xy` | X and primary Y axes. |
| `y(`*n*`)` | *n*th Y axis, where *n* is a scalar value ranging from 1 to 8. |
| `y(`*n*1,*n*2,*n*3,...`)` | Collection of Y axes described by the sequence of scalar values *n*1, *n*2, *n*3, ..., each ranging from 1 to 8. |
| `y(`*v*`)` | Collection of Y axes described by the vector *v*. |
| **3D Graphs** | |
| `x` | X axis only. |
| `y` | Y axis only. |
| `z` | Z axis only. |
| `xy` | X and Y axes. |
| `xz` | X and Z axes. |
| `yz` | Y and Z axes. |
| `xyz` | X, Y, and Z axes. |

Table 3-7 summarizes valid axis properties.

**Table 3-7.** Axis Properties

| Property | | Data Type | Description |
|---|---|---|---|
| label. | color | HiQ Color | Defines the color for the axis labels. |
| | decimalPlaces | Integer | Defines the number of decimal places to display for the axis labels. Valid values include <`auto`> and the range 0–15. |
| | font | HiQ Font | Defines the font for the axis labels. |
| | format | HiQ Constant | Defines the format of the labels. Valid values include <`decimal`> <`scientific`> <`engineering`> |
| | normal | Boolean | Draws the labels at the normal axis position when `true`. |
| | opposite | Boolean | Draws the labels at the opposite axis position when `true`. |
| majorGrid | color | HiQ Color | Defines the color of the major grid lines. |
| | divisions | Integer | Defines the number of major grid divisions the axis contains. Valid values include <`auto`> and the range 1–100. |
| | insideTick | Boolean | Draws the tick marks on the inside of the axis when set to `true`. |
| | normalTick | Boolean | Draws tick marks at the normal axis location when set to `true`. |
| | oppositeTick | Boolean | Draws tick marks at the opposite axis location when set to `true`. |
| | outsideTick | Boolean | Draws the tick marks on the outside of the axis when set to `true`. |
| | visible | Boolean | Draws the major grid lines when `true`. |

**Table 3-7.** Axis Properties (Continued)

| **Property** | | **Data Type** | **Description** |
|---|---|---|---|
| minorGrid | color | HiQ Color | Defines the color of the minor grid lines. |
| | divisions | Integer | Defines the number of minor grid divisions between each major grid division. (Valid values: 1–100) |
| | insideTick | Boolean | Draws tick marks on the inside of the axis when `true`. |
| | normalTick | Boolean | Draws the tick marks at the normal axis location when `true`. |
| | oppositeTick | Boolean | Draws the tick marks at the opposite axis location when `true`. |
| | outsideTick | Boolean | Draws tick marks on the outside of the axis when `true`. |
| | visible | Boolean | Draws the minor grid lines when `true`. |
| range. | inverted | Boolean | Draws an inverted axis, starting with the minimum value and ending with the maximum value when this property is set to `true`. When `false`, this property draws the axis normally, starting with the maximum value and proceeding to the maximum value. |
| | max | Real | Defines the maximum value of the axis. |
| | min | Real | Defines the minimum value of the axis. |
| | mode | HiQ Constant | Specifies the range mode of the axis, which defines how to compute the range of the axis. Valid values include<br><`auto`>—Computes the minimum and maximum values for the axis based on the extents of the plots.<br><`manual`>—Uses the values of the `range.min` and `range.max` properties to define the range. |

**Table 3-7.** Axis Properties (Continued)

| **Property** | | **Data Type** | **Description** |
|---|---|---|---|
| scaling.mode | | HiQ Constant | Defines the scaling of the axis. Axes can be scaled either linearly or logarithmically. Valid values include<br>`<linear>`<br>`<log>` |
| title | | Text | Defines the title of the axis. |
| title. | color | HiQ Color | Defines the color of the axis title. |
| | font | HiQ Font | Defines the font of the axis title. |
| | normal | Boolean | Draws the title at the normal axis position when `true`. |
| | opposite | Boolean | Draws the title at the opposite axis position when `true`. |
| visibility | | HiQ Constant | Defines the axis visibility.<br>Valid values include<br>`<on>`—Always visible.<br>`<off>`—Never visible.<br>`<auto>`—Drawn if the axis has an associated plot. |

Table 3-8 contains axis property examples.

**Table 3-8.** Examples: Setting Axis Properties

| HiQ-Script | Description |
|---|---|
| `g.axis.x.visibility = <off>;` | Turns off the visibility of the X axis. |
| `g.axis.y(2).title = "Voltage";` | Sets the second Y axis title to `Voltage`. |
| `g.axis.y(1,3,6).label.color = <red>;` | Sets the label color for the first, third, and sixth Y axes to red. |
| `axisList = {vector: 2,4,7};` `g.axis.y(axisList).title.color=<blue>;` | Sets the label color for the second, fourth, and seventh Y axes to blue. |
| `g.axis.xyz.scaling.mode = <auto>;` | Set the scaling mode for the X, Y, and Z axes to auto. |
| `g.axes.label.format = <scientific>;` | Sets the label format for all axes to scientific. |

## Light Properties

To set a property of an individual light in a 3D graph, use the following form:

```
graph.light(lightID).property = value;
```

where `graph` specifies the graph to modify, `lightID` specifies the light to modify, `property` is the name of the light property to set, and `value` is the new property value to apply. Valid values for `lightID` are `1`, `2`, `3`, and `4`. To set a property for all lights in the graph, use the following form:

```
graph.lights.property = value;
```

Table 3-9 summarizes the light properties.

**Table 3-9.** Light Properties

| Property | Data Type | Description |
|---|---|---|
| attenuation | HiQ Constant | Defines the attenuation style of the light source. Valid values include `<none>` `<linear>` `<quadratic>` |
| color | HiQ Color | Defines the color of the light source. |
| distance | Real | Defines the distance of the light source from the center of the graph. |
| enable | Boolean | Enables the light when set to `true`. |
| latitude | Real | Defines the latitudinal position of the light source. |
| longitude | Real | Defines the longitudinal position of the light source. |

Table 3-10 contains light property examples.

**Table 3-10.** Examples: Setting Light Properties

| HiQ-Script | Description |
|---|---|
| `g.light(1).enable = true;` | Enables the first light. |
| `g.light(4).color = <red>;` | Sets the color of the fourth light to red. |
| `g.lights.attenuation = <quadratic>;` | Sets the attenuation mode for all lights to quadratic. |

☞ **Note** ***Use the context help from the Graph property page to obtain additional information about individual properties.***

## Querying Graph Properties

You can query a graph property for its current value using the same property notation syntax that you use to set properties. For example, use the following syntax to query a graph for its title:

```
title = g.title;
```

Because property values might be different, you cannot query aggregate properties. For example, you can set the title color property of all plots in the graph:

```
g.plots.title.color = <red>;
```

However, you cannot query the title color property of all plots as in the following code, which generates a run-time error:

```
color = g.plots.title.color;
```

## Using Auto Scaling

Graph axes support both auto and manual scaling. When auto scaling is active, the range of the axis automatically adjusts to include the minimum and maximum values of all plots in the graph. When manual scaling is active, the axis range remains fixed based on the currently defined minimum and maximum values.

## Using Legends

Use legends to describe the contents of the graph. A legend contains a title and icon for each plot in the graph. The icon resembles the visual appearance of the plot and the title is the current value of the `plot.title` property. To configure the legend interactively, use the **Graph** tab on the **Graph** property page. To configure the legend programmatically, use the legend properties of the graph. For a complete list of legend properties, refer to *Setting Graph Properties* earlier in this chapter.

You can move and size the legend within the graph. To move the legend, depress the <Alt> key and click-drag within the legend area. To size the legend, use the standard Windows sizing techniques. To restore the graph to its default layout scheme, select **Default Layout** from the right popup.

## Removing Plots

You can interactively remove a plot from a graph with one of the following two methods, both of which you can undo.

Select **Add/Remove Plot...** from the graph popup, which displays the Add/Remove Plots dialog box. From this dialog, you can add and remove plots from the graph. The Available Plots control lists all of the Plot objects that you can add to the graph. The Graph's Plots control lists all of the plots currently contained by the graph. Use the **Add** >>, **Add All** >>, << **Remove**, and << **Remove All** controls to select the desired plots.

OR

Select the plot you want to delete. Right click to display the plot popup, and select **Remove**.

To programmatically remove plots from a graph, use the `removePlot` function in one of the following forms:

- To remove all plots from a graph

  ```
  removePlot(graph);
  ```

  where `graph` is the graph to modify.
- To remove an embedded plot from a graph

  ```
  removePlot(graph,plotID);
  ```

  where `graph` is the graph to modify, and `plotID` is the ID of the plot to remove.
- To remove a Plot object from a graph

  ```
  removePlot(graph,plot);
  ```

  where `graph` is the graph to modify, and `plot` is the plot object to remove.

**Note** ***When you remove an embedded plot from a graph, you delete the plot. When you remove a linked plot from a graph, you do not delete the Plot object, only the view.***

# 4

# HiQ Objects and Object Properties

This chapter explains HiQ objects in general, describes each HiQ object specifically, and provides all properties and property descriptions for each object.

## HiQ Objects

An object is an entity in a HiQ Notebook that contains data of a specific type, such as numeric, graphic, text, or HiQ-Script. Objects work together in a Notebook to generate and display solutions to analysis and visualization problems. You can divide HiQ objects into three categories.

- Numeric Objects—Scalars, vectors, matrices, and polynomials, all having integer, real, and complex components. Numeric objects contain the actual data you are analyzing.
- Visualization Objects—Two- and three-dimensional graphs and text objects. Although you can place numeric objects on the Notebook page to view their actual values, use graphs and text to better understand the data.
- Auxiliary Objects—Scripts, colors, fonts, and constants.

### Object Creation

You can create objects two different ways: interactively by using the Tools toolbar and dragging the object out on a Notebook page or dynamically from script. Although you can create most objects interactively, objects such as fonts and colors can be created only from script.

For more information about creating objects interactively, see the *Getting Results with HiQ* manual.

## Object Views

Although objects are always stored in a Notebook, they are not always visible on the Notebook page—an object can exist without a view. When you interactively create an object by selecting a tool from the Tools toolbar and placing it on the Notebook page, you create both an object and a single view of that object.

Except for ActiveX objects and controls, objects can have more than one view. When an object has multiple views, each view has the same properties. Multiple views allow you to represent the object on more than one Notebook page. If you do not want to place a view of an object on the printable Notebook page, use floating views to interact with the object. You can create a floating view of an object by right clicking on the object name in the Object List and selecting **View in Window**.

You can copy views to the clipboard, by right clicking on them and selecting **Copy** from the **View** menu, and paste them into any application that allows you to paste bitmaps or metafiles.

### Creating Views

Objects are listed under the Objects entry for the Notebook in the Notebook Explorer. To create a view of an object, select the object in the Explorer and drag it to the Notebook page.

### Deleting Views

If you delete a view of an object, only that view is deleted—the object and all other views remain in the Notebook. However, if you delete the object, all of its views are deleted.

## Object Properties

Object properties can define the look of the object and control the behavior of the object. Use properties to customize object views and control the data stored in the object. For example, you can customize a vector by defining the background color for different views of the vector, or you can control the number of elements the vector contains using the `size` property.

### Default Property Settings

When you create an object, it inherits the default properties for that object type. To change the default property settings, create an object with your desired settings. Select the object view, right click, and choose **Defaults»Update Default Properties** from the popup menu. If you change the properties of an object and decide that you prefer the previous defaults, select **Defaults»Apply Default Properties** from the right-click popup of the object view. To restore the original defaults to the object, select **Defaults»Apply Factory Properties**.

### Changing Properties

You can change object properties two ways. To change properties interactively, right click on an object view and select **Properties...** from the popup menu. From the property pages, you can interactively set or change any object property.

You can change any of the properties programmatically with HiQ-Script. For example, to set the background color of a vector, `v`, use the following HiQ-Script:

```
v.background.color = myColor;
```

`background.color` is the name of the background color property for vector `v`. With this line of script, the background color changes to `myColor`, a HiQ Color object.

## HiQ Object Descriptions

The following sections describe each HiQ object in detail. The tables in each section list and define the properties for that object.

## Numeric Scalar Objects

Numeric scalars store single numeric values—integer, real or complex.

- Integer scalar—Stores a single integer in the range $-2^{31}$ through $2^{31}-1$.
- Real scalar—Stores a value in the range $-1.8 \times 10^{308}$ to $1.5 \times 10^{308}$ with 16 decimal places of precision. The real scalar with the smallest non-zero magnitude is $2.23 \times 10^{-308}$.
- Complex scalar—Stores a single complex number using two real values. Each component of the complex number has the same limits as a single real value.

**Table 4-1.** Numeric Scalar Object Properties

| Property | | Data Type | Description |
|---|---|---|---|
| background.color | | HiQ Color | Defines the background color of object views. |
| border. | color | HiQ Color | Defines the border color of object views. |
| | style | HiQ Constant[a] | Defines the border style for object views. |
| cell. | color | HiQ Color | Defines the text color that displays the value of the object. |
| | font | HiQ Font | Defines the font that displays the value. |
| | width | Real | Defines the number of characters that are visible. (Valid range: 1.0–99.99) |

**Table 4-1.** Numeric Scalar Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| type | | HiQ Constant[b] | Returns the type of the object. (Read Only) |
| type. | numeric | HiQ Constant | Defines the type of element stored in the numeric object. (Read Only)<br>Valid values include<br>`<integer>`<br>`<real>`<br>`<complex>` |
| | object | HiQ Constant | Defines the type of numeric object.<br>(Read Only) Valid values include<br>`<scalar>`<br>`<vector>`<br>`<matrix>`<br>`<polynomial>` |
| **Integer Properties** | | | |
| base | | HiQ Constant | Defines the base used to display the value of the object. Valid values include<br>`<decimal>`<br>`<binary>`<br>`<binaryB>`<br>`<octal>`<br>`<octal0>`<br>`<octalO>`<br>`<hexadecimal>`<br>`<hexadecimal0x>`<br>`<hexadecimalDollar>`<br>`<hexadecimalH>` |
| digits | | Integer | Defines the minimum number of digits to display. (Valid range: 1–32) |

**Table 4-1.** Numeric Scalar Object Properties (Continued)

| Property | Data Type | Description |
|---|---|---|
| **Real Properties** | | |
| decimalPlaces | Integer | Defines the number of decimal places to display. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| exponentialDigits | Integer | Defines the number of exponential digits to display. (Valid range: 1–3) |
| format | HiQ Constant | Defines the real display format to use. Valid values include `<real>` `<scientific>` `<engineering>` |
| **Complex Real Properties** | | |
| complexFormat | HiQ Constant | Defines the complex mode used to display the value. Valid values include `<sumI>` `<sumJ>` `<pair>` `<degrees>` `<radians>` `<gradians>` |
| i | Real | Defines the imaginary part of the number. |

**Table 4-1.** Numeric Scalar Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| imaginary. | decimalPlaces | Integer | Defines the number of decimal places to display for the imaginary part of the number. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| | exponential Digits | Integer | Defines the number of exponential digits to display for the imaginary part of the number. (Valid range: 1–3) |
| | format | HiQ Constant | Defines the real display format to use for the imaginary part of the number. Valid values include `<real>` `<scientific>` `<engineering>` |
| r | | Real | Defines the real part of the number. |
| real. | decimalPlaces | Integer | Defines the number of decimal places to display for the real part of the number. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| | exponential Digits | Integer | Defines the number of exponential digits to display for the real part of the number. (Valid range: 1–3) |
| | format | HiQ Constant | Defines the real display format to use for the real part of the number. Valid values include `<real>` `<scientific>` `<engineering>` |

a. For a complete list of HiQ Constants for border, see Table B-2, *Border Style Constants*, in Appendix B, *HiQ Constants*.

b. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Numeric Vector Objects

Vector objects store multiple scalar objects as single objects. Each element of a vector is equivalent to its scalar counterpart. You can assume that vectors are single-column matrices in the linear algebra sense.

### Accessing Elements of a Vector

You can access a specific vector element in HiQ-Script using square brackets ([] operator). The first element is always indexed at 1. The index of the last element equals the size of the vector.

If you access a value at an index greater than the current size, the vector grows so that the index is valid. Any new elements are initialized to zero. Although vectors can grow to accommodate a larger index, vectors cannot automatically shrink to fit the number of elements. If you need to fix a vector at a specific size, set the `size` property, and the vector assumes the new size.

### Automatically Creating an Element

You automatically create a vector when you access an index of a scalar object or an object that does not exist.

For example, you can create an integer vector `A` with an initial size of two elements, if `A` has not already been assigned or `A` is currently a scalar object.

```
A[2] = 5;
```

The first element is zero, and the second element is 5. You also can create a vector using the vector initializer syntax.

```
MyVector = {v: 1, 2, 3, 4};
```

With this syntax, you create a four-element vector containing the values 1, 2, 3, and 4.

**Note** ***When you know the maximum size required for a vector, set the vector size to its maximum to improve script performance (so the vector does not resize each time you access an out-of-range element).***

**Table 4-2.** Numeric Vector Object Properties

| Property | | Data Type | Description |
|---|---|---|---|
| background.color | | HiQ Color | Defines the background color of object views. |
| border. | color | HiQ Color | Defines the border color of object views. |
| | style | HiQ Constant[a] | Defines the border style for object views. |
| cell. | color | HiQ Color | Defines the text color that displays the value of the object. |
| | font | HiQ Font | Defines the font that displays the values contained in the vector. |
| | width | Real | Defines the number of characters visible in each cell. (Valid range: 1.0–99.99) |
| grid.line.color | | HiQ Color | Defines the line color of the lines that separate each cell. |
| grid.visible | | Boolean | Makes visible the lines that separate values when set to `true`. When `false`, this property turns off the grid lines. |
| label(*n*) | | Text | Defines the label text for the value at index *n*. *n* must be an Integer scalar greater than zero. You do not need to define any values in the vector for *n* to set the label at *n*. |
| labels. | background.color | HiQ Color | Defines the background color in the label area. |
| | color | HiQ Color | Defines the font color that displays the vector labels. |
| | default.visible | Boolean | Turns on default labels when set to `true`. When `false`, this property turns off default labels. |
| | font | HiQ Font | Defines the font that displays the vector labels. |

**Table 4-2.** Numeric Vector Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| labels. (*continued*) | user.visible | Boolean | Turns on user labels when set to `true`. When `false`, this property turns off user labels. |
| | visible | Boolean | Turns on both user and default labels when set to `true`. When set to `false`, this property turns off both user and default labels. This property returns `true` if any labels are visible, and `false` if no labels are visible. |
| size | | Integer | Defines the size of the vector—that is, the number of elements in the vector—which must be greater than zero. |
| type | | HiQ Constant[b] | Returns the type of the object. (Read Only) |
| type. | numeric | HiQ Constant | Defines the type of element stored in the numeric object. (Read Only)<br>Valid values include<br>`<integer>`<br>`<real>`<br>`<complex>` |
| | object | HiQ Constant | Defines the type of numeric object. (Read Only) Valid values include<br>`<scalar>`<br>`<vector>`<br>`<matrix>`<br>`<polynomial>` |

**Table 4-2.** Numeric Vector Object Properties (Continued)

| Property | Data Type | Description |
|---|---|---|
| **Integer Properties** | | |
| base | HiQ Constant | Defines the base used to display the value of the object. Valid values include<br>`<decimal>`<br>`<binary>`<br>`<binaryB>`<br>`<octal>`<br>`<octal0>`<br>`<octalO>`<br>`<hexadecimal>`<br>`<hexidecimal0x>`<br>`<hexidecimalDollar>`<br>`<hexadecimalH>` |
| digits | Integer | Defines the minimum number of digits to display. (Valid range: 1–32) |
| **Real Properties** | | |
| decimalPlaces | Integer | Defines the number of decimal places to display. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| exponentialDigits | Integer | Defines the number of exponential digits to display. (Valid range: 1–3) |
| format | HiQ Constant | Defines the real display format to use. Valid values include<br>`<real>`<br>`<scientific>`<br>`<engineering>` |

**Table 4-2.** Numeric Vector Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| **ComplexReal Properties** | | | |
| complexFormat | | HiQ Constant | Defines the complex mode used to display the value. Valid values include<br>`<sumI>`<br>`<sumJ>`<br>`<pair>`<br>`<degrees>`<br>`<radians>`<br>`<gradians>` |
| i | | Real Vector | Defines the complex part of the vector. The size of the vector must be the same as the current vector. |
| imaginary. | decimalPlaces | Integer | Defines the number of decimal places to display for the imaginary part of the number. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| | exponential Digits | Integer | Defines the number of exponential digits to display for the imaginary part of the number. (Valid range: 1–3) |
| | format | HiQ Constant | Defines the real display format to use for the imaginary part of the number. Valid values include<br>`<real>`<br>`<scientific>`<br>`<engineering>` |

**Table 4-2.** Numeric Vector Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| r | | Real Vector | Defines the real part of the vector. The size of the vector must be the same as the current vector. |
| real. | decimalPlaces | Integer | Defines the number of decimal places to display for the real part of the number. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| | exponential Digits | Integer | Defines the number of exponential digits to display for the real part of the number. (Valid range: 1–3) |
| | format | HiQ Constant | Defines the real display format to use for the real part of the number. Valid values include `<real>` `<scientific>` `<engineering>` |

a. For a complete list of HiQ Constants for border, see Table B-2, *Border Style Constants*, in Appendix B, *HiQ Constants*.

b. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Numeric Matrix Objects

Matrix objects store multiple scalar objects as single objects.

### Accessing Elements of a Matrix

To access a single matrix element in HiQ-Script, specify the row and column of the element, enclosed in square brackets ([] operator). The first element is indexed at 1,1 (row and column index, respectively).

Like Vector objects, Matrix objects can grow if you access a value at an index greater than one of the current dimensions. Any new elements are initialized to zero. Although Matrix objects can grow to accommodate a larger index, they cannot automatically shrink to fit the number of elements. If you need to fix a matrix at a specific size, set the `size`, `rows`, or `columns` properties, and the matrix assumes the new size.

### Automatically Creating an Element by Accessing It

You automatically create a matrix when you access an element of a scalar object or an element of an object that currently does not exist.

For example, you can create an 2–by–2 integer matrix `A`, as long as `A` has not already been used or `A` is currently a scalar object.

```
A[2,2] = 5;
```

The element at 2,2 has a value of 5; all other elements are initialized to zero. You also can create a matrix by using the matrix initializer syntax.

```
MyMatrix = {M: 1, 2; 3, 4};
```

This syntax creates a 2-by-2 element matrix containing the values 1, 2; 3, 4.

☞ **Note** ***When you know the maximum size required for a matrix, set the matrix to its maximum size first to improve script performance (so the matrix does not resize each time you access an out-of-range element). Each element of a matrix is equivalent to its scalar counterpart and can be treated identically.***

**Table 4-3.** Numeric Matrix Object Properties

| Property | | Data Type | Description |
|---|---|---|---|
| background.color | | HiQ Color | Defines the background color of object views. |
| border. | color | HiQ Color | Defines the border color of object views. |
| | style | HiQ Constant[a] | Defines the border style of object views. |
| cell. | color | HiQ Color | Defines the text color that displays the value of the object. |
| | font | HiQ Font | Defines the font that displays the values in the matrix. |
| | width | Real | Defines the number of characters visible in each cell. (Valid range: 1.0–99.99) |
| columns | | Integer | Defines the number of columns in the matrix, which must be greater than zero. |
| grid. | column.<br>visible | Boolean | Draws the lines that separate columns when set to `true`. When `false`, this property turns off the column grid lines. |
| | line.color | HiQ Color | Defines the color used for the lines that separate each cell. |
| | row.visible | Boolean | Draws the lines that separate rows when set to `true`. When `false`, this property turns off the row grid lines. |
| | visible | Boolean | Draws the lines that separate values when set to `true`. When `false`, this property turns off the grid lines. |
| labels. | background.<br>color | HiQ Color | Defines the background color in the label area. |
| | column(*n*) | Text | Defines the text of the label for the values at column index *n*. *n* must be an Integer scalar greater than zero but can exceed the number of columns in the matrix. |
| | color | HiQ Color | Defines the font color that displays the vector labels. |

**Table 4-3.** Numeric Matrix Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| labels. (*continued*) | column. default.visible | Boolean | Turns on default column labels when set to `true`. When `false`, this property turns off default column labels. |
| | column.user. visible | Boolean | Turns on user column labels when set to `true`. When `false`, this property turns off user column labels. |
| | column. visible | Boolean | Turns on column labels when set to `true`. When `false`, this property turns off column labels. This property returns `true` if any column labels are visible and `false` if no column labels are visible. |
| | default.visible | Boolean | Turns on all default labels when set to `true`. When `false`, this property turns off all default labels. This property returns `true` if any default labels are visible and `false` if no default labels are visible. |
| | font | HiQ Font | Defines the font that displays the vector labels. |
| | row(*n*) | Text | Defines the text of the label for the values at row index *n*. *n* must be an Integer scalar greater than zero but can exceed the number of rows in the matrix. |
| | row.default. visible | Boolean | Turns on default row labels when set to `true`. When `false`, this property turns off default row labels. |
| | row.user. visible | Boolean | Turns on user row labels when set to `true`. When `false`, this property turns off user row labels. |
| | row.visible | Boolean | Turns on row labels when set to `true`. When `false`, this property turns off row labels. This property returns `true` if any row labels are visible and `false` if no row labels are visible. |

**Table 4-3.** Numeric Matrix Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| labels. (*continued*) | user.visible | Boolean | Turns on all user labels when set to `true`. When `false`, this property turns off all user labels. This property returns `true` if any user labels are visible and `false` if no user labels are visible. |
| | visible | Boolean | Turns on all user and default labels when set to `true`. When `false`, this property turns off all user and default labels. This property returns `true` if any labels are visible and `false` if no labels are visible. |
| rows | | Integer | Defines the number of rows in the matrix, which must be greater than zero. |
| size | | Integer Vector | Defines the dimensions of the matrix in a two element vector. The first element is the number of rows, and the second element is the number of columns. |
| storage | | HiQ Constant | Specifies the underlying storage for the matrix. Valid values include `<rect>` `<upperTri>` `<lowerTri>` `<band>` `<symmetric>` `<hermitian>` |
| type | | HiQ Constant[b] | Returns the type of the object. (Read Only) |

**Table 4-3.** Numeric Matrix Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| type. | numeric | HiQ Constant | Defines the type of element stored in the numeric object. (Read Only) Valid values include<br>`<integer>`<br>`<real>`<br>`<complex>` |
| | object | HiQ Constant | Defines the type of numeric object. (Read Only) Valid values include<br>`<scalar>`<br>`<vector>`<br>`<matrix>`<br>`<polynomial>` |
| **Integer Properties** | | | |
| base | | HiQ Constant | Defines the base used to display the value of the object. Valid values include<br>`<decimal>`<br>`<binary>`<br>`<binaryB>`<br>`<octal>`<br>`<octal0>`<br>`<octalO>`<br>`<hexadecimal>`<br>`<hexidecimal0x>`<br>`<hexidecimalDollar>`<br>`<hexadecimalH>` |
| digits | | Integer | Defines the minimum number of digits to display. (Valid range: 1–32) |

**Table 4-3.** Numeric Matrix Object Properties (Continued)

| Property | Data Type | Description |
|---|---|---|
| **Real Properties** | | |
| decimalPlaces | Integer | Defines the number of decimal places to display. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| exponentialDigits | Integer | Defines the number of exponential digits to display. (Valid range: 1–3) |
| format | HiQ Constant | Defines the real display format to use. Valid values include `<real>` `<scientific>` `<engineering>` |
| **ComplexReal Properties** | | |
| complexFormat | HiQ Constant | Defines the complex mode used to display the value. Valid values include `<sumI>` `<sumJ>` `<pair>` `<degrees>` `<radians>` `<gradians>` |
| i | Real Matrix | Defines the complex part of the matrix. The dimensions of the matrix must be the same as the current matrix. |

**Table 4-3.** Numeric Matrix Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| imaginary. | decimalPlaces | Integer | Defines the number of decimal places to display for the imaginary part of the number. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| | exponential Digits | Integer | Defines the number of exponential digits to display for the imaginary part of the number. (Valid range: 1–3) |
| | format | HiQ Constant | Defines the real display format to use for the imaginary part of the number. Valid values include `<real>` `<scientific>` `<engineering>` |
| r | | Real Matrix | Defines the real part of the matrix. The dimensions of the matrix must be the same as the current matrix. |
| real. | decimalPlaces | Integer | Defines the number of decimal places to display for the real part of the number. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| | exponential Digits | Integer | Defines the number of exponential digits to display for the real part of the number. (Valid range: 1–3) |
| | format | HiQ Constant | Defines the real display format to use for the real part of the number. Valid values include `<real>` `<scientific>` `<engineering>` |

a. For a complete list of HiQ Constants for border, see Table B-2, *Border Style Constants*, in Appendix B, *HiQ Constants*.

b. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Numeric Polynomial Objects

Unlike scalars, vectors, and matrices, Polynomial objects are either real or complex, not integer. Polynomial objects can represent up to a 1024 degree polynomial. Polynomial coefficients are either all real numbers or all complex numbers, each having the same characteristics as a scalar of the same type.

You can use polynomials as any other numeric objects with respect to HiQ built-in operators. For example, you can multiply or add two polynomials as you would two matrices. You also can evaluate a polynomial at a specific value.

To create a polynomial from script, use the polynomial initializer syntax. The following syntax creates the polynomial $x^2 + 2x + 1$.

```
MyPolynomial = {poly: “x^2 + 2x + 1”};
```

You can evaluate a polynomial as you would a function. The following code places the value of `MyPolynomial`, evaluated at x = 4, into `result`.

```
result = MyPolynomial(4);
```

**Table 4-4.** Numeric Polynomial Properties

| Property | | Data Type | Description |
|---|---|---|---|
| background.color | | HiQ Color | Defines the background color of object views. |
| border. | color | HiQ Color | Defines the border color of object views. |
| | style | HiQ Constant[a] | Defines the border style of object views. |
| cell. | color | HiQ Color | Defines the text color that displays the value of the object. |
| | font | HiQ Font | Defines the font that displays the value of the polynomial. |
| | width | Real | Defines the number of visible characters. (Valid range: 1.0–99.99) |

**Table 4-4.** Numeric Polynomial Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| degree | | Integer | Specifies the degree of the polynomial. (Read Only) |
| exponent.style | | HiQ Constant | Defines that style in which exponents are displayed. Valid values include `<raised>` `<caret>` `<fortran>` |
| justify | | HiQ Constant | Defines polynomial justification. Valid values include `<left>` `<right>` |
| type | | HiQ Constant[b] | Returns the type of the object. (Read Only) |
| type. | numeric | HiQ Constant | Defines the type of element stored in the numeric object. (Read Only) Valid values include `<integer>` `<real>` `<complex>` |
| | object | HiQ Constant | Defines the type of numeric object. (Read Only) Valid values include `<scalar>` `<vector>` `<matrix>` `<polynomial>` |

**Table 4-4.** Numeric Polynomial Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| **Real Properties** | | | |
| decimalPlaces | | Integer | Defines the number of decimal places to display. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| exponentialDigits | | Integer | Defines the number of exponential digits to display. (Valid range: 1–3) |
| format | | HiQ Constant | Defines the real display format to use. Valid values include `<real>` `<scientific>` `<engineering>` |
| **Complex Properties** | | | |
| complexFormat | | HiQ Constant | Defines the complex mode used to display the value. Valid values include `<sumI>` `<sumJ>` `<pair>` `<degrees>` `<radians>` `<gradians>` |
| imaginary. | decimalPlaces | Integer | Defines the number of decimal places to display for the imaginary part of the number. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| | exponential Digits | Integer | Defines the number of exponential digits to display for the imaginary part of the number. (Valid range: 1–3) |
| | format | HiQ Constant | Defines the real display format to use for the imaginary part of the number. Valid values include `<real>` `<scientific>` `<engineering>` |

**Table 4-4.** Numeric Polynomial Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| real. | decimalPlaces | Integer | Defines the number of decimal places to display for the real part of the number. If the value is negative, the absolute value defines the number of decimal places to display and trailing zeros are removed. |
| | exponential Digits | Integer | Defines the number of exponential digits to display for the real part of the number. (Valid range: 1–3) |
| | format | HiQ Constant | Defines the real display format to use for the real part of the number. Valid values include `<real>` `<scientific>` `<engineering>` |

a. For a complete list of HiQ Constants for border, see Table B-2, *Border Style Constants*, in Appendix B, *HiQ Constants*.

b. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Text Objects

Text objects store an array of character values. Consider HiQ Text objects as vectors that store characters. To create a Text object, assign a string to any object. For example, you can create a Text object containing the string `Hello`.

```
MyText = “Hello”;
```

You can access individual characters with the subscript operator and concatenate two Text objects with the addition operator. For example, the following script creates a Text object named `Result` that contains the string `Hello World`.

```
Text1 = “Hello “;

Text2 = “World”;

Result = Text1 + Text2;
```

You can convert Numeric objects to Text objects with the `toText` built-in function. The `toNumeric` function converts a Text object to a Numeric object.

**Table 4-5.** Text Object Properties

| Property | | Data Type | Description |
|---|---|---|---|
| background.color | | HiQ Color | Defines the background color of object views. |
| border. | color | HiQ Color | Defines the border color of object views. |
| | style | HiQ Constant[a] | Defines the border style of object views. |
| font | | HiQ Font | Defines the font used when displaying the text. |
| font.color | | HiQ Color | Defines the font color that displays the text. |
| length | | Integer | Specifies the number of characters in the Text object. (Read Only) |
| type | | HiQ Constant[b] | Returns the type of the object. (Read Only) |

a. For a complete list of HiQ Constants for border, see Table B-2, *Border Style Constants*, in Appendix B, *HiQ Constants*.

b. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Script Objects

Use Script objects to write your own HiQ-Script programs. Inside HiQ-Script, you can initialize a script, convert a script to text, or save a script to a file. You also can access script properties from HiQ-Script.

**Table 4-6.** Script Object Properties

| Property | | Data Type | Description |
|---|---|---|---|
| autoIndent | | Boolean | Turns auto indent on when set to `true`. When `false`, this property turns auto indent off. |
| background.color | | HiQ Color | Defines the background color of object views. |
| bifFont | | HiQ Font | Defines the font that displays built-in function names. |
| bifFont.color | | HiQ Color | Defines the font color that displays built-in function names. |
| border. | color | HiQ Color | Defines the border color of object views. |
| | style | HiQ Constant[a] | Defines the border style of object views. |
| commentFont | | HiQ Font | Defines the font that displays comments. |
| commentFont.color | | HiQ Color | Defines the font color that displays comments. |
| constantFont | | HiQ Font | Defines the font that displays HiQ constants. |
| constantFont.color | | HiQ Color | Defines the font color that displays HiQ constants. |
| keywordFont | | HiQ Font | Defines the font that displays HiQ keywords. |
| keywordFont.color | | HiQ Color | Defines the font color that displays HiQ keywords. |
| scriptFont | | HiQ Font | Defines the font that displays script text. |
| scriptFont.color | | HiQ Color | Defines the font color that displays script text. |

**Table 4-6.** Script Object Properties (Continued)

| Property | Data Type | Description |
|---|---|---|
| syntaxHighlighting | Boolean | Performs syntax highlighting when set to `true`. When syntax highlighting is not active, all text is displayed in the script font. |
| type | HiQ Constant[b] | Returns the type of the object. (Read Only) |

a. For a complete list of HiQ Constants for border, see Table B-2, *Border Style Constants*, in Appendix B, *HiQ Constants*.

b. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Color Objects

Use Color objects to represent a color in HiQ-Script. Often, you might use Color objects to manipulate object properties. To create a color from script, use the color initializer syntax. For example, you can create a dark red color.

```
MyRed = {color: 128, 0, 0};
```

You can create medium-green and blue colors as well.

```
MyGreen = {color: 0, 200, 0};
MyBlue = {color: 0, 0, 200};
```

You can specify color components ranging from 0 to 255. If you specify a value larger than 255, the value defaults to 255.

☞ **Note** ***You cannot view Color objects on the Notebook page.***

**Table 4-7.** Color Object Properties

| Property | Data Type | Description |
|---|---|---|
| red | Integer | Defines the red component of the color. Any values greater than 255 default to 255. |
| green | Integer | Defines the green component of the color. Any values greater than 255 default to 255. |
| blue | Integer | Defines the blue component of the color. Any values greater than 255 default to 255. |
| type | HiQ Constant[a] | Returns the type of the object. (Read Only) |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Font Objects

Use Font objects to represent a font in HiQ-Script. Often, you use Font objects to manipulate object properties. To create a font from script, use the font initializer syntax. For example, you can create a 10-point Courier New font.

```
MyFont = {font: "Courier New", 10};
```

If you specify an unavailable font, a similar font is substituted.

☞ **Note** ***You cannot view Font objects on the Notebook page.***

**Table 4-8.** Font Object Properties

| Property | Data Type | Description |
|---|---|---|
| bold | Boolean | Bolds the font when set to `true`. When `false`, this property displays the font at its normal weight. |
| italic | Boolean | Italicizes the font when set to `true`. |
| name | Text | Defines the font name. |
| size | Integer | Defines font size in points. |
| strikeout | Boolean | Strikes out characters when set to `true`. |
| type | HiQ Constant[a] | Returns the type of the object. (Read Only) |
| underline | Boolean | Underlines characters when set to `true`. |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Function Objects

Use Function objects to define your own functions. Function objects are compiled versions of functions you write in HiQ-Script. You can call a Function object from script.

```
B = myFunction();
```

To create a function during script execution, use the function initializer syntax. For example, you can create a function that squares its parameter.

```
MyFunc = {function: x: “x^2”};
```

You then can call this function as you would any other function.

```
XSquared = MyFunc(x);
```

☞ **Note** ***You cannot view Function objects on the Notebook page.***

**Table 4-9.** Function Object Properties

| **Property** | **Data Type** | **Description** |
|---|---|---|
| type | HiQ Constant[a] | Returns the type of the object. (Read Only) |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## ActiveX Objects

ActiveX objects include any object that you insert in your Notebook with the **Edit»Insert Object** command. You cannot create an ActiveX object programmatically, nor can you use an ActiveX object on the right side of a simple assignment statement. If the ActiveX object has an automation interface, you can access its properties and methods using DOT notation.

For more information about ActiveX objects and accessing their automation interface, see Chapter 1, *ActiveX Connectivity*.

**Table 4-10.** ActiveX Object Properties

| Property | Data Type | Description |
|---|---|---|
| type | HiQ Constant[a] | Returns the type of the object. (Read Only) |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## ActiveX Control Objects

ActiveX Control objects include any object that you insert in your Notebook with the **Edit»Insert Control** command. You cannot create an ActiveX Control object programmatically, nor can you use an ActiveX Control object on the right side of a simple assignment statement. If the ActiveX Control object has an automation interface, you can access its properties and methods using DOT notation.

For more information about ActiveX Control objects and accessing their automation interface, see Chapter 1, *ActiveX Connectivity*.

**Table 4-11.** ActiveX Control Object Properties

| Property | Data Type | Description |
|---|---|---|
| type | HiQ Constant[a] | Returns the type of the object. (Read Only) |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## ActiveX Interface Objects

ActiveX Interface objects represent ActiveX interfaces. You can create ActiveX Interface objects using the `createInterface` built-in function or by calling an automation interface method that returns an ActiveX Interface.

You cannot view ActiveX Interface objects on the Notebook page, and ActiveX Interface objects are not saved with the Notebook.

**Table 4-12.** ActiveX Interface Object Properties

| Property | Data Type | Description |
|---|---|---|
| type | HiQ Constant[a] | Returns the type of the object. (Read Only) |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## HiQ Constant Objects

HiQ Constant objects represent constants in HiQ-Script. You create HiQ Constant objects when you assign a HiQ constant to an object. For example, the following syntax creates a HiQ Constant object with the value `<line>`.

```
myConstant = <line>;
```

Although HiQ Constant objects and numeric constants both use angle brackets, they behave very differently. Numeric constants, such as <pi>, are short-hand representations of other objects (in this case, a real scalar with the value of pi). These numeric constants are not HiQ Constant objects.

**Note** ***Do not use HiQ Constant objects in arithmetic expressions.***

You cannot view HiQ Constant objects on the Notebook page.

**Table 4-13.** HiQ Constant Object Properties

| Property | Data Type | Description |
|---|---|---|
| type | HiQ Constant[a] | Returns the type of the object. (Read Only) |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Untyped Objects

An Untyped object is an object that has never been given a value. Once you assign an object a value, the object is no longer untyped and can never be untyped again. You can assign a value to an Untyped object by assigning a value to it or by setting its `type` property.

Consider the following syntax example. In line 1, `A` has not been assigned a value, so its type is `<untyped>` and `B` becomes a HiQ Constant object with the value `<untyped>`. In line 2, `A` is assigned the value 5 and becomes an integer scalar object (no longer untyped). In line 3, `C` becomes a HiQ Constant object with the value `<integer>`.

```
B = A.type;    //line 1
A = 5;         //line 2
C = A.type;    //line 3
```

**Table 4-14.** Untyped Object Properties

| Property | Data Type | Description |
|---|---|---|
| type | HiQ Constant[a] | Returns the type of the object. You can set this property to any HiQ Type Constant and the object changes to the specified type. |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

## Graph Objects

Two types of Graph objects exist in HiQ: 2D graphs and 3D graphs. Graphs do not contain data, but they contain plots that contain data. Use graphs to visually display a numeric set of data on the Notebook page.

For more information about graphs and their use, see Chapter 3, *Using HiQ Graphics*.

**Table 4-15.** Graph Object Properties

| Property | | Data Type | Description |
|---|---|---|---|
| axes.*property* | | | Sets properties for all axes at the same time. Replace *property* with the property you are setting or getting. See Table 4-16, *Axis Properties*, for a list and description of axes properties. |
| axis. | x.*property* | | Provides access to an x-axis property. Replace *property* with the property you are setting or getting. See Table 4-16, *Axis Properties*, for a list and description of axes properties. |
| | xy.*property* | | Sets both the x- and y-axis property at the same time. Replace *property* with the property you are setting or getting. See Table 4-16, *Axis Properties*, for a list and description of axes properties. |
| | xyz.*property* | | Sets properties of the x-, y-, and z-axes at the same time (3D only). Replace *property* with the property you are setting or getting. See Table 4-16, *Axis Properties*, for a list and description of axes properties. |
| | xz.*property* | | Sets properties of both the x- and z-axis at the same time (3D only). Replace *property* with the property you are setting or getting. See Table 4-16, *Axis Properties*, for a list and description of axes properties. |

**Table 4-15.** Graph Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| axis. (*continued*) | y(*n*).*property* | | Provides access to a property on any of the y-axes. Replace *n* with a comma separated list of axis index, a single index value, or a vector containing y-axis indexes. When getting a value, you can specify only one axis. Replace *property* with the property you are setting or getting. See Table 4-16, *Axis Properties*, for a list and description of axes properties. |
| | y.*property* | | Provides access to a y-axis property (in 2D graphs, the primary y-axis). Replace *property* with the property you are setting or getting. See Table 4-16, *Axis Properties*, for a list and description of axes properties. |
| | yz.*property* | | Sets properties of both the y- and z-axis at the same time. Replace *property* with the property you are setting or getting. See Table 4-16, *Axis Properties*, for a list and description of axes properties. |
| | z.*property* | | Provides access to a z-axis property (3D only). Replace *property* with the property you are setting or getting. See Table 4-16, *Axis Properties*, for a list and description of axes properties. |
| background. | border.color | HiQ Color | Defines the border color of the background area. |
| | border.style | HiQ Constant[a] | Defines the border style of the background area. |
| | color | HiQ Color | Defines the background color of the graph. |
| border. | color | HiQ Color | Defines the color of the graph border. |
| | style | HiQ Constant[a] | Defines the style of the graph border. |

**Table 4-15.** Graph Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| frame. | color | HiQ Color | Defines the color of the frame area. |
| | visible | Boolean | Displays the frame area of the graph when set to `true`. The frame area includes the area of the graph, which is filled with the frame color and the graph title. |
| legend. | backColor | HiQ Color | Defines the background color of the legend. |
| | border.color | HiQ Color | Defines the border color of the legend. |
| | border.style | HiQ Constant[a] | Defines the border style of the legend. |
| | font | HiQ Font | Defines the font of the legend. |
| | includeUntitled | Boolean | Defines which plots are included in the legend.<br>`true`—Shows all plots in the legend.<br>`false`—Shows only plots that have a title currently defined. |
| | textColor | HiQ Color | Defines the text color of the legend. |
| | visible | Boolean | Displays the legend when set to `true`. |
| plot(*n*).*property* | | | Provides access to the properties of an embedded plot. Replace *n* with the handle of the desired plot and *property* with the property you are setting or getting. |
| plots.*property* | | | Sets the properties of all embedded plots. Replace *property* with the property you are setting or getting. |
| title | | Text | Defines the title of the graph. |
| title. | color | HiQ Color | Defines the text color of the graph title. |
| | visible | Boolean | Displays the graph title when set to `true`. |
| type | | HiQ Constant[b] | Returns the type of the object. (Read Only) |

**Table 4-15.** Graph Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| **3D Properties (Valid for 3D Graphs)** | | | |
| dither | | Boolean | Defines the dither mode of the graph.<br><br>`true`—Dithering is enabled. Combinations of colors are used to approximate selected colors that cannot be directly displayed because of a limited number of display colors on the system.<br><br>`false`—Dithering is disabled.<br><br>Note: This property is valid on 256-color displays only. |
| fastDraw | | Boolean | Defines how the graph is drawn during interactive operations such as rotating, zooming, and panning.<br><br>`true`—Draws a reduced representation of the graph and its plots.<br><br>`false`—Draws the entire graph and its plots. Using this mode can create unresponsive interaction for complex graphs. |
| grid. | frameColor | HiQ Color | Defines the color of the grid frame. |
| | smoothing | Boolean | Defines the smoothing mode for grid lines.<br><br>`true`—Uses a technique called *anti-aliasing* to create smoother grid lines.<br><br>`false`—Draws grid lines without smoothing. |
| | xy | Boolean | Draws the X-Y grid plane when `true`. |
| | xz | Boolean | Draws the X-Z grid plane when `true`. |
| | yz | Boolean | Draws the Y-Z grid plane when `true`. |

**Table 4-15.** Graph Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| lights.*property* | | | Sets the properties of all lights. See Table 4-17, *Graph Light Properties*, for a list and description of light properties. |
| light(*n*).*property* | | | Provides access to the properties of a single light. Replace *n* with the index of the light, ranging from 1–4. See Table 4-17, *Graph Light Properties*, for a list and description of light properties. |
| lighting. | ambientColor | HiQ Color | Defines the ambient light color for the graph when lighting is enabled. |
| | enable | Boolean | Enables graph lighting when `true`. |
| projectionStyle | | HiQ Constant | Defines the projection style of the graph. Valid values include `<orthographic>` `<perspective>` |
| smoothing | | Boolean | Defines the smoothing mode for drawing plots on the graph.<br>`true`—Uses a technique called *anti-aliasing* to create smoother lines and polygons when drawing plots.<br>`false`—Draws plots without smoothing. |
| view. | autoDistance | Boolean | Defines how the viewing distance is set.<br>`true`—Viewing distance is automatically calculated.<br>`false`—Viewing distance is defined by the `view.distance` property. |
| | distance | Real | Specifies the distance of the viewing position from the origin. |
| | latitude | Real | Defines the latitude of the viewing position when the `view.mode` property is `<viewUserDefined>`. |

**Table 4-15.** Graph Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| view. (*continued*) | longitude | Real | Defines the longitude of the viewing position when the `view.mode` property is `<viewUserDefined>`. |
| | mode | HiQ Constant | Defines the viewing position of the graph. Valid values include `<viewXYPlane>` `<viewxzPlane>` `<viewyZPlane>` `<viewUserDefined>` |

a. For a complete list of HiQ Constants for border, see Table B-2, *Border Style Constants*, in Appendix B, *HiQ Constants*.

b. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

**Table 4-16.** Axis Properties

| Property | | Data Type | Description |
|---|---|---|---|
| label. | color | HiQ Color | Defines the color for the axis labels. |
| | decimalPlaces | Integer | Defines the number of decimal places to display for the axis labels. Valid values include `<auto>` and the range 0–15. |
| | font | HiQ Font | Defines the font for the axis labels. |
| | format | HiQ Constant | Defines the format of the labels. Valid values include `<decimal>` `<scientific>` `<engineering>` |
| | normal | Boolean | Draws the labels at the normal axis position when `true`. |
| | opposite | Boolean | Draws the labels at the opposite axis position when `true`. |

**Table 4-16.** Axis Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| majorGrid. | color | HiQ Color | Defines the color of the major grid lines. |
| | divisions | Integer | Defines the number of major grid divisions the axis contains. Valid values include <`auto`> and the range 1–100. |
| | insideTick | Boolean | Draws the tick marks on the inside of the axis when set to `true`. |
| | normalTick | Boolean | Draws tick marks at the normal axis location when set to `true`. |
| | oppositeTick | Boolean | Draws tick marks at the opposite axis location when set to `true`. |
| | outsideTick | Boolean | Draws the tick marks on the outside of the axis when set to `true`. |
| | visible | Boolean | Draws the major grid lines when `true`. |
| minorGrid. | color | HiQ Color | Defines the color of the minor grid lines. |
| | divisions | Integer | Defines the number of minor grid divisions between each major grid division. (Valid values: 1–100) |
| | insideTick | Boolean | Draws tick marks on the inside of the axis when `true`. |
| | normalTick | Boolean | Draws the tick marks at the normal axis location when `true`. |
| | oppositeTick | Boolean | Draws the tick marks at the opposite axis location when `true`. |
| | outsideTick | Boolean | Draws tick marks on the outside of the axis when `true`. |
| | visible | Boolean | Draws the minor grid lines when `true`. |

**Table 4-16.** Axis Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| range. | inverted | Boolean | Draws an inverted axis, starting with the minimum value and ending with the maximum value when this property is set to `true`. When `false`, this property draws the axis normally, starting with the maximum value and proceeding to the maximum value. |
| | max | Real | Defines the maximum value of the axis. |
| | min | Real | Defines the minimum value of the axis. |
| | mode | HiQ Constant | Specifies the range mode of the axis, which defines how to compute the range of the axis. Valid values include<br><`auto`>—Computes the minimum and maximum values for the axis based on the extents of the plots.<br><`manual`>—Uses the values of the `range.min` and `range.max` properties to define the range. |
| scaling.mode | | HiQ Constant | Defines the scaling of the axis. Axes can be scaled either linearly or logarithmically. Valid values include<br>`<linear>`<br>`<log>` |
| title | | Text | Defines the title of the axis. |

**Table 4-16.** Axis Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| title. | color | HiQ Color | Defines the color of the axis title. |
| | font | HiQ Font | Defines the font of the axis title. |
| | normal | Boolean | Draws the title at the normal axis position when `true`. |
| | opposite | Boolean | Draws the title at the opposite axis position when `true`. |
| visibility | | HiQ Constant | Defines the axis visibility. Valid values include<br><`on`>—Always visible.<br><`off`>—Never visible.<br><`auto`>—Drawn if the axis has an associated plot. |

**Table 4-17.** Graph Light Properties

| Property | Data Type | Description |
|---|---|---|
| attenuation | HiQ Constant | Defines the attenuation style of the light source. Valid values include <`none`>, <`linear`>, and <`quadratic`>. |
| color | HiQ Color | Defines the color of the light source. |
| distance | Real | Defines the distance of the light source from the origin of the graph. |
| enable | Boolean | Enables light when set to `true`. |
| latitude | Real | Defines the latitudinal position of the light source. |
| longitude | Real | Defines the longitudinal position of the light source. |

## Plot Objects

Two types of Plot objects exist in HiQ: 2D plots and 3D plots. Graphs contain plots, and plots contain the data that is actually graphed. You can view plots by placing them on graphs only.

**Table 4-18.** Plot Object Properties

| Property | | Data Type | Description |
|---|---|---|---|
| fill.color | | HiQ Color | Defines the fill color of the plot if you define the style as a filled plot. Filled plot styles include<br>`<verticalBar>`<br>`<horizontalBar>`<br>`<surface>`<br>`<surfaceLine>`<br>`<surfaceNormal>`<br>`<surfaceContour>` |
| line. | color | HiQ Color | Defines the line color of the plot. |
| | style | HiQ Constant | Defines the line style of the plot. Valid values include<br>`<solidLine>`<br>`<dotLine>`<br>`<dashLine>`<br>`<dotDashLine>`<br>If you set this property to anything other than `<solidLine>`, the line width is set to zero. |
| | width | Real | Defines the width of the line in points. If the value is greater than zero, the line style is set to `<solidLine>`. If you specify a zero line width, the line appears as narrow as possible while still remaining visible. (Valid Range: 0–100) |
| numGraphs | | Integer | Returns the number of graphs displaying the plot. (Read Only) |

**Table 4-18.** Plot Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| point. | color | HiQ Color | Defines the color of the points of the plot. |
| | frequency | Integer | Defines the frequency of points in the plot. For example, a frequency of one indicates that all points should be drawn. A frequency of two indicates that every other point should be drawn. This value must be greater than zero. |
| | size | Real | Defines the size of the plot points in points. (Valid range: 0–100) |
| | style | HiQ Constant | Defines the style of the point. Valid values include `<emptySquare>` `<solidSquare>` `<emptyCircle>` `<solidCircle>` `<diamond>` `<asterisk>` `<boldX>` `<noPoint>`<br>The following values are valid for 3D plots: `<wireframeSphere>` `<solidSphere>` `<wireframeCube>` `<solidCube>` |

**Table 4-18.** Plot Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| style | | HiQ Constant | Defines the style of the plot. Valid values for 2D plots include<br>`<point>`<br>`<line>`<br>`<linePoint>`<br>`<verticalBar>`<br>`<horizontalBar>`<br>Valid values for 3D surface plots include<br>`<point>`<br>`<line>`<br>`<hiddenLine>`<br>`<contour>`<br>`<surface>`<br>`<surfaceLine>`<br>`<surfaceNormal>`<br>`<surfaceContour>`<br>Valid values for 3D curve plots include<br>`<point>`<br>`<line>` |
| title | | Text | Defines the plot title. This title appears in the legend and on the graph. |
| title. | color | HiQ Color | Defines the color of the title displayed on the graph, not in the legend. |
| | font | HiQ Font | Defines the font of the plot title displayed on the graph, not in the legend. |
| | visible | Boolean | Displays the title on the graph when `true`. |
| type | | HiQ Constant[a] | Returns the type of the object. (Read Only) This property is valid for Plot objects only. |
| visible | | Boolean | Displays the plot on its graphs when set to `true`. |

**Table 4-18.** Plot Object Properties (Continued)

| Property | Data Type | Description |
|---|---|---|
| **2D Properties (Valid for 2D Plots)** | | |
| coordinateSystem | HiQ Constant | Defines the coordinate system of the plot. Valid values include `<cartesian>` `<polar>` |
| line.interpolation | HiQ Constant | Specifies the interpolation style used to draw the line of the plot. Valid values include<br>`<linear>`—Draws the plot point-to-point.<br>`<cubicSpline>`—Draws the plot with bezier curves that pass through each point. |
| yAxis | Integer | Defines the index of the y-axis with which the plot is associated. (Valid range: 1–8) |
| **3D Properties (Valid for 3D Plots)** | | |
| cacheData | Boolean | Improves drawing performance by caching intermediate calculations when set to `true`. However, you use more memory in the process. When `false`, the plot does not cache intermediate calculations, which reduces memory usage. |
| colorMap.style | HiQ Constant | Defines the color map used by the plot. Valid values include `<none>` `<shaded>` `<grayscale>` `<spectrum>` |
| contour(*n*).*property* | | Provides access to the properties of a single contour of the plot. See Table 4-19, *Plot Contour Properties*, for a list and description of contour properties. |

**Table 4-18.** Plot Object Properties (Continued)

| **Property** | | **Data Type** | **Description** |
|---|---|---|---|
| contour. | anchor.enable | Boolean | Enables the contour anchor if `true`. The anchor defines a value that a contour is guaranteed to pass through. |
| | anchor.value | Real | Defines the value of the contour anchor. |
| | basis | HiQ Constant | Defines the basis of the plots contours. Valid values include<br><`magnitude`>—Contours based on the magnitude data, if specified. Otherwise, contours based on the Z data.<br><`x`>—Contours based on X data.<br><`y`>—Contours based on Y data.<br><`z`>—Contours based on Z data. |
| | interval | Integer | Defines the distance between each level of the contour. When you set this value, the number of levels adjusts to accommodate the new interval. |
| | levelList | Real Vector | Defines the contour levels of the plot. Each element of the vector contains the position of a contour. |
| | levels | Integer | Defines the number of contour levels for the plot. |
| contours.*property* | | | Sets the properties of all plot contours at the same time. See Table 4-19, *Plot Contour Properties*, for a list and description of contour properties. |

**Table 4-18.** Plot Object Properties (Continued)

| Property | | Data Type | Description |
|---|---|---|---|
| coordinateSystem | | HiQ Constant | Defines the coordinate system of the plot. Valid values include `<cartesian>` `<cylindrical>` `<spherical>` |
| fill.style | | HiQ Constant | Defines the fill style of the plot. Valid values include `<smooth>` `<flat>` |
| projection. | xy | Boolean | Draws the X-Y plane projection of the plot when `true`. |
| | xz | Boolean | Draws the X-Z plane projection of the plot when `true`. |
| | yz | Boolean | Draws the Y-Z plane projection of the plot when `true`. |
| showProjectionsOnly | | Boolean | Defines the show projections only mode. `true`—Draws all projections that are currently enabled but does not draw the plot. `false`—Draws all projections that are currently enabled and draws the plot. |
| transparency | | Integer | Indicates the percentage of transparency, where a value of 0 specifies opaque and 100 specifies completely transparent. |

a. For a complete list of HiQ Constants for type, see Table B-1, *Object Type Constants*, in Appendix B, *HiQ Constants*.

**Table 4-19.** Plot Contour Properties

| Property | | Data Type | Description |
|---|---|---|---|
| color | | HiQ Color | Defines the color of the contour line. |
| label | | Text | Labels the contour. If the text contains a `%value`, the value of the level is substituted for the `%value` tag. If the text contains a `%level`, the level number is substituted for the `%level` tag. |
| label. | color | HiQ Color | Defines the color of the contour label. |
| | decimalPlaces | Integer | Defines the number of decimal places used to format the contour label. |
| | font | HiQ Font | Defines the font of the contour label. |
| | format | HiQ Constant | Defines the contour label format. Valid values include `<decimal>` `<scientific>` `<engineering>` |
| | visible | Boolean | Draws the contour label when `true`. |
| level | | Real | Defines the position of the plot. |
| style | | HiQ Constant | Defines the line style of the contour line. Valid values include `<solidLine>` `<dotLine>` `<dashLine>` `<dotDashLine>` |
| width | | Real | Defines the width of the contour line in points. (Valid range: 0–100) |

# 5 HiQ-Script Basics

This chapter introduces HiQ-Script, the built-in scripting language that you can use to build algorithms you need to solve your problems. Although HiQ-Script and its usages are demonstrated in Script objects, you also can use all the scripts in this chapter in the HiQ Command Window.

Although previous experience with programming languages is useful, it is not necessary. HiQ-Script draws from the most useful features of FORTRAN, Pascal, and C. In some ways, HiQ-Script is similar to pseudocode commonly used in algorithm descriptions, yet you can compile and run HiQ-Script.

To effectively program in HiQ-Script, you should be familiar with basic programming concepts as they apply to HiQ. This chapter introduces the following concepts:

- *HiQ-Script*
- *Naming Conventions*
- *Script Objects*
- *Comments*
- *Expressions*
- *Assignment Statements*
- *Numeric Objects*
- *User Functions*
- *Object Scope*
- *Flow Control and Looping*

You can find more detailed information about HiQ-Script syntax in Chapter 6, *HiQ-Script Reference*.

## HiQ-Script

With HiQ-Script, you can manipulate objects in a Notebook, control HiQ behavior, and when you are using ActiveX, control other applications. The Command Window and the Script object offer interfaces to HiQ-Script. The Command Window immediately executes a single statement of HiQ-Script and returns the results. A Script object contains a single statement or a series of statements that execute on command to perform specific tasks. Use Script objects to write custom algorithms that process data exactly the way you want it processed.

Unlike traditional programming languages, HiQ-Script does not require you to declare objects, allocate memory, or size objects before using them. Because HiQ-Script was engineered to eliminate these difficult tasks, you can concentrate on the real power of HiQ-Script—analysis and manipulation of your data.

When writing HiQ-Script, you are creating a series of commands to control HiQ objects. HiQ objects are the fundamental entities in HiQ. Examples of HiQ objects include Numeric, Graph, Text, and Script objects. Each object is designed to meet a particular data analysis and visualization need.

Numeric objects hold data you are analyzing and the values that your algorithms generate. HiQ Graph and Text objects let you visualize data. A Script object holds the HiQ-Scripts that you write. The Script object is essentially a text editor, similar to Notepad, with added features to help you write your scripts. For information about HiQ objects, see Chapter 4, *HiQ Objects and Object Properties*.

Because HiQ-Script is a typeless language, you do not need to declare an object or define its type before using it. By assigning a value of a different type to an object, you change the type of that object.

## Naming Conventions

To name an object in HiQ-Script, you can use all letters of the alphabet (both uppercase and lowercase), digits (0–9), and the underscore (_). Object names must start with a letter or an underscore.

☞ **Note** ***Because all names with two or more consecutive underscores are reserved by HiQ, you cannot use them when writing your programs.***

All object and function names must be unique. All names are case-sensitive in HiQ-Script (except for names of built-in functions, keywords, and constants). For example, the object `a` and the object `A` are two unique objects.

The names of built-in HiQ functions, keywords, and constants are *not* case-sensitive. For example, HiQ recognizes a call to the `cos` built-in function whether your HiQ-Script calls `cos`, `Cos`, `COS`, or even `cOs`.

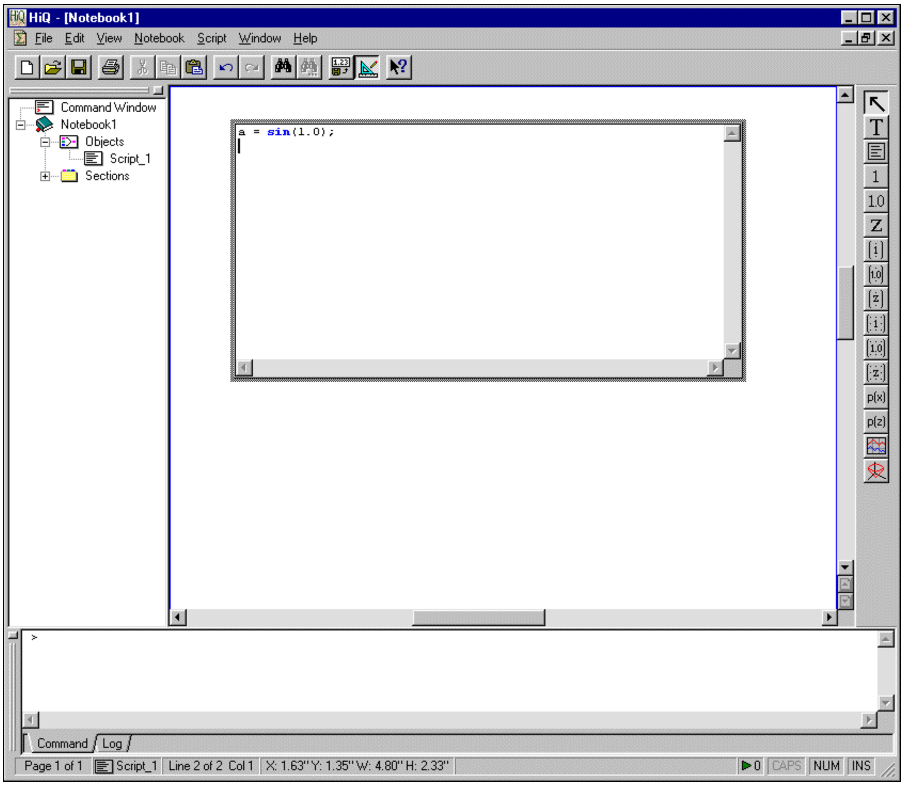
## Script Objects

A Script object contains a single statement or a series of statements that execute on command. To increase performance, HiQ-Script compiles to a pseudocode that is then executed.

To place a Script object on the Notebook page, select the Script tool from the toolbar and use your mouse to drag out a rectangle on the page. After creating the Script object, you can enter HiQ-Script. When the Script object view is active, you see a flashing caret. If the Script is not active, click on it. Type the following HiQ-Script.

```
a = sin(1.0);
```

Figure 5-1 shows the active Script object placed on the Notebook page.



```
a = sin(1.0);
```

**Figure 5-1.** Active Script Object on the Notebook Page

## Compiling Your Script

Right click on the script and select **Compile** from the popup menu. If entered correctly, the script successfully compiles. If you get a message in the **Compile Error** window, verify that you correctly typed the command and try compiling again.

Because HiQ automatically compiles a script before executing it, you do not have to manually compile a script. However, it is useful to help you find syntax errors as you write your HiQ-Script.

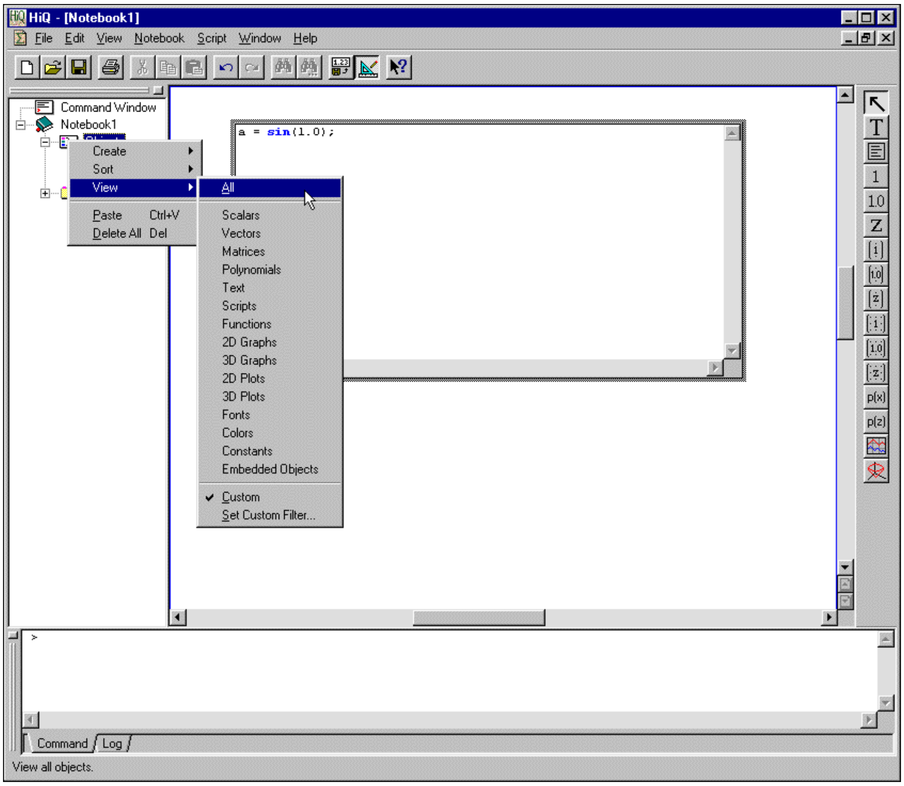
**Note** ***HiQ compiles scripts automatically before they are executed.***

While compiling the script, HiQ creates a new object that represents the executable pseudocode. This object is called a *function object*. You can distinguish function object names from their corresponding script objects by the `_Run` attached at the end of the function object name.

## Running Your Script

Right click on the Script and select **Run** from the popup menu. HiQ compiles and executes the lines in your script object. In this case, HiQ computes the sin of 1.0 and assigns the result to a new object `a`.

The Object List in the HiQ Explorer now contains two objects, `a` and `Script_1`. `Script_1` is the Script object, and `a` is the new object that was generated by running the script. Because function objects are filtered from the Object List by default, the function object `Script_1_Run` is hidden. You can view function objects in the Object List by right clicking on **Objects** and choosing **Objects»View»All**.



```
a = sin(1.0);
```

**Figure 5-2.** Select Objects»View»All to View Function Objects

### Syntax Highlighting

To make your scripts more readable, HiQ can automatically highlight syntax in your program. Right click on the script and select **Properties** to edit its properties. On the **View** page, you can change the font and font characteristics of the main script, comments, keywords, built-in functions, and constants.

## Comments

Use comments to annotate your script. Comments start with two forward slashes (`//`). All text that appears on a line after two forward slashes is treated as a comment. You can place a comment after HiQ-Script code. All of the following comments are valid.

```
//  This is the first comment.
```

```
a = 1;  //  This comment is after script code.
```

```
while a < 10 do
    v[a] = myFunction(a); // Use comments to explain your
                          // script code.
end while;
```

Comments explain your code to others and also help you document your algorithms.

## Expressions

An expression is a combination of symbols—operands, or values, and operators, such as +, -, *, and /—that represent a value. In HiQ, expressions consist of objects, numeric values, operators, and function calls. The following examples are valid expressions in HiQ.

```
3 + 4
```

```
3 + sin(3.14 + b)
```

```
sin(a) * cos(b) + c
```

Expressions cannot stand alone in HiQ-Script. In the following examples, the expressions are assigned to objects, making them valid HiQ-Script assignment statements.

```
a = 3.14;
```

```
b = 3 + sin(3.14 + b);
```

```
c = sin(a) * cos(b) + c;
```

Because expressions evaluate to a given value, you can use expressions in place of objects.

```
a = sin(x); // Evaluates the sin of a single object.
b = sin(x+y+2.5); // Evaluates the sin of an expression.
```

Expressions can be used only on the right side of an assignment statement. The following examples are illegal assignment statements.

```
3 = sin(4); // illegal
sin(b) + sin(a) = cos(d); // illegal
```

## Assignment Statements

The assignment statement is one of several types of statements in HiQ. It consists of two parts. To the right of the equal sign is an expression. To the left is the object to which you are assigning the expression. The following assignment statement assigns the value of the expression to the object `a`.

```
a = sin(1.0);
```

The expression consists of a single function call to the trigonometric function `sin`. The `sin` function is a HiQ built-in function.

You can call functions with the name of the function followed by the list of function parameters enclosed in parentheses. The `sin` function has only one parameter—the argument of the function—which is 1.0 in this case. The `sin` function returns the sine of the argument, and the statement assigns the result of the sine function to the object `a`.

☞ **Note** ***Notice that HiQ statements end with a semicolon (`;`). A semicolon indicates that a statement is complete. In HiQ, all statements end with a semicolon.***

HiQ executes each statement in the order that it appears. Changes to an object are reflected in the current statement. For example, the following two statements are equivalent to the third statement.

```
a = sin(3.14);
B = sin(a);


B = sin(sin(3.14));
```

In the first example, the object `a` is assigned the result of the expression `sin(3.14)`, and the object `B` is assigned the value of the expression `sin(a)`. The second example achieves the same result in one statement by assigning the sine of `sin(3.14)` to the value `B`.

## Numeric Objects

HiQ recognizes distinct numeric object types—scalars, vectors, matrices, and polynomials—and manipulates them using common mathematical syntax.

Because matrix and vector objects are linear algebra constructs, HiQ can perform common linear algebra operations on them. For example, the following script multiplies two matrices.

```
result = m1 * m2;
```

HiQ performs linear algebra matrix multiplication to complete this operation. However, you can multiply two scalar objects using the same syntax. HiQ knows how to complete the operation based on the type of the objects. If `m1` and `m2` are scalars, HiQ performs scalar multiplication.

### Creating Numeric Objects

HiQ creates a numeric object depending on how it is referenced in the script. For example, if the object being assigned to is referenced with a single subscript, HiQ creates a vector, as in the following example.

```
v[1] = 4; // v is a vector.
```

In this example, `v` is a one-element vector. If required, HiQ appropriately sizes an object to make the assignment. For example, the following script resizes the vector `v` to ten elements. A value of 8 is assigned to the tenth element, elements two through nine are initialized to zero, and the first element remains 4.

```
v[10] = 8;
```

Matrices behave the same way. The following script creates a matrix with five rows and eight columns. The value in row 5, column 8 is 1.5. All other elements are initialized to zero.

```
m[5,8] = 1.5;
```

You also can create vectors and matrices with built-in functions. The built-in functions `createVector` and `createMatrix` create vectors and matrices and initialize them. For example, the following statement creates a random 10-by-10 matrix.

```
m = createMatrix(10, 10, <random>);
```

## Initializer Syntax

If you want to create a vector or matrix with predetermined values, use the HiQ object initializer syntax. Object initializer syntax exists for most object types. The following initializer syntax creates a vector containing the values 1, 2, 3, and 4.

```
v = {vector: 1, 2, 3, 4};
```

In this assignment statement, the vector `v` is assigned the result of the initializer, `{vector: 1, 2, 3, 4}`.

Initializer syntax begins with an opening curly brace (`{`) and continues with the type of object to create, a colon (`:`), the value of the object, and finally a closing brace (`}`).

The following initializer syntax creates a 2-by-2 matrix.

```
m = {matrix: 1, 2; 3, 4};
```

Matrix `m` is a two element-by-two element matrix. The element at 1,1 is 1 and the element at 1,2 is 2, and so on. To indicate that the object is two-dimensional, use a semicolon (`;`) to mark the end of a row. Initializer syntax is described for each object in Chapter 6, *HiQ-Script Reference*.

**Note** ***If the object type is missing in the initializer syntax, HiQ creates a matrix object.***

## Subscripts

Use the subscript operator (`[ ]`) to access a single element. For example, the following syntax accesses the third element of the vector `v`.

```
v[3]
```

Because the subscript operator accepts any numeric value evaluating to an integer greater than zero, you can place an expression inside the subscript operator. Because vectors are one-dimensional, use a single index value to specify an element in a vector. To access a single value in a two-dimensional matrix object, specify the row index and the column index, separated with a comma. For example, the following expression accesses the element in the second row and third column of the matrix `m`.

```
m[2,3]
```

The following examples use valid subscripts to access elements of matrices and vectors.

```
v[6] = 12;
M[3,5] = v[7];
M[r,c] = m[2,3] + x;
M[4,5] = sin(v[1]) + cos(m[10,12]);
```

## Subranges

Use subranges to access a subrange of a complete vector or matrix. A subrange can be defined using two special operators—the colon (`:`) and the asterisk (*). Consider the following four-element vector.

```
v = {vector: 1, 2, 3, 4};
v2 = v;          // Make a copy of the entire vector.
w = v[1:3];      // Create an object with the first three
                 // elements of the vector v.
```

In the third line, the colon (`:`) and the subscript operator create a vector that contains the elements of `v` starting at one and ending at three. The following example creates a matrix using the first 2-by-2 elements of a matrix `m`.

```
m2 = m[1:2,1:2];
```

When you use the other subrange operator, `*`, you include either all elements of the object or all remaining elements of the object, depending on how you use it. For example, the following script creates a matrix, `m2`, with the first two rows of a matrix `m`, including all of the columns.

```
m2 = m[1:2,*];
```

The following example creates a vector containing the elements of `v` starting at 3 and continuing to the end.

```
v2 = v[3:*];
```

For more information about the subrange operators, see the *Subrange Operator* section in Chapter 6, *HiQ-Script Reference*.

## Polynomial Objects

Like vectors and matrices, polynomials can be created using the `createPoly` function or with polynomial initializer syntax. For example, the following script creates the polynomial x^2 + 2x + 1.

```
poly = {polynomial: "x^2 + 2x + 1"};
```

Because polynomials are a built-in object type, HiQ-Script performs polynomial algebra using the common algebraic operators. For example, the following script adds two polynomials, `p1` and `p2`, and then multiplies two polynomials.

```
p3 = p1 + p2;
p4 = p1 * p2;
```

Polynomials also behave like single-input, single-output functions.
For example, the following script evaluates a polynomial at the value 3.

```
result = p(3);
```

## Type Conversion

Each of the numeric objects—scalars, vectors, matrices, and polynomials—can have a numeric type of integer, real, or complex. HiQ determines the numeric type of an object based on the expression creating the object. For example, the following script creates an integer scalar.

```
x = 4;
```

The following script creates a real scalar.

```
x = 4.5;
```

HiQ uses the appropriate numeric type to compute an expression. For example, the following script adds an integer scalar to a real scalar to produce a real scalar.

```
x = 4;

y = 4.5;

z = x + y; // z is a real scalar.
```

HiQ provides built-in functions that force an object to a specific numeric type. For example, the following script creates an integer scalar from a real scalar.

```
x = toInteger(4.7); // x is an integer scalar.
```

You have two syntax options when referencing complex numbers. You can use ordered pairs to create a complex number, as in the following example where the real part is 3 and imaginary part is 2.

```
c = (3,2); // c is a complex scalar.
```

You also can use the HiQ constant `<i>`. The following script creates an identical complex number.

```
c = 3 + 2 * <i>; // c is a complex scalar.
```

## Numeric Constants

Numeric constants are predefined values in HiQ-Script. All numeric constants start with an open angle bracket (<) and end with a closed angle bracket (>). You cannot change the value of a numeric constant, but you can use a constant anywhere you use an expression, including within an expression.

Examples of numeric constants include `<pi>`, `<e>`, and `<i>`. The following assignment statements use valid numeric constants.

```
x = sin(<pi>);

y = sin(2 * <pi>);

z = 1 + <e>;
```

## User Functions

You can create your own functions in HiQ-Script. Consider the following example, which requires a value to be cubed many times.

```
A = (2*x + 3)^3;

B = (2*c + 3)^3;

D = (2*b + 3)^3;
```

Because these operations have to be executed many times, it is more efficient to encapsulate the whole process in a user function. You only have to define the function once, and then you can use it whenever you need it.

### Writing a Function

You can define a function anywhere in a Script object, except within another function definition. Functions begin with the keyword `function` and end with the keywords `end function`. If the function returns values, use the keyword `return` to specify which values to return.

For example, the following function `myCubedFunc` requires a single input, cubes the input, and then returns the result.

```
function myCubedFunc(x)
   result = (2*x + 3)^3;
   return result;
end function;
```

To use your function, you must compile the Script object, which creates the function object with the name of the function. In the preceding example, compiling the script creates a new function object named `myCubedFunc` that you can call from other scripts.

## Calling a Function

You can call user functions just as you would call built-in functions for computing results.

```
A = myCubedFunc(x);

B = myCubedFunc(c);

D = myCubedFunc(b);
```

User functions are HiQ objects, and they behave just like other objects in HiQ. User functions appear in the Object List of the Explorer. You can write as many functions as you want within a single script, and you can call them from any other script.

## Structure of a Function

It is important to understand the parts of a function. Consider the following user function.

```
function myFunc(x)
   result = (2*x + 3)^3;
   return result;
end function;
```

The `function` keyword indicates that you are starting a function. You can name the function any valid HiQ object name. In this case, the function name is `myFunc`. Following the function name is the parameter list. The parameter list contains a comma-delimited list of object names. If the function does not require parameters, do not include anything between the parentheses.

The body of the function consists of any HiQ-Script statements that you need for the function to compute. Although it is customary to indent the body statements within a function, it is not required. One you finish writing the function body, enter `end function;` to indicate that the function is completely defined.

## Return Statement

The `return` statement tells HiQ to exit the current function and return a value from the function. This value is the result of calling the function. The `return` does not need to be in the last line of the function, and it can return more than one object. For example, the following function returns two objects, `result1` and `result2`.

```
function multi(x)
   result1 = x^3;
   result2 = x^4;
   return result1, result2;
end function;
```

You can have the `multi` function return the first element, as in the following example.

```
a = multi(3);
```

Or you can retrieve both elements returned from the function, as in the following example.

```
[a,b] = multi(3);
```

To retrieve only the second item returned from the function, use a comma as a placeholder for the first returned object.

```
[,b] = multi(3);
```

## User Function Initialization Syntax

Using initializer syntax, you can define a new function dynamically while your HiQ-Script program is running. Function initialization syntax generally takes the following form.

`myFct = {function:`*`parameter_list:body`*`};`

The following example creates and uses a new function that takes one parameter and returns a value.

```
body = "cos(x)*sinh(x)";
myFct = {function:x:body};
y = myFct(x);
```

The definition of the function `myFct` is not required before running the script, as it is in the following example.

```
function myFct(x)
   return cos(x)*sinh(y);
end function;

y = myFct(x);
```

This syntax gives you the flexibility to create new functions using Text objects to define the script code. These Text objects can be placed on the

Notebook page and changed by the user without having to edit a Script object.

If the body of the function is more than one line, you must include a `return` statement in the body, as in the following example.

```
body = "y[1] = -10*x[1] + 10*t;" + <CRLF>;
body = body + "y[2] = -5*x[2] + 5*t;" + <CRLF>;
body = body + "return y;";
myFct = {function:x,t:body};
```

## Object Scope

Objects created in a user function are local to that function. No other functions or HiQ-Script can access them. HiQ assumes that all objects inside a function are *local*, and that all objects outside a function are *project*.

- *Local objects* do not appear in the Object List. Local objects are not saved with the notebook and are accessible only from within the function that uses them.
- *Project objects* are those that appear in the Object List for the Notebook. Project objects are saved with the notebook and can be accessed from any script.

You can change the scope of an object with the `project` and `local` keywords. The following script declares `result1` and `result2` as project objects. As project objects, `result1` and `result2` appear in the Object List after the function executes.

```
function multi(x)
   project result1, result2;
   result1 = x^3;
   result2 = x^4;
   return result1, result2;
end function;
```

Outside a function, the `local` keyword declares an object as local, indicating that it is temporary and not to be added to the Object List. For example, the following script uses an object named `temp`, which does not appear in the Notebook after the script completes.

```
local temp;
temp = sin(<pi>);
a = temp;
```

## Flow Control and Looping

HiQ-Script provides several constructs for controlling execution flow and repetition. Conditional statements (if-then-else and select) execute specific statements depending on a condition. Looping statements (for and while) execute a series of statements many times.

### If-Then-Else Statement

The following example assigns a different value to the object `b` depending on the condition defined for object `a`.

```
if a == 5 then
   b = 10;
else
   b = 0;
end if;
```

Following the keyword `if` is a conditional expression. In this example, if the conditional expression is true, the following statement is executed (the value 10 is assigned to the object `b`). If the conditional expression is false, the `else` statement is executed (a value of 0 is assigned to the object `b`).

You can omit the `else` if you do not want anything to happen, as in the following example.

```
if a == 5 then
   b = 10;
end if;
```

`B` is assigned the value 10 only if `a` equals 5. Otherwise, the value of `B` does not change.

You can have multiple conditional expressions in a single if-then-else statement. If you want `b` to be 10 if `a` is 5, or `b` to be 20 if `a` is 10, and `b` to be 0 otherwise, use the following script.

```
if a == 5 then
   b = 10;
else if a == 10 then
   b = 20;
else
   b = 0;
end if;
```

## Conditional Expressions

A conditional expression is any statement that involves a comparison evaluating to true or false. Consider the following script.

```
if a == 5 then
   b = 10;
else
   b = 0;
end if;
```

Although the expression `a == 5` looks like an assignment statement, the double equal sign (==) means *is equal to*. If `a` is equal to the value 5, `b` is assigned the value 10. Otherwise, `b` is assigned the value 0.

You can use the following operators in conditional expressions.

| **Operator** | **Description** |
|---|---|
| < | less than |
| > | greater than |
| <= | less than or equal to |
| >= | greater than or equal to |
| == | is equal to |
| != | not equal to |
| ! | logical NOT, which reverses the logic of an expression |

You can combine conditional expressions with the following operators.

| **Operator** | **Description** |
|---|---|
| `\|\|` | inclusive or |
| `or` | |
| `&&` | and |
| `and` | |

Use parentheses to control the order of evaluation. The following table contains valid examples of logical expressions.

| Expression | Description |
|---|---|
| a < b | a is less than b |
| (b <= c) \|\| (a != d) | b is less than or equal to c or a is not equal to d |
| !(b = c && c < d) | the opposite of the following statement:<br>b is equal to c and c is less than d |

To lean more about logical expressions in HiQ-Script, see the *Logical Expression* section in Chapter 6, *HiQ-Script Reference*.

## Select Statement

Use the select statement when you need to compare many conditions. The following example compares the object `a` to each of the defined cases and executes the appropriate case.

```
Select a from
   Case 5:
      B = 10;
   Case 10:
      B = 20;
   Default:
      B = 0;
End select;
```

In this example, if `a` is 5, `B` is set to 10. If `a` is 10, `B` is set to 20. Otherwise, `B` is set to zero.

## For Loop

The for loop repeats a series of statements a specified number of times. The following script creates a 20-element vector containing the values of the sine of the index.

```
for index=1 to 20 do
   v[index] = sin(index);
end for;
```

This code executes the statement `v[index] = sin(index)` twenty times, and each time `index` is incremented by 1. A for loop always begins with the keyword `for` and then a loop initializer, which indicates the name of the counter and the initial value of the counter. In this example, the loop initializer is `index=1`. The object `index` is the loop counter and it starts at a value of 1. This value also is changed at each iteration of the loop. You can use any object name for the counter. Following the loop initializer is the keyword `to` and then the terminating value for the counter. The terminating value is the last value the counter object should have when the loop stops executing.

After the `do` keyword are the body statements. In this case, there is one body statement, `v[index] = sin(index);`. You can have as many statements in the for loop body as you want, and you can use the loop counter in those expression, as long as an expression does not change the value of the loop counter. In this example, the loop counter is the index to the vector as well as the value for the `sin` function to evaluate. The loop counter cannot be modified within the body of the for loop.

After the body statements, the loop counter is incremented by one, and the new value is checked against the termination value. If the new value is equal to the terminating value the loop stops executing.

To increase the loop variable by a value other than 1, specify a step value using the `step` keyword. The following example increments the loop counter, `index`, by two at each iteration.

```
for index = 1 to 20 step 2 do
   v[index] = v[index] ^ 2;
end for;
```

## While Loop

The while loop repeats a series of statements until a condition is false. For example, the following script continues squaring a value until the result is greater than 1000.

```
while x < 1000 do
   x = x ^ 2;
end while;
```

This code keeps executing the statement `x = x ^ 2`, which squares the value of `x` and assigns the result back to `x`, as long as the value of the object `x` is less than 1000.

While loops always contain the keyword `while`, a conditional expression, the keyword `do`, and body statements. You can have as many statements as you want in the body. After the statements, enter `end while;` to mark the end of the loop.

HiQ executes the statements in the loop as long as the conditional statement is true. Because the conditional statement is executed first, when the conditional statement evaluates to false, the body statements are not executed. Always verify that the conditional expression will eventually evaluate to false, or the loop will execute forever. If a script does get stuck in an infinite loop, right click on the script and select **Terminate**.

# 6 HiQ-Script Reference

This chapter contains an alphabetical reference of HiQ-Script elements, including expressions and statements. If you are new to HiQ-Script, read Chapter 5, *HiQ-Script Basics*, before using this chapter.

## Algebraic Expression

### Purpose

Determines the values of algebraic operations.

### Syntax

```
literal
constant
object_name
object_name[subrange]
object_name.property
color_initializer
font_initializer
function_initializer
matrix_initializer
polynomial_initializer
vector_initializer
algebraic_binary_expr
algebraic_unary_expr
function_call
(algebraic_expression)
```

## Syntax Descriptions

| Name | Description |
|---|---|
| *literal* | An integer, real, complex, or text literal. |
| *constant* | A HiQ-Script constant. |
| *object_name* | The name of an object. |
| *subrange* | The subrange of *object_name* to get as the value of the expression. |
| *property* | The property or method of *object_name* to get as the value of the expression. |
| *color_initializer* | A color initializer. See *Color Initialization Operator*. |
| *font_initializer* | A font initializer. See *Font Initialization Operator*. |
| *function_initializer* | A function initializer. See *Function Initialization Operator*. |
| *matrix_initializer* | A matrix initializer. See *Matrix Initialization Operator*. |
| *polynomial_initializer* | A polynomial initializer. See *Polynomial Initialization Operator*. |
| *vector_initializer* | A vector initializer. See *Vector Initialization Operator*. |
| *algebraic_binary_expr* | An algebraic binary expression. See *Algebraic Binary Operators*. |
| *algebraic_unary_expr* | An algebraic unary expression. See *Algebraic Unary Operators*. |
| *function_call* | A call to a function. See *Function Call*. |

## Comments

For more information about properties and methods, see Chapter 4, *HiQ Objects and Object Properties*.

For more information about subranges, see *Subrange Operator* later in this chapter.

## See Also

*Precedence*, *Algebraic Unary Operators*, *Algebraic Binary Operators*, *Matrix Initialization Operator*, *Vector Initialization Operator*, *Polynomial Initialization Operator*, *Function Initialization Operator*, *Font Initialization Operator*, *Function Call*, *Subrange Operator*, *Integer Literal*, *Real Literal*, *Complex Literal*, *Text Literal*, *Constant*

## Algebraic Binary Operators

### Purpose

Performs an algebraic operation on two expressions.

### Syntax

*`expression1 operator expression2`*

### Syntax Descriptions

| Name | Description |
|---|---|
| *`expression1`*, *`expression2`* | Algebraic expressions. |
| *`operator`* | One of the following:<br>^ ** * / \ % + - .^ .** .* ./ .\ .% .+ .- |

### Comments

The following tables describe the various operations, the operand types allowed, and the type of the result.

#### Exponentiation (^ **)

| expression1 | expression2 | Result |
|---|---|---|
| integer scalar | real scalar | (1) |
| real scalar | real scalar | real scalar |
| scalar | complex scalar | complex scalar |
| matrix | integer scalar | same as *`expression1`* |
| polynomial | integer scalar | same as *`expression1`* |
| (1) If the result is expressible as an integer scalar, an integer scalar. Otherwise, a real scalar. | | |

## Multiplication (*)

| expression1 | expression2 | Result |
|---|---|---|
| integer scalar | integer scalar | (1) |
| scalar | scalar | (2) |
| matrix | matrix | (3) |
| scalar | matrix | (3) |
| matrix | scalar | (3) |
| scalar | vector | (4) |
| vector | scalar | (4) |
| scalar | polynomial | (5) |
| polynomial | scalar | (5) |
| vector | matrix | (3) |
| matrix | vector | (4) |

(1) An integer scalar unless the result overflows, in which case the result is a real scalar.

(2) If *expression1* or *expression2* is complex, a complex scalar. Otherwise, a real scalar.

(3) If either expression is complex, a complex matrix. If neither expression is complex and either is real, a real matrix. Otherwise, an integer matrix.

(4) If either expression is complex, a complex vector. If neither expression is complex and either is real, a real vector. Otherwise, an integer vector.

(5) If *expression1* or *expression2* is complex, a complex polynomial. Otherwise, a real polynomial.

## Division (/)

| expression1 | expression2 | Result |
|---|---|---|
| integer scalar | integer scalar | (1) |
| scalar | scalar | (2) |
| matrix | matrix | (3) |
| matrix | scalar | (3) |
| vector | scalar | (4) |
| polynomial | scalar | (5) |

(1) If *`expression1`* is divisible by *`expression2`*, an integer scalar. Otherwise, a real scalar.

(2) If *`expression1`* or *`expression2`* is complex, a complex scalar. Otherwise, a real scalar.

(3) If *`expression1`* or *`expression2`* is complex, a complex matrix. Otherwise, a real matrix.

(4) If *`expression1`* or *`expression2`* is complex, a complex vector. Otherwise, a real vector.

(5) If *`expression1`* or *`expression2`* is complex, a complex polynomial. Otherwise, a real polynomial.

For matrices **A** and **B**, **A**/**B** is equivalent to **A**`*`inv(**B**).

## Left Division (\)

| expression1 | expression2 | Result |
|---|---|---|
| integer scalar | integer scalar | (1) |
| scalar | scalar | (2) |
| matrix | vector | (3) |

(1) If *`expression2`* is divisible by *`expression1`*, an integer scalar. Otherwise, a real scalar.

(2) If *`expression1`* or *`expression2`* is complex, a complex scalar. Otherwise, a real scalar.

(3) If *`expression1`* or *`expression2`* is complex, a complex vector. Otherwise, a real vector.

For scalars a and b, a\b is equivalent to b/a.

For matrix **A** and vector **b**, **A****b** is equivalent to `solve(A,b)`.

## Mod (%)

| expression1 | expression2 | Result |
|---|---|---|
| integer scalar | integer scalar | integer scalar |
| integer scalar | real scalar | real scalar |
| real scalar | integer scalar<br>real scalar | real scalar |
| real polynomial | real polynomial | real polynomial |
| real polynomial | complex polynomial | complex polynomial |
| complex polynomial | real polynomial<br>complex polynomial | complex polynomial |

## Addition (+)

| expression1 | expression2 | Result |
|---|---|---|
| integer scalar | integer scalar | (1) |
| scalar | scalar | (2) |
| matrix | matrix | (3) |
| matrix | scalar | (3) |
| scalar | matrix | (3) |
| scalar | vector | (4) |
| vector | scalar | (4) |
| vector | vector | (4) |
| polynomial | scalar | (5) |
| scalar | polynomial | (5) |
| text | text | text |

(1) An integer scalar unless the result overflows, in which case the result is a real scalar.

(2) If *`expression1`* or *`expression2`* is complex, a complex scalar. Otherwise, a real scalar.

(3) If either expression is complex, a complex matrix. If neither expression is complex and either is real, a real matrix. Otherwise, an integer matrix.

(4) If either expression is complex, a complex vector. If neither expression is complex and either is real, a real vector. Otherwise, an integer vector.

(5) If *`expression1`* or *`expression2`* is complex, a complex polynomial. Otherwise, a real polynomial.

Addition of a scalar to vectors or matrices adds the scalar to each element of the vector or matrix.

Addition of text appends the second operand to the first.

## Subtraction (-)

| **expression1** | **expression2** | **Result** |
|---|---|---|
| integer scalar | integer scalar | (1) |
| scalar | scalar | (2) |
| matrix | matrix | (3) |
| matrix | scalar | (3) |
| scalar | matrix | (3) |
| scalar | vector | (4) |
| vector | scalar | (4) |
| vector | vector | (4) |
| polynomial | scalar | (5) |
| scalar | polynomial | (5) |

(1) An integer scalar unless the result overflows, in which case the result is a real scalar.

(2) If *`expression1`* or *`expression2`* is complex, a complex scalar. Otherwise, a real scalar.

(3) If either expression is complex, a complex matrix. If neither expression is complex and either is real, a real matrix. Otherwise, an integer matrix.

(4) If neither expression is complex, a complex vector. If neither expression is complex and either is real, a real vector. Otherwise, an integer vector.

(5) If *`expression1`* or *`expression2`* is complex, a complex polynomial. Otherwise, a real polynomial.

Subtraction of a scalar from vectors and matrices subtracts the scalar from each element of the vector or matrix.

## Elementwise Exponentiation (.^ .**)

| **expression1** | **expression2** | **Result** |
|---|---|---|
| matrix | scalar | (1) |
| matrix | matrix | (1) |
| vector | scalar | (2) |
| vector | vector | (2) |
| (1) If *`expression1`* or *`expression2`* is complex, a complex matrix. Otherwise, a real matrix. (2) If *`expression1`* or *`expression2`* is complex, a complex vector. Otherwise, a real vector. | | |

If the second operand is a scalar, the operation is equivalent to standard exponentiation.

For matrices **A** and **B**: **C** = **A** .^ **B** means **C**[**i**,**j**] = **A**[**i**,**j**]^**B**[**i**,**j**].

For vectors **a** and **b**: **c** = **a**.^ **b** means **c**[**i**] = **a**[**i**]^**b**[**i**].

## Elementwise Multiplication (.*)

| **expression1** | **expression2** | **Result** |
|---|---|---|
| matrix | matrix | (1) |
| vector | vector | (2) |
| (1) If either expression is complex, a complex matrix. If neither expression is complex and either is real, a real matrix. Otherwise, an integer matrix. (2) If either expression is complex, a complex vector. If neither expression is complex and either is real, a real vector. Otherwise, an integer vector. | | |

For matrices **A** and **B**: **C** = **A** .* **B** means **C**[**i**,**j**] = **A**[**i**,**j**]*B[**i**,**j**].

For vectors **a** and **b**: **c** = **a**.* **b** means **c**[**i**] = **a**[**i**]*b[**i**].

## Elementwise Division (./)

| expression1 | expression2 | Result |
|---|---|---|
| matrix | matrix | (1) |
| vector | vector | (2) |
| (1) If *expression1* or *expression2* is complex, a complex matrix. Otherwise, a real matrix.<br>(2) If *expression1* or *expression2* is complex, a complex vector. Otherwise, a real vector. | | |

For matrices **A** and **B**: **C** = **A** ./ **B** means **C**[**i**,**j**] = **A**[**i**,**j**]/**B**[**i**,**j**].

For vectors **a** and **b**: **c** = **a**./ **b** means **c**[**i**] = **a**[**i**]/**b**[**i**].

## Elementwise Left Division (./)

| expression1 | expression2 | Result |
|---|---|---|
| matrix | matrix | (1) |
| vector | vector | (2) |
| (1) If *expression1* or *expression2* is complex, a complex matrix. Otherwise, a real matrix.<br>(2) If *expression1* or *expression2* is complex, a complex vector. Otherwise, a real vector. | | |

For matrices **A** and **B**: **C** = **A** .\ **B** means **C**[**i**,**j**] = **B**[**i**,**j**]/**A**[**i**,**j**].

For vectors **a** and **b**: **c** = **a**.\ **b** means **c**[**i**] = **b**[**i**]/**a**[**i**].

## Elementwise Mod (.%)

| expression1 | expression2 | Result |
|---|---|---|
| matrix | matrix | (1) |
| vector | vector | (2) |
| (1) If either is complex, a complex matrix. If neither expression is complex and either is real, a real matrix. Otherwise, an integer matrix.<br>(2) If either is complex, a complex vector. If neither expression is complex and either is real, a real vector. Otherwise, an integer vector. | | |

For matrices **A** and **B**: **C** = **A** .% **B** means **C**[**i**,**j**] = **A**[**i**,**j**]%**B**[**i**,**j**].

For vectors **a** and **b**: **c** = **a**.% **b** means **c**[**i**] = **a**[**i**]%**a**[**i**].

## Elementwise Addition (.+)

| expression1 | expression2 | Result |
|---|---|---|
| matrix | matrix | (1) |
| vector | vector | (2) |
| (1) If either expression is complex, a complex matrix. If neither expression is complex and either is real, a real matrix. Otherwise, an integer matrix. (2) If either expression is complex, a complex vector. If neither expression is complex and either is real, a real vector. Otherwise, an integer vector. | | |

## Elementwise Subtraction (.-)

| expression1 | expression2 | Result |
|---|---|---|
| matrix | matrix | (1) |
| vector | vector | (2) |
| (1) If either expression is complex, a complex matrix. If neither expression is complex and either is real, a real matrix. Otherwise, an integer matrix. (2) If either expression is complex, a complex vector. If neither expression is complex and either is real, a real vector. Otherwise, an integer vector. | | |

## See Also

*Algebraic Expression*, *Algebraic Unary Operators*, *Precedence*

## Algebraic Unary Operators

### Purpose

Performs an algebraic operation an expression.

### Syntax

```
expression postfix_operator
prefix_operator expression
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *expression* | An algebraic expression. |
| *postfix_operator* | ' |
| *prefix_operator* | - |

### Comments

The following tables describe the various operations, the operand types allowed, and the type of the result.

#### Conjugate Transpose (‘)

| expression | Result |
|---|---|
| integer matrix<br>integer vector | integer matrix |
| real matrix<br>real vector | real matrix |
| complex matrix<br>complex vector | complex matrix |

A transpose on an *n*-element vector returns a 1-by-*n* matrix.

## Additive Inverse (-)

| **expression** | **Result** |
|---|---|
| integer scalar | integer scalar |
| real scalar | real scalar |
| complex scalar | complex scalar |
| integer matrix<br>real matrix | real matrix |
| complex matrix | complex matrix |
| integer vector<br>real vector | real vector |
| complex vector | complex vector |
| real polynomial | real polynomial |
| complex polynomial | complex polynomial |

## See Also

*Algebraic Expression*, *Algebraic Binary Operators*, *Precedence*

## Assignment

### Purpose

Evaluates an expression and places the result in an object.

### Syntax

#### Form 1

```
variable = expression;
```

#### Form 2

```
[variable_list] = function_name(argument_list);
```

#### Form 3

```
variable[subrange] = expression;
```

#### Form 4

```
variable.property = expression;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *`variable`* | The name of the object to be modified. |
| *`expression`* | Any valid algebraic expression. |
| *`variable_list`* | A comma-separated list of object names to be modified. |
| *`function_name`* | The name of a built-in or user-defined function. Built-in function names are not case sensitive. User-defined function names are case sensitive. |
| *`argument_list`* | An optional list of algebraic expressions to pass to the function. |
| *`subrange`* | The portion of *`variable`* to receive the value of *`expression`*. |
| *`property`* | The property of *`variable`* to receive the value of *`expression`*. |

## Comments

If the object `variable` (or any object in `variable_list` in Form 2) has its value locked, the assignment fails.

In Forms 1 and 2, if the object to which you are assigning does not have its data type locked, the object becomes the type of the value from which you are assigning.

In Forms 1 and 2, if the object to which you are assigning has its data type locked and if the type of the value from which you are assigning is coercible into the object type to which you are assigning, the value is coerced, leaving the type of the object unchanged. Otherwise, an error occurs.

In Form 3, if the type of *`expression`* is coercible into the type of *`variable`*, the coercion occurs. If the type of *`variable`* can be coerced to accept *`expression`* and the data type of *`variable`* is not locked, *`variable`* changes type. Otherwise, an error occurs. If the subrange is beyond the range of *`variable`*, *`variable`* grows to accommodate that range.

Type matching for Form 4 occurs based on the property. See Chapter 4, *HiQ Objects and Object Properties*, for valid property values for all HiQ objects.

Logical expressions cannot be assigned in HiQ. For example, the following assignment is not valid:

```
a = b < 3;
```

## See Also

*Algebraic Expression*, *Function Call*, *Property Operator*, *Subrange Operator*

## assume

### Purpose

Sets the scope for variables.

### Syntax

```
assume local;
assume project;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| `assume local` | All objects in the function have local scope unless explicitly declared as project. |
| `assume project` | All objects in the function have project scope unless explicitly declared as local. |

### Comments

An object with local scope appears in the Explorer and can be shared by all functions in the Notebook. An object with local scope can be used only by the function in which it is declared, and the object is destroyed when the function ends.

### See Also

*project*, *local*

## Color Initialization Operator

### Purpose

Creates a color from a set of algebraic expressions.

### Syntax

`{color: `*`red`*`, `*`green`*`, `*`blue`*`}`

### Syntax Descriptions

| Name | Description |
|---|---|
| `red` | An integer expression denoting the red component. |
| `green` | An integer expression denoting the green component. |
| `blue` | An integer expression denoting the blue component. |

### Comments

Specify color components ranging from 0 to 255. Values outside the range are legal but are constrained to the range. For example, if you specify a value of 300, the color value defaults to 255.

### See Also

*Matrix Initialization Operator*, *Vector Initialization Operator*, *Polynomial Initialization Operator*, *Function Initialization Operator*, *Font Initialization Operator*, *Algebraic Expression*

## Complex Literal

### Purpose

Represents a complex value.

### Syntax

(*realPart, imaginaryPart*)

### Syntax Descriptions

| Name | Description |
|---|---|
| *realPart* | A real literal describing the real part of the complex value. |
| *imaginaryPart* | A real literal describing the imaginary part of the complex value. |

### Comments

Each part of the complex value must be in the range –1.79e308 to 1.79e308.

### See Also

*Real Literal*, *Integer Literal*, *Text Literal*

## Constant

### Purpose

Defines a constant value.

### Syntax

```
<constant>
TRUE
FALSE
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *`constant`* | The name of a HiQ-Script constant. |
| `TRUE` | A keyword evaluating to 1. |
| `FALSE` | A keyword evaluating to 0. |

### Comments

For a list of the valid HiQ-Script constants, see the *HiQ Constants* topic in the online help.

### See Also

*Algebraic Expression*, *Logical Expression*

## exit

### Purpose

Terminates processing of a block of statements. Execution begins at the statement following the block exited.

### Syntax

```
exit;
exit block-type;
exit count block-type;
exit block-type;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *block-type* | A keyword from the following list:<br><br>if<br>for<br>while<br>repeat<br>select<br>block<br><br>ifs<br>fors<br>whiles<br>repeats<br>selects<br>blocks |
| *count* | An integer literal indicating the number of blocks to exit. |

### Comments

If the *block-type* is not used, the function jumps out of the innermost block.

If *block-type* is used, the function continues executing at the first statement after the end of that block type, even if it requires jumping out of other block types.

The block keyword refers to any statement block type.

## Font Initialization Operator

### Purpose

Creates a font from a set of expressions.

### Syntax

`{font: name, size}`

### Syntax Descriptions

| Name | Description |
|---|---|
| *name* | A text expression containing the font name. |
| *size* | An integer expression containing the point size of the font. |

### Comments

If the font specified by *name* is not on your computer, the operating system returns its best match. As a result, the initialization does not fail if the font requested is not on the computer.

*size* must be a positive integer.

### See Also

*Matrix Initialization Operator*, *Vector Initialization Operator*, *Polynomial Initialization Operator*, *Color Initialization Operator*, *Function Initialization Operator*

## for

### Purpose

Repeatedly executes a block of statements. A counter variable updates at each iteration.

### Syntax

```
for counter = start to finish do
      statements
end for;

for counter = start to finish step step-size do
      statements
end for;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *`counter`* | Name of object to modify on each iteration. |
| *`start`* | An algebraic expression that evaluates to an integer or real scalar. *`counter`* is set to the result of the expression. |
| *`finish`* | An algebraic expression that evaluates to an integer or real scalar. *`counter`* is incremented by 1 or *`step-size`*, if specified, until it reaches the result of the expression. |
| *`step-size`* | An algebraic expression that evaluates to an integer or real scalar. *`counter`* is incremented by the result of the expression on each iteration. |
| *`statements`* | Zero or more statements. |

### Comments

*`counter`* is an integer if *`start`*, *`finish`*, and *`step-size`* (if present) are all integers. Otherwise, *`counter`* is real. The expressions for *`start`*, *`finish`*, and *`step-size`* are calculated before the loop begins and not re-evaluated each iteration. At the start of each iteration, HiQ sets the value of `counter` for the $n^{th}$ iteration using the formula

$$\texttt{counter} = \texttt{start} + (n - 1) * \texttt{step-size}$$

*`counter`* cannot be changed by the *`statements`*. If a statement performs a function call passing *`counter`* as a parameter, the function cannot change its value.

### See Also

*while*, *repeat*, *next*, *exit*, *Algebraic Expression*

## function

### Purpose

Defines a function.

### Syntax

```
function name(param_list)
      statements
end function;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *name* | Name of the function. The name must be a valid object name and cannot be the name of the script in which the function resides. |
| *param_list* | Optional comma-delimited list of parameter names. The parameter names must be object names. |
| *statements* | One or more valid statements. |

### Comments

The caller can call a function with fewer parameters than specified. The object `__ins` holds the number of parameters with which the caller called the function.

The caller can request a different number of returns than specified in a return statement. The object `__outs` holds the number of parameters the caller requested.

You can reference function parameters with the array `__param`, as in the following example.

```
function foo(a,b,c,d)
   select d from
      case 1: return __param[1]; //returns a
      case 2: return __param[2]; //returns b
      case 3: return __param[3]; //returns c
      default: return __param[4]; //returns d
   end select;
end function;
```

Function blocks are not statements; that is, they cannot appear inside any statement block. They can appear only in the scope of external statements.

The position in which a function call appears in relation to its definition is not important. It can appear before, after, or within another script.

The default scoping for functions is local. For a complete description of scoping, see the *assume* section earlier in this chapter.

None of the parameter names in `param_list` can have the same name as `name` or as the name of the script in which the function resides.

## See Also

*return*, *Function Initialization Operator*

## Function Call

### Purpose

Calls a built-in or user-defined function.

### Syntax

```
function_name(argument_list);
variable = function_name(argument_list);
[variable_list] = function_name(argument_list);
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *function_name* | The name of a built-in or user-defined function. Built-in function names are not case sensitive. User-defined function names are case sensitive. |
| *argument_list* | An optional list of algebraic expressions to pass to the function. |
| *variable* | The name of the object to receive the returned value of the function. If the function returns more than one value, *variable* receives the first returned value. |
| *variable_list* | A comma-delimited list of object names to receive the returned values of the functions. The objects receive values in the order they are returned by the called function. If you do not want a specific value, omit names in *variable_list*, as in the following example. `[,b,c] = f();` The first value returned by `f` is discarded, `b` receives the second value, and `c` receives the third value. |

### Comments

Objects passed as parameters to a function are passed by reference. That is, the function can modify the object value. Any subrange or property passed as a parameter to a function is passed by value. That is, a copy of the subrange or property is passed to the function, and the value of the subrange or property cannot be changed.

### See Also

*function*, *return*, *Assignment*

## Function Initialization Operator

### Purpose

Creates a function from an expression.

### Syntax

```
{f: body}
{f: arglist: body}
{func: body}
{func: arglist: body}
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *arglist* | A comma-delimited list of parameters for the function. |
| *body* | A text expression that contains the body of the function. |

### Comments

The *body* of the generated function behaves differently depending on whether a semicolon is present. If a semicolon is present, *body* is interpreted as a complete sequence of statements. The following two code examples provide identical results.

```
minimum={func: x,y: “if (x < y) then return x; else return y; endif;”};
```

```
function minimum(x, y)
   if (x < y) then
      return x;
   else
      return y;
   endif;
end function;
```

If a semicolon is absent, *`body`* is interpreted as an algebraic expression and the return value of the function. All variables used are assumed to have project scoping. The following two code examples provide identical results.

```
aSinPlusCos = {func: x: “a * sin(x) + cos(x)”};


function aSinPlusCos(x)
   assume project;
   return a * sin(x) + cos(x);
end function;
```

## See Also

*Matrix Initialization Operator*, *Vector Initialization Operator*, *Polynomial Initialization Operator*, *Color Initialization Operator*, *Font Initialization Operator*, *function*, *assume*

## if

### Purpose

Executes a block of statements only when a condition is true.

### Syntax

#### Form 1

```
if condition then
      statements
end if;
```

#### Form 2

```
if condition then
      statements
else
      statements
end if;
```

#### Form 3

```
if condition then
      statements
else if condition then
      statements
         .
         .
         .
else
      statements
end if;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *condition* | A logical expression. The statements in the block are executed only if the expression evaluates to true. |
| *statements* | Zero or more statements. |

## Comments

You can specify the else if block repeatedly and omit the else block.

Conditions are evaluated in the order that they appear.

Conditions are completely evaluated and do not short circuit as in C and C++. In the following example, the expression `f(3)` is evaluated even if a < b.

```
if a < b or f(3) = 7 then
   //statements omitted
end if;
```

## See Also

*while*, *select*, *exit*, *Logical Expression*

## Integer Literal

### Purpose

Represents an integer value.

### Syntax

`integer`

### Syntax Descriptions

| Name | Description |
|---|---|
| `integer` | An sequence of digits, optionally preceded by a minus sign. |

### Comments

Integers must be in the closed range [$-2^{31}-1$, $2^{31}$].

### See Also

*Real Literal*, *Complex Literal*, *Text Literal*

## local

### Purpose

Defines the scope of a list of variables as local.

### Syntax

`local` *`variable_list`*`;`

### Syntax Descriptions

| **Name** | **Description** |
|---|---|
| *`variable_list`* | Comma-delimited list of variable object names. |

### Comments

The default scoping for functions is local. For a complete description of scoping, see *assume* earlier in this chapter.

### See Also

*assume*, *project*

## Logical Expression

### Purpose

Used by flow-control constructs to determine the path of execution.

### Syntax

```
algebraic_expression
logical_unary_expr
logical_binary_expr
relational_expr
```

### Syntax Descriptions

| Name | Description |
|---|---|
| `algebraic_expression` | An algebraic expression that evaluates to an integer scalar. |
| `logical_unary_expr` | A logical unary expression. See *Logical Unary Operators*. |
| `logical_binary_expr` | A logical binary expression. See *Logical Binary Operators*. |
| `relational_expr` | A relational expression. See *Relational Operators*. |

### Comments

An integer is considered true if its value is not zero and false if its value is zero.

### See Also

*Algebraic Expression*, *Precedence*, *Logical Unary Operators*, *Logical Binary Operators*, *Relational Operators*

## Logical Binary Operators

### Purpose

Performs a logical operation on two expressions.

### Syntax

#### Form 1

```
expression1 and expression2
expression1 && expression2
```

#### Form 2

```
expression1 or expression2
expression1 || expression2
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *expression1*, *expression2* | An algebraic or logical expression. If *expression* is an algebraic expression, it must be an integer. |

### Comments

The value of Form 1 is true if both expressions are true. Otherwise, it is false.

The value of Form 2 is true if either expression or both expressions are true. Otherwise, it is false.

An integer is considered true if its value is not zero and false if its value is zero.

### See Also

*Logical Expression*, *Logical Unary Operators*, *Relational Operators*

## Logical Unary Operators

### Purpose

Performs a logical operation on an expression.

### Syntax

#### Form 1

```
not expression
```

#### Form 2

```
! expression
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *`expression`* | An algebraic or logical expression. If *`expression`* is an algebraic expression, it must be an integer scalar. |

### Comments

If *`expression`* is false, the value of both forms is true. If *`expression`* is true, the value of both forms is false.

An integer is considered true if its value is not zero and false if its value is zero.

### See Also

*Logical Expression*, *Logical Unary Operators*, *Relational Operators*

## Matrix Initialization Operator

### Purpose

Creates a matrix from a set of expressions.

### Syntax

```
{row_list_1; row_list_2; … row_list_n}
{m: row_list_1; row_list_2; … row_list_n}
{matrix: row_list_1; row_list_2; … row_list_n}
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *row_list* | A comma-delimited list of algebraic expressions. |

### Comments

The list must consist only of scalars, vectors, and matrices. Vectors are inserted into the matrix as columns. To insert a vector as a row, use the transpose operator.

Within each *row_list* all expressions must have the same number of rows. All *row_lists* must have the same number of columns.

If any element in the *row_list* is complex, the resulting matrix is complex. If no element is complex and any element is real, the resulting matrix is real. Otherwise, the resulting matrix is integer.

### See Also

*Algebraic Unary Operators*, *Vector Initialization Operator*, *Polynomial Initialization Operator*, *Color Initialization Operator*, *Function Initialization Operator*, *Font Initialization Operator*

*createMatrix* in Chapter 7, *Function Reference*

## next

### Purpose

Continues on to the next state.

### Syntax

```
next;
next block_type;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *`block_type`* | A keyword from the following list.<br>`case`<br>`for`<br>`while`<br>`repeat` |

### Comments

In a for loop, while loop, or repeat loop, `next` causes execution to continue at the end statement for that block.

In a select block, `next` causes execution to jump to the next case of the select if there is one. Otherwise, execution jumps to the end of the select block. You must use the *`block_type`* case in a select block.

If *`block_type`* is used, the function continues executing at the first statement after the end of that block type, even if it requires jumping out of other block types.

### See Also

*select*, *for*, *while*, *repeat*

## Polynomial Initialization Operator

### Purpose

Creates a polynomial from a set of expressions.

### Syntax

#### Form 1

```
{p: expression_list}
{polynomial: expression_list}
```

#### Form 2

```
{p: init_text}
{polynomial: init_text}
```

### Syntax Descriptions

| **Name** | **Description** |
|---|---|
| `expression_list` | A comma separated list of algebraic expressions. |
| `init_text` | A text representation of the polynomial. |

### Comments

In Form 1, the coefficients are taken from the `expression_list` highest order first. For example, `{p:1,0,2}` is the polynomial $x^2 + 2$.

In Form 2, you must use the variable **x**. You can omit the multiplication sign and use either ^ or ****** to indicate exponentiation. For example, the following polynomial is valid:

```
"5x^3+2x^2-x+1"
```

### See Also

*Matrix Initialization Operator*, *Vector Initialization Operator*, *Color Initialization Operator*, *Function Initialization Operator*, *Font Initialization Operator*

*createPoly* in Chapter 7, *Function Reference*

## Precedence

### Purpose

Determines the order in which expressions are evaluated.

### Comments

The following table describes the order of evaluation of HiQ expressions.

| Operator Precedence Higher to Lower | Direction of Evaluation |
|---|---|
| . (Property) [ ] (Subscript) | Left to right. |
| ( ) (Grouping) | Left to right. |
| + (unary) - (unary) not ! | Right to left. |
| ^ ** | Left to right. |
| * / \ % | Left to right. |
| + (binary) - (binary) | Left to right. |
| < <= > >= != <> = == | Left to right. |
| and && | Left to right. |
| or \|\| | Left to right. |

### See Also

*Logical Unary Operators*, *Logical Binary Operators*, *Relational Operators*, *Algebraic Unary Operators*, *Algebraic Binary Operators*, *Property Operator*, *Subrange Operator*

## project

### Purpose

Defines the scope of a list of variables to be project.

### Syntax

```
project variable_list;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *`variable_list`* | Comma-delimited list of object names. |

### Comments

The default scoping for functions is local. For a complete description of scoping, see *assume* earlier in this chapter.

### See Also

*assume*, *local*

## Property Operator

### Purpose

Accesses a property or method of an object.

### Syntax

`object.operator`

### Syntax Descriptions

| Name | Description |
|---|---|
| *`object`* | The object whose property or method is accessed. |
| *`operator`* | The property or method. |

### Comments

For a complete list and description of HiQ object properties, see Chapter 4, *HiQ Objects and Object Properties*.

## Real Literal

### Purpose

Represents an real value.

### Syntax

```
wholepart.
wholepart.fractionalPart
.fractionalPart
wholepart.Epower
wholepart.fractionalPartEpower
.fractionalPart.Epower
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *wholepart* | The whole portion of the real. |
| *fractionalPart* | The fractional portion of the real. |
| *power* | The power of ten by which the rest of the number is multiplied. |

### Comments

The range of reals in HiQ is –1.79e308 to 1.79e308.

The following are examples of real literals:

4.5
1.35E-5
0.3513
12.

### See Also

*Integer Literal*, *Complex Literal*, *Text Literal*

## Relational Operators

### Purpose

Performs a comparison of two expressions.

### Syntax

#### Form 1—Equality

```
expression1 = expression2
expression1 == expression2
```

#### Form 2—Inequality

```
expression1 <> expresssion2
expression1 != expresssion2
```

#### Form 3—Greater Than

```
expression1 > expression2
```

#### Form 4—Less Than

```
expression1 < expression2
```

#### Form 5—Greater Than Or Equal To

```
expression1 >= expression2
```

#### Form 6—Less Than Or Equal To

```
expression1 <= expression2
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *expression1, expression2* | Algebraic expressions. In addition Forms 1 and 2 can be logical expressions. |

### Comments

For all relational operations, if the relationship is true, the result is true. If the relationship is false, the result is false.

Forms 1 and 2 accept the following combinations of types for the expressions:

| **expression1** | **expression2** |
|---|---|
| integer, real, or complex scalar | integer, real, or complex scalar |
| integer, real, or complex vector | integer, real, or complex vector |
| integer, real, or complex matrix | integer, real, or complex matrix |
| real or complex polynomial | real or complex polynomial |
| text | text |

Forms 3 through 6 accept the following combinations of types for the expressions:

| **expression1** | **expression2** |
|---|---|
| integer, real, or complex scalar | integer, real, or complex scalar |
| text | text |

All text comparisons are case sensitive and use the ASCII sorting sequence.

## See Also

*Logical Expression*, *Logical Unary Operators*, *Logical Binary Operators*

## repeat

### Purpose

Repeatedly executes a block of statements until a condition is true. The condition is evaluated after the statements have executed.

### Syntax

```
repeat
        statements
end repeat when condition;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *condition* | Logical expression. Until this expression evaluates to true, the block of statements repeatedly executes. |
| *statements* | Zero or more statements. |

### See Also

*for*, *while*, *repeat forever*, *next*, *exit*, *Logical Expression*

## repeat forever

### Purpose

Repeatedly executes a block of statements. Exit from this block of statements only occurs as a result of a return or exit statement.

### Syntax

```
repeat forever
      statements
end repeat;
```

### Syntax Descriptions

| **Name** | **Description** |
|---|---|
| *statements* | One or more statements. |

### Comments

The only way to exit this loop is to include an exit or return statement within it.

### See Also

*for*, *while*, *repeat*, *next*, *return*, *exit*, *Logical Expression*

## return

### Purpose

Exits a function. If an expression is specified, that expression is returned to the calling function.

### Syntax

```
return;
return return_list;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *`return_list`* | A comma separated list of algebraic expressions. |

### Comments

All expressions in *`return_list`* are evaluated before the function returns to the caller. The caller can request a different number of return values than supplied by the return.

### See Also

*function*

## select

### Purpose

Selects a group of statements to be executed based on the evaluation of an expression.

### Syntax

```
select selector from
      case item :
            statements
               .
               .
               .
      default:
            statements
end select;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *selector* | An algebraic expression that determines which case to choose. |
| *item* | An algebraic expression. The first *item* that has the same value as *selector* is selected, and the statements associated with that case are executed. |
| *statements* | One or more valid statements. |

### Comments

If no *item* has the same value as *selector*, the statements associated with default are executed.

The default case is optional.

After executing the last statement associated with the case, execution jumps to the end of the select statement. If you want to fall through to the next case, use the `next case` statement.

### See Also

*next*, *exit*

## Subrange Operator

### Purpose

Defines a subrange of a complete object.

### Syntax

```
object[element]
object[range]
object[element, element]
object[range, element]
object[element, range]
object[range, range]
```

### Syntax Descriptions

| Name | Description |
|---|---|
| `object` | The object whose subrange is being taken. The object must be a vector, matrix, polynomial, or text. |
| `element` | One of the following:<br>An integer expression<br>*<br>Nothing<br>See *Comments* for an explanation. |
| `range` | A range of the form *element1*:*element2* |

### Comments

When you use an integer to specify `element`, you indicate the subrange of a particular element. If you specify `element` with an asterisk or leave it blank, the subrange refers to all the elements.

```
vect[3]   // Refers to the third element of the vector
text[*]   // Refers to the entire text
```

Use two integers in a range to indicate a closed `range`, in which case the size of `range` is fully qualified. Use an asterisk or a blank in a `range` to indicate an open `range`. An open `range` in an expression goes to start or end of the `range`, as in the following example.

```
vect = {v:1,2,3,4,5,6,7,8,9};
w1 = v[6:*];//w1 is 6,7,8,9
w2 = v[*:3];//w2 is 1,2,3
```

On the left hand side of an assignment, an open *range* indicates that the object should grow to fit, as in the following example.

```
vect = {v:1,2,3,4};
vect[3:*] = {v:10,11};          //vect is now 1,2,10,11
vect[3:*] = {v:100,101,102,103};//vect is now 1,2,100,101,102,103
```

Not all forms of subranging are valid for all types of objects. The tables below list which forms are valid and the type of the resulting subrange.

## Vector

| Form | Result |
|---|---|
| v[i] | Scalar (the $i^{th}$ element of the vector) |
| v[ ]<br>v[*] | Vector (the vector itself) |
| v[i:k] | Vector (the $i^{th}$ through $k^{th}$ elements of the vector) |

## Text

| Form | Result |
|---|---|
| t[i] | Text (the $i^{th}$ character of the text) |
| t[ ]<br>t[*] | Text (the text itself) |
| t[i:k] | Text (the $i^{th}$ through $k^{th}$ characters of the text) |

## Polynomial

| Form | Result |
|---|---|
| p[i] | Scalar (the coefficient of $x^i$) |

## Matrix

| Form | Result |
|---|---|
| m[i] | Vector (the ith row of the matrix) |
| m[ ]<br>m[*] | Matrix (the matrix itself) |
| m[i:k] | Matrix (rows i through k of the matrix) |
| m[i,k] | Scalar (the (i,k)th element of the matrix) |
| m[ ,k]<br>m[*,k] | Vector (the kth column of matrix) |
| m[i, ]<br>m[i,*] | Vector (the ith row of matrix) |
| m[i:k,p] | Vector (the ith through kth elements of the pth column) |
| m[i:k, ]<br>m[i:k, *] | Matrix (rows i through k of the matrix) |
| m[i,p:q] | Vector (the pth through qth elements of the ith column) |
| m[ ,p:q]<br>m[*,p:q] | Matrix (columns p through q of the matrix) |
| m[i:j,p:q] | Matrix (the elements in rows i through j and columns p through q) |

## See Also

*Algebraic Expression*, *Assignment*, *Matrix Initialization Operator*, *Polynomial Initialization Operator*, *Vector Initialization Operator*

## Text Literal

### Purpose

Represents text.

### Syntax

*"`text`"*

### Syntax Descriptions

| Name | Description |
|---|---|
| *`text`* | A sequence of characters that define the text. The sequence of characters cannot contain a linefeed or a double quote. |

### See Also

*Real Literal*, *Complex Literal*, *Integer Literal*

## Vector Initialization Operator

### Purpose

Creates a vector from a set of expressions.

### Syntax

```
{v: list}
{vector: list}
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *`list`* | A comma-delimited list of algebraic expressions. Scalars, vectors, and matrices with either a single row or column are valid. |

### Comments

*`list`* can consist only of scalars, vectors, single row matrices, and single column matrices.

If any element in *`list`* is complex, the resulting vector is complex. If none are complex and any is real, the resulting vector is real. Otherwise, the resulting vector is integer.

### See Also

*Matrix Initialization Operator*, *Polynomial Initialization Operator*, *Color Initialization Operator*, *Function Initialization Operator*, *Font Initialization Operator*

*createVector* in Chapter 7, *Function Reference*

## while

### Purpose

Repeatedly executes a block of statements while a particular condition is true. The condition is evaluated before the statements are executed.

### Syntax

```
while condition do
      statements
end while;
```

### Syntax Descriptions

| Name | Description |
|---|---|
| *condition* | Logical expression. While this expression evaluates to true, the block of statements repeatedly executes. |
| *statements* | Zero or more statements. |

### See Also

*for*, *repeat*, *repeat forever*, *Logical Expression*

# Function Reference

This chapter contains an alphabetical list and description of every HiQ built-in function.

## abs

### Purpose

Computes the absolute value or complex magnitude of a number.

### Usage

```
y = abs(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, or Matrix | The input argument. |
| `y` | Scalar, Vector, or Matrix | The absolute value of the input argument. |

### Comments

For complex values, `abs(x)` returns the complex magnitude *r* in the polar representation of a complex number

$$z = re^{i\theta}$$

For vectors and matrices, `abs(x)` returns the absolute value or complex magnitude on an element-by-element basis.

### See Also

`arg`, `sign`

## addPlot

### Purpose

Adds a plot to a graph.

### Usage

Adds an existing plot object to a graph.

```
addPlot(graph, plot)
```

Adds a new 2D curve plot to a graph.

```
plotID = addPlot(graph, y)
plotID = addPlot(graph, x, y)
plotID = addPlot(graph, x, yFct)
```

Adds a new 3D surface plot to a graph.

```
plotID = addPlot(graph, Z, colorMap)
plotID = addPlot(graph, x, y, Z, colorMap)
plotID = addPlot(graph, x, y, ZFct, colorMap)
```

Adds a new 3D parametric curve plot to a graph.

```
plotID = addPlot(graph, x, y, z, colorMap)
plotID = addPlot(graph, tParam, xFct, yFct, zFct, colorMap)
```

Adds a new 3D parametric surface plot to a graph.

```
plotID = addPlot(graph, X, Y, Z, colorMap)
plotID = addPlot(graph, uParam, vParam, XFct, YFct, ZFct, colorMap)
```

Changes the plot data associated with an embedded plot.

```
plotID = addPlot(graph, plotID, ...)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `graph` | 2D or 3D Graph | The graph to which you want to add the specified plot. |
| `plot` | 2D or 3D Plot | The plot you want to add to the specified graph. |
| `y` | Real Vector | The y data set for a 2D or 3D curve or a 3D surface plot. |
| `x` | Real Vector | The x data set for a 2D or 3D curve or a 3D surface plot. |

| Name | Type | Description |
|---|---|---|
| `yFct` | Function | The y function to evaluate for a 2D curve or a 3D parametric curve plot. |
| `Z` | Real Matrix | The z data set for a 3D surface or parametric surface plot. |
| `colorMap` | Real Matrix | Set of data defining the plot color map values to use. Must have the same dimensions as the 3D z data. (Optional.) |
| `ZFct` | Function | The z function for a 3D surface or parametric surface plot. |
| `z` | Real Vector | The z data set for a 3D curve. |
| `tParam` | Real Vector | The t parametric data for a 3D parametric curve. |
| `xFct` | Function | The x function to evaluate for a 3D parametric curve plot. |
| `zFct` | Function | The z function to evaluate for a 3D parametric curve plot. |
| `X` | Real Matrix | The x data set for a 3D parametric surface plot. |
| `Y` | Real Matrix | The y data set for a 3D parametric surface plot. |
| `uParam` | Real Vector | The u parametric data for a 3D parametric surface. |
| `vParam` | Real Vector | The v parametric data for a 3D parametric surface. |
| `XFct` | Function | The x function for a 3D parametric surface plot. |
| `YFct` | Function | The y function for a 3D parametric surface plot. |
| `plotID` | Integer Scalar | A handle representing the new embedded plot or existing changed plot. |
| `plotID` | Integer Scalar | A handle representing the new embedded plot or existing changed plot. |

## Comments

The first usage links a plot object to a graph. A plot object is a HiQ object returned from `CreatePlot`. A graph object is a HiQ object returned from `CreateGraph`. The graph and plot objects must have the same dimension. For example, if you create a 3D graph using `CreateGraph`, the plot you create using `CreatePlot` also must be 3D. The following example creates a 3D graph object and 3D plot object and adds the plot object to the graph.

```
myGraph = createGraph(<Graph3D>);

myPlot = createPlot(x, y, z);

addPlot(myGraph, myPlot);
```

The remaining usages embed a plot directly into the graph without creating a separate plot object. HiQ assigns a unique plot handle to each plot embedded in the graph. You can use the plot handle to modify the properties of the plot. For example, the following script changes the color of an embedded 2D curve plot represented by the handle `plot1`.

```
graph.plots(plot1).color = <red>;
```

The final usage allows you to change the data of an existing plot. For example, the following script changes the data of an existing embedded 2D curve plot represented by the handle `plot1`.

```
plot1 = addPlot(graph,plot1,x,y);
```

If a plot with the specified plot handle, `plot1`, does not exist in the graph or you have not assigned a value to `plot1`, the above script adds a new embedded plot and returns a new plot handle.

When the x-axis data is not supplied in a 2D plot or the x-axis and y-axis data are not supplied in a 3D plot, HiQ uses the positive integers.

For 3D plots, the **z** data set, or the color map if provided, is used to determine the color of the plot. Use the `colorMap.style` property of the plot to define the color palette.

## See Also

`changePlotData`, `createGraph`, `createPlot`, `removePlot`

## airy

### Purpose

Computes the Airy functions Ai and Bi.

### Usage

```
[ai, bi] = airy(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `ai` | Real Scalar | The value of the Airy function Ai. |
| `bi` | Real Scalar | The value of the Airy function Bi. |

### Comments

The Airy functions Ai and Bi are solutions to the Airy differential equation

$$\frac{d^2f}{dx^2} - xf = 0$$

#### Illustrating the second derivative relationships of the Airy function.

```
// Show the second derivative relationships for the airy function,
// i.e., d2f/dx2 = x*F where F = Ai(x) or Bi(x).

// Grab a random evaluation point.
x = random(-5, 5);

// Compute the airy functions at the evaluation point.
[ai, bi] = airy(x);

// Generate an individual function to compute the second derivatives.
Ai = {f:x:"airy(x)"};
Bi = {f:x:"[,bix] = airy(x); return bix;"};

// Compute the second derivative for each at the evaluation point.
d2Ai = derivative(Ai, x, 2);
d2Bi = derivative(Bi, x, 2);
```

```
// Compute the difference in the two computations.
diffAi = d2Ai - ai*x;
diffBi = d2Bi - bi*x;

// Show the results.
message("Difference in Ai(x) = " + totext(diffAi));
message("Difference in Bi(x) = " + totext(diffBi));
```

## See Also

`besselI`, `besselJ`, `besselK`, `besselY`

## arccos

### Purpose

Computes the inverse cosine.

### Usage

```
y = arccos(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The inverse cosine of the input in radians. |

### Comments

The inverse cosine is defined for the real domain [ –1, 1 ].

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccosh`, `arcsin`, `cos`

## arccosh

### Purpose

Computes the inverse hyperbolic cosine.

### Usage

```
y = arccosh(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The inverse hyperbolic cosine of the input. |

### Comments

The inverse hyperbolic cosine is defined for the real domain (1, ∞).

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccos`, `arcsinh`, `cosh`

## arccot

### Purpose

Computes the inverse cotangent.

### Usage

```
y = arccot(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The inverse cotangent of the input in radians. |

### Comments

The inverse cotangent is defined for the real domain (–∞, ∞).

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccoth`, `arctan`, `cot`

## arccoth

### Purpose

Computes the inverse hyperbolic cotangent.

### Usage

```
y = arccoth(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real or Complex Scalar | The input argument. |
| y | Real or Complex Scalar | The inverse hyperbolic cotangent of the input. |

### Comments

The inverse hyperbolic cotangent is defined for the real domain [ –1, 1 ].

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccot`, `arctanh`, `coth`

## arccsc

### Purpose

Computes the inverse cosecant.

### Usage

```
y = arccsc(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real or Complex Scalar | The input argument. |
| y | Real or Complex Scalar | The inverse cosecant of the input in radians. |

### Comments

The inverse cosecant is defined for the real domain [ –1, 1 ].

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccsch`, `arcsec`, `csc`

## arccsch

### Purpose

Computes the inverse hyperbolic cosecant.

### Usage

```
y = arccsch(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The inverse hyperbolic cosecant of the input. |

### Comments

The inverse hyperbolic cosecant is defined for the real domain $(-\infty, \infty)$, $x \neq 0$.

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccsc`, `arcsech`, `csch`

## arcsec

### Purpose

Computes the inverse secant.

### Usage

```
y = arcsec(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real or Complex Scalar | The input argument. |
| y | Real or Complex Scalar | The inverse secant of the input in radians. |

### Comments

The inverse secant is defined for the real domain [ –1, 1 ].

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccsc`, `arcsech`, `sec`

## arcsech

### Purpose

Computes the inverse hyperbolic secant.

### Usage

```
y = arcsech(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The inverse hyperbolic secant of the input. |

### Comments

The inverse hyperbolic secant is defined for the real domain [ 0, 1 ].

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccsch`, `arcsec`, `sech`

## arcsin

### Purpose

Computes the inverse sine.

### Usage

```
y = arcsin(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real or Complex Scalar | The input argument. |
| y | Real or Complex Scalar | The inverse sine of the input in radians. |

### Comments

The inverse sine is defined for the real domain [ –1, 1 ].

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccos`, `arcsinh`, `sin`

## arcsinh

### Purpose

Computes the inverse hyperbolic sine.

### Usage

```
y = arcsinh(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The inverse hyperbolic sine of the input. |

### Comments

The inverse hyperbolic sine is defined for the real domain (–∞, ∞).

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccosh`, `arcsin`, `sinh`

## arctan

### Purpose

Computes the inverse tangent.

### Usage

```
y = arctan(x)
y = arctan(num, den)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `num` | Real or Complex Scalar | The length of the opposite side. |
| `den` | Real or Complex Scalar | The length of the adjacent side. |
| `y` | Real or Complex Scalar | The inverse tangent of the input in radians. |

### Comments

The inverse tangent is defined for the real domain $(-\infty, \infty)$.

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);
```

```
// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);

// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccot`, `arctanh`, `tan`

## arctanh

### Purpose

Computes the inverse hyperbolic tangent.

### Usage

```
y = arctanh(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The inverse hyperbolic tangent of the input. |

### Comments

The inverse hyperbolic tangent is defined for the real domain [–1, 1 ].

### Examples

#### Illustrating inverse trigonometric identities.

```
// Use identities to compute inverse trigonometrics using inverse
// hyperbolic trigonometrics and vice versa.

// Grab a random argument for the computation.
y = random(-<pi>, <pi>);

// Compute arccosh(iy) and arccos(iy).
arccosh_iy = <i>*arccos(<i>*y);
arccos_iy = -<i>*arccosh(<i>*y);

// Compute arccoth(iy) and arccot(y).
arccoth_iy = -<i>*arccot(y);
arccot_y = <i>*arccoth(<i>*y);

// Compute arccsch(iy) and arccsc(y).
arccsch_iy = -<i>*arccsc(y);
arccsc_y = -<i>*arccsch(<i>*y);
```

```
// Compute arcsech(iy) and arcsec(iy).
arcsech_iy = -<i>*arcsec(<i>*y);
arcsec_iy = <i>*arcsec(<i>*y);

// Compute arcsinh(iy) and arcsin(y).
arcsinh_iy = <i>*arcsin(y);
arcsin_y = <i>*arcsinh(<i>*y);

// Compute arctanh(iy) and arctan(iy).
arctanh_iy = <i>*arctan(y);
arctan_y = <i>*arctanh(<i>*y);
```

## See Also

`arccoth`, `arctan`, `tanh`

## arg

### Purpose

Computes the argument (principle value or phase angle) of a complex number.

### Usage

```
y = arg(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Complex Scalar, Vector, or Matrix | The input argument. |
| `y` | Scalar, Vector, or Matrix | The principle value of the input argument. |

### Comments

The argument of a complex number is the angle $\theta$ in the polar representation of a complex number

$$z = re^{i\theta}$$

For vectors and matrices, `arg(x)` returns the principle value of the input on an element-by-element basis. The return data type and size are identical to the input data type and size. The range of the result is $[-\pi, \pi]$.

### See Also

`abs`, `mod`, `sign`

# avgDev

## Purpose

Computes the average deviation of a data sample.

## Usage

```
y = avgDev(x, xMean)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input data set. |
| *`xMean`* | Real Scalar | The mean of the input data set. (Optional.) |
| `y` | Real Scalar | The average deviation of the data set. |

## Comments

The average deviation of an *n*-element data sample is the average absolute deviation of elements in the sample from the mean of the sample and is defined as

$$\frac{\sum_{i=1}^{n} \left| x_i - \bar{x} \right|}{n}$$

This function executes faster if you provide the mean of the data sample in the parameter `xMean`.

## See Also

`mean`, `stdDev`

## bandwidth

### Purpose

Computes the lower and upper bandwidths of a matrix.

### Usage

```
[mb, nb] = bandwidth(A, tolr)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Matrix | The input matrix. |
| *`tolr`* | Real Scalar | Tolerance used to determine zero elements. (Optional. Default = `0.0`) |
| `mb` | Integer Scalar | Lower bandwidth of the input matrix. |
| `nb` | Integer Scalar | Upper bandwidth of the input matrix. |

### Comments

The lower bandwidth, $m_b$, and upper bandwidth, $n_b$, of the input matrix **A** are defined as follows:

$$m_b \equiv \min_p \text{ such that } a_{ij} = 0(|a_{ij}| \le tolr) \text{ for all } i > j + p$$

$$n_b \equiv \min_q \text{ such that } a_{ij} = 0(|a_{ij}| \le tolr) \text{ for all } j > i + q$$

In other words, the upper bandwidth is the minimum super-diagonal that contains non-zero elements, and the lower bandwidth is the minimum sub-diagonal that contains non-zero elements. The optional parameter, *`tolr`*, can be used to specify an arbitrary tolerance on the elements.

### Examples

#### Determining the most efficient matrix storage type.

```
// Given a real matrix A storing all elements, convert the
// matrix to the storage type that is most efficient.
project A;
```

```
// Compute the current bandwidths of the adjusted matrix.
// The second input treats elements within an epsilon
// neighborhood of zero as zero.
[mb, nb] = bandwidth(A, <epsilon>);

// To compute the number of stored elements in the matrix,
// get the matrix dimensions.
[m, n] = dim(A);

// Select the storage type that would be most efficient.
if (m == n  && (mb == 0 || nb == 0)) then
   // The most efficient matrix type could be triangular...
   if (.5*(m+1) < mb+nb+1) then
      if (mb == 0) then
         matrixType = <upperTri>;
      else
         matrixType = <lowerTri>;
      end if;
   else if (mb+nb+1 < m) then
      matrixType = <band>;
   else
      matrixType = <rect>;
   end if;
else if (mb+nb+1 < m) then
   matrixType = <band>;
else
   matrixType = <rect>;
end if;

// Now that the optimal storage type is known, convert
// the matrix.
if matrixType == <band> then
   A = convert(A, matrixType, mb, nb);
else
   A = convert(A, matrixType);
end if;
```

## See Also

convert, dim, sparsity, vanish

## basis

### Purpose

Creates the Kronecker or Heaviside basis vector.

### Usage

```
a = basis(n, type, i)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `n` | Integer Scalar | The dimension of the vector. |
| *`type`* | HiQ Constant | The type of basis vector to create. (Optional. Default = `<kronecker>`)<br>`<heaviside>`<br>`<kronecker>` |
| *`i`* | Integer Scalar | The basis index of the vector. (Optional. Default = `1`) |
| `a` | Real Vector | The *n*-dimensional basis vector. |

### Comments

The Kronecker and Heaviside vectors are used to form a basis in *n*-dimensional vector space. The Kronecker vector is defined as

$$\mathbf{a}_k = \begin{cases} 1 & \text{if } k = i \\ 0 & \text{if } k \neq i \end{cases}$$

The Heaviside vector is defined as

$$\mathbf{a}_k = \begin{cases} 1 & \text{if } k \leq i \\ 0 & \text{if } k > i \end{cases}$$

This function returns a zero vector if the optional input parameter *`i`* is zero.

## Examples

### Computing the local angular velocity in a moving fluid.

```
// Compute the local angular velocity at point P in a fluid
// moving with velocity field v.

// Define the velocity field.
v = {f:x:"x[1]*basis(3, <kronecker>, 2)"};

// Generate a computation point for the angular velocity.
point = createVector(3, <random>, -5, 5);

// Compute the angular velocity.
velocity = .5*curl(v, point);
```

## See Also

createVector

## besselI

### Purpose

Computes the modified Bessel function of the first kind.

### Usage

```
y = besselI(x, order)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| *`order`* | Integer or Real Scalar | The order of the Bessel function. (Optional. Default = `0`) |
| `y` | Real Scalar | The value of the modified Bessel function of the first kind. |

### Comments

The modified Bessel function of the first kind of order $\nu$, or $I_\nu$, (also known as the general hyperbolic Bessel function) is a solution of the differential equation

$$x^2 \frac{d^2 w}{dx^2} + x\frac{dw}{dx} - (x^2 + \nu^2)w = 0$$

This function is defined over the interval $(-\infty, \infty)$ if `order` is an integer and the interval $(-\infty, 0]$ if `order` is real.

### See Also

`airy`, `besselJ`, `besselK`, `besselY`

# besselJ

## Purpose

Computes the Bessel function of the first kind.

## Usage

```
y = besselJ(x, order)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| *`order`* | Integer or Real Scalar | The order of the Bessel function. (Optional. Default = `0`) |
| `y` | Real or Complex Scalar | The value of the Bessel function of the first kind. |

## Comments

The Bessel function of the first kind of order ν, or $J_\nu$, is a solution of the differential equation

$$x^2 \frac{d^2 w}{dx^2} + x\frac{dw}{dx} + (x^2 - v^2)w = 0$$

This function is defined over the interval (–∞, ∞) if `order` is an integer and the interval (–∞, 0] if `order` is real.

## See Also

`airy`, `besselI`, `besselJs`, `besselK`, `besselY`

## besselJs

### Purpose

Computes the spherical Bessel function of the first kind.

### Usage

```
y = besselJs(x, order)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| *`order`* | Integer Scalar | The order of the Bessel function. (Optional. Default = `0`) |
| `y` | Real Scalar | The value of the spherical Bessel function of the first kind. |

### Comments

The spherical Bessel function of the first kind of order $n$, $j_n$, is a solution to the differential equation

$$x^2\frac{d^2w}{dx^2} + 2x\frac{dw}{dx} + (x^2 - n(n+1))w = 0$$

It is related to the Bessel function of the first kind by the following equation.

$$j_n(x) = \sqrt{\frac{\pi}{2x}}J_v(x), \ v = n + \frac{1}{2}$$

### See Also

`besselI`, `besselJ`, `besselK`, `besselY`, `besselYs`

## besselK

### Purpose

Computes the modified Bessel function of the second kind.

### Usage

```
y = besselK(x, order)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| *`order`* | Integer Scalar | The order of the modified Bessel function. (Optional. Default = `0`) |
| `y` | Real Scalar | The value of the modified Bessel function of the second kind. |

### Comments

The modified Bessel function of the second kind of order $v$, or $K_v$, (also known as the Basset function) is a solution of the differential equation

$$x^2\frac{d^2w}{dx^2} + x\frac{dw}{dx} - (x^2 + v^2)w = 0$$

### See Also

`airy`, `besselI`, `besselJ`, `besselY`

## besselY

### Purpose

Computes the Bessel function of the second kind.

### Usage

```
y = besselY(x, order)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| *`order`* | Integer or Real Scalar | The order of the Bessel function. (Optional. Default = `0`) |
| `y` | Real or Complex Scalar | The value of the Bessel function of the second kind. |

### Comments

The Bessel function of the second kind of order $v$, or $Y_v$, is a solution of the differential equation

$$x^2\frac{d^2w}{dx^2} + x\frac{dw}{dx} + (x^2 - v^2)w = 0$$

### See Also

`airy`, `besselI`, `besselJ`, `besselK`, `besselYs`

## besselYs

### Purpose

Computes the spherical Bessel function of the second kind.

### Usage

```
y = besselYs(x, order)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| *`order`* | Integer Scalar | The order of the Bessel function. (Optional. Default = `0`) |
| `y` | Real Scalar | The value of the spherical Bessel function of the second kind. |

### Comments

The spherical Bessel function of the second kind of order $n$, or $j_n$, is a solution to the differential equation

$$x^2\frac{d^2w}{dx^2} + 2x\frac{dw}{dx} + (x^2 - n(n+1))w = 0$$

It is related to the Bessel function of the second kind by the following equation.

$$y_n(z) = \sqrt{\frac{\pi}{2z}}Y_v(z) \quad \text{where } v = n + \frac{1}{2}$$

### See Also

`besselI`, `besselJ`, `besselJs`, `besselK`, `besselY`

## beta

### Purpose

Computes the beta function.

### Usage

Computes the complete beta function.

```
z = beta(x, y)
```

Computes the incomplete beta function.

```
z = beta(x, y, a)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real Scalar | The first argument of the beta function |
| y | Real Scalar | The second argument of the beta function. |
| a | Real Scalar | The upper limit of the incomplete beta integral. |
| z | Real Scalar | The value of the beta function. |

### Comments

The `beta` function is defined by the following equation.

$$\beta(x, y) = \int_0^1 t^{x-1}(1-t)^{y-1}dt$$

The incomplete `beta` function is defined by the following equation.

$$I_a(x, y, a) = \frac{1}{\beta(x, y)}\int_0^a t^{x-1}(1-t)^{y-1}dt$$

### See Also

`digamma`, `gamma`

## cbrt

### Purpose

Computes the cube root of a number.

### Usage

```
y = cbrt(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The cube root of the input argument. |

### Comments

The cube root $y$ of a number $x$ is defined as

$$y = \sqrt[3]{x}$$

### Examples

#### Computing all three cube roots.

```
// Define an extension to cube root that computes the 3
// cube roots, including the complex ones.

// Define the generic root function that computes the k-th
// root factor for x^1/3.
function cbrtK(x, k)
   t = <pi>*(.5*(1.0 - sign(x)) + 2.0*k)/3.0;

   return cos(t) - <i>*sin(t);
end function;

// Define the function that computes the 3 cube roots.
function cbrt3(x)
   // Specify that the user function cbrtK() will be called.
   project cbrtK;

   // Each computed k-th factor is multiplied by cbrt(|x|).
   cbrtAbs = cbrt(abs(x));
   // Compute the k-th roots for k = 0, 1, 2.
   root0 = cbrtAbs*cbrtK(x, 0);
   root1 = cbrtAbs*cbrtK(x, 1);
   root2 = cbrtAbs*cbrtK(x, 2);

   // Return the three computed roots using multiple returns.
   return root0, root1, root2;
end function;

// Try out the new cube root extension on an input.
x = random(-10, 10);

[x1, x2, x3] = cbrt3(x);

// Display the results.
message("The three cube roots of " + totext(x) + " are: " + <lf> +
      "    " + totext(x1) + <lf> +
      "    " + totext(x2) + <lf> +
      "    " + totext(x3));
```

## See Also

sqrt

## CDF

### Purpose

Computes the cumulative distribution function.

### Usage

Computes the cumulative distributions requiring one parameter.

```
y = CDF(x, aType, a)
```

Computes the cumulative distributions requiring two parameters.

```
y = CDF(x, bType, a, b)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Integer or Real Scalar | The input argument. |
| `aType` | HiQ Constant | The distribution type requiring a single parameter.<br>`<chiSq>`<br>`<student>`<br>`<geometric>`<br>`<poisson>` |
| `a` | Real Scalar | The first distribution parameter. |
| `bType` | HiQ Constant | The distribution type requiring two parameters.<br>`<beta>`<br>`<cauchy>`<br>`<exponential>`<br>`<f>`<br>`<gamma>`<br>`<normal>`<br>`<weibull>`<br>`<binomial>`<br>`<negBinomial>` |
| `b` | Real Scalar | The second distribution parameter. |
| `y` | Real Scalar | The value of the cumulative distribution. |

## Comments

The cumulative distributions are defined by the following equations.

| | |
|---|---|
| `CDF(x, <chiSq>, a)` | $\frac{1}{2^{\frac{a}{2}}\Gamma\left(\frac{a}{2}\right)}\int_0^x z^{\frac{a}{2}-1} e^{\frac{-z}{2}} dz$ |
| `CDF(x, <student>, a)` | $\frac{\Gamma\left(\frac{a+1}{2}\right)}{(a\pi)^{\frac{1}{2}}\Gamma\left(\frac{a}{2}\right)}\int_{-\infty}^x \left(1+\frac{z^2}{a}\right)^{-\frac{a+1}{2}} dz$ |
| `CDF(k, <geometric>, a)` | $\sum_{i=0}^{k} a(1-a)^i$ |
| `CDF(k, <poisson>, a)` | $\sum_{i=0}^{k} \frac{e^{-a}a^i}{k!}$ |
| `CDF(x, <beta>, a, b)` | $\frac{1}{\beta(a, b)}\int_0^x t^{a-1}(1-t)^{b-1}dt$ |
| `CDF(x, <cauchy>, a, b)` | $\int_{-\infty}^x \frac{1}{\pi b\left[1+\left(\frac{t-a}{b}\right)^2\right]}dt$ |
| `CDF(x, <exp>, a, b)` | $\int_a^x \frac{1}{b}e^{-\left(\frac{t-a}{b}\right)}dt$ |
| `CDF(x, <f>, a, b)` | $\frac{a^{\frac{a}{2}}b^{\frac{b}{2}}}{B(a, b)}\int_0^x \frac{t^{\frac{a}{2}-1}}{(b+at)^{a+b}}dt$ |

| | |
|---|---|
| `CDF(x, <gamma>, a, b)` | $\frac{a^b}{\Gamma(b)}\int_0^x z^{b-1}e^{-az}dz$ |
| `CDF(x, <normal>, a, b)` | $\frac{1}{\sqrt{2\pi}b}\int_0^x e^{\frac{(t-a)^2}{2b^2}}dt$ |
| `CDF(x, <weibull>, a, b)` | $ab\int_0^x t^{a-1}e^{-bt^a}dt$ |
| `CDF(k, <binomial>, a, b)` | $\sum_{m=0}^{k}\binom{n}{m}p^m(1-p)^{n-m}$ |
| `CDF(k, <negBinomial>, a, b)` | $\sum_{m=0}^{k}\binom{n+m-1}{m}p^n(1-p)^m$ |

## See Also

PDF

## ceil

### Purpose

Rounds a number towards positive infinity.

### Usage

```
y = ceil(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar, Vector, or Matrix | The input argument. |
| `y` | Real Scalar, Vector, or Matrix | The ceiling of the input argument. |

### Comments

For vectors and matrices, `ceil(x)` returns the ceiling of the input on an element-by-element basis.

### Examples

#### Computing the ceiling of a vector of data.

```
// Generate two step functions that 'surround' a
// data set and graph the results.

// Create a set of 500 points in (-5, 5) sorted by size.
data = createVector(25, <random>, 1, 25, <uniform>);
data = sort(data);

// Create the graph and plot the generated data.
[graph, plotData] = createGraph(data);

// Once the graph is created, add the plots of the
// upper and lower bounds for the data.
plotTop = addPlot(graph, ceil(data));
plotBottom = addPlot(graph, floor(data));
```

```
// Change the plot color and style to make the plots
// easier to distinguish.
graph.plot(plotData).style = <point>;
graph.plot(plotData).point.size = 2;

graph.plot(plotTop).line.color = <ltblue>;
graph.plot(plotBottom).line.color = <red>;
```

## See Also

`floor`, `round`

## changePlotData

### Purpose

Changes the data associated with a plot object without changing the attributes of the plot object.

### Usage

Changes the data in a 2D curve plot.

```
changePlotData(plot, y)
changePlotData(plot, x, y)
changePlotData(plot, x, yFct)
```

Changes the data in a 3D surface plot.

```
changePlotData(plot, Z, colorMap)
changePlotData(plot, x, y, Z, colorMap)
changePlotData(plot, x, y, ZFct, colorMap)
```

Changes the data in a 3D parametric curve plot.

```
changePlotData(plot, x, y, z, colorMap)
changePlotData(plot, xFct, yFct, zFct, tParam, colorMap)
```

Changes the data in a 3D parametric surface plot.

```
changePlotData(plot, X, Y, Z, colorMap)
changePlotData(plot, XFct, YFct, ZFct, uParam, vParam, colorMap)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `plot` | 2D or 3D Plot | The plot object that will contain the new data. |
| `y` | Real Vector | The y data set for a 2D or 3D curve or a 3D surface plot. |
| `x` | Real Vector | The x data set for a 2D or 3D curve or a 3D surface plot. |
| `yFct` | Function | The y function to evaluate for a 2D curve or a 3D parametric curve plot. |
| `Z` | Real Matrix | The z data set for a 3D surface or parametric surface plot. |

| Name | Type | Description |
|---|---|---|
| *colorMap* | Real Vector or Matrix | Set of data defining the color map values to use. Must have the same dimensions as the 3D z data. (Optional.) |
| `ZFct` | Function | The z function to evaluate for a 3D surface or parametric surface plot. |
| `z` | Real Vector | The z data set for a 3D curve. |
| `xFct` | Function | The x function to evaluate for a 3D parametric curve plot. |
| `zFct` | Function | The z function to evaluate for a 3D parametric curve plot. |
| `tParam` | Real Vector | The t parametric data for a 3D parametric curve. |
| `X` | Real Matrix | The x data set for a 3D parametric surface. |
| `Y` | Real Matrix | The y data set for a 3D parametric surface. |
| `XFct` | Function | The x function to evaluate for a 3D parametric surface plot. |
| `YFct` | Function | The y function to evaluate for a 3D parametric surface plot. |
| `uParam` | Real Vector | The u parametric data for a 3D parametric surface. |
| `vParam` | Real Vector | The v parametric data for a 3D parametric surface. |

## Comments

Use this function to change the data in an existing plot object. All graphs that link with the specified plot reflect the new data the next time the graph is redrawn. When the x-axis data is not supplied in a 2D plot or the x-axis and y-axis data are not supplied in a 3D plot, HiQ uses the positive integers. For 3D plots, the **z** data set, or the color map if provided, is used to determine the color of the plot. Use the `colorMap.style` property of the plot to define the color palette.

To change the data in an embedded plot, use `addPlot`.

## See Also

`addPlot`, `createPlot`, `removePlot`

## choleskyD

### Purpose

Computes the Cholesky decomposition of a symmetric, positive definite matrix.

### Usage

```
L = choleskyD(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Matrix | A square *n*x*n* matrix. |
| `L` | Matrix | The Cholesky decomposition of the input matrix. |

### Comments

If a matrix **A** is real symmetric or complex Hermitian and positive definite, the decomposition

$$\mathbf{A} = \mathbf{L}\mathbf{L}^{\mathrm{T}} \quad \text{if } \mathbf{A} \text{ is real}$$
$$\mathbf{A} = \mathbf{L}\mathbf{L}^{\mathrm{H}} \quad \text{if } \mathbf{A} \text{ is complex}$$

is called the Cholesky decomposition where **L** is a lower triangular matrix, $\mathbf{L}^{\mathrm{T}}$ is the transpose of **L**, and $\mathbf{L}^{\mathrm{H}}$ is the complex conjugate transpose (Hermitian) of **L**. It is a special case of the LU decomposition.

This function assumes the matrix **A** is symmetric or Hermitian and only uses the lower triangular elements of the matrix. If **A** is not positive definite, HiQ generates an error.

### Examples

#### Solving a symmetric, positive definite linear system.

This example shows how to solve a linear system, taking advantage of the symmetric, positive definite properties of the system matrix.

```
//Solving a symmetric, positive definite linear system.

//Create a 5x5 Moler matrix. The Moler matrix is
//symmetric and positive definite.
A = createMatrix(5,5,<moler>);
```

```
//Create the vector b from 1 to 5.
b = seq(5);

//Compute the decomposition (LL') of the
//symmetric, positive definite matrix A.
L = choleskyD(A);

//Solve the system Ax = b using the symmetric, positive
//definite decomposition matrix L.
x = solve(L,b,<choleskyD>);
```

## See Also

`LUD`, `solve`, `symD`

## clearLog

### Purpose

Clears the Log Window.

### Usage

```
clearLog()
```

### Comments

To save the contents of the Log Window before clearing, call `saveLog` with the name of the file to store the contents.

### See Also

`logMessage`, `saveLog`

## close

### Purpose

Closes an open file.

### Usage

```
close(fid)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | The file ID of the open file to close. |

### Comments

Files are automatically closed when a script finishes running. Use the `open` function to open a file.

### See Also

`open`

## compose

### Purpose

Computes the composition of two polynomials or permutations.

### Usage

```
z = compose(x, y)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Polynomial or Integer Vector | The first polynomial or permutation to compose. |
| `y` | Polynomial or Integer Vector | The second polynomial or permutation to compose. |
| `z` | Polynomial or Integer Vector | The resulting composition. |

### Comments

The composition $s$ of two polynomials $p$ and $q$ is defined by the equation

$s = p(q(x))$

where the degree of $s$ is equal to the sum of the degrees of $p$ and $q$. The polynomial $q$ replaces the independent variable of $p$.

The resulting composition polynomial is normalized. (The leading coefficient of the polynomial is equal to one.)

The composition $s$ of two $n$-element permutation vectors $p$ and $q$ is defined as

$$s_i = p_{qi}, 1 = 1, \ldots, n$$

For more information on permutation vectors, see `permu`.

### See Also

`divide`, `inv`, `permu`

## cond

### Purpose

Computes the condition number of a matrix.

### Usage

`x = cond(A, nType)`

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Matrix | The input matrix. |
| *`nType`* | HiQ Constant | The norm to use for the condition. (Optional. Default = `<L2>`)<br>`<L1>`<br>`<L2>`<br>`<L2sq>`<br>`<frob>`<br>`<Li>` |
| `x` | Real Scalar | The condition number of the input matrix. |

### Comments

The condition number $x$ of a matrix **A** is defined as

$$x = \|\mathbf{A}\|\|\mathbf{A}^{-1}\|$$

where $\|\mathbf{A}\|$ is the norm of the matrix **A**. This number is an important characteristic in the analysis of the accuracy of the solution to a linear system $\mathbf{Ax} = \mathbf{y}$. This function uses different methods depending on the value of `nType`. For example, the condition number based on L2 norm is computed more efficiently using singular values rather than a strict implementation of the formula above.

### See Also

`norm`

## conj

### Purpose

Computes the complex conjugate of a number.

### Usage

```
y = conj(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Complex Scalar, Vector, or Matrix | The input argument. |
| `y` | Complex Scalar, Vector, or Matrix | The complex conjugate of the input argument. |

### Comments

For vectors and matrices, `conj(x)` returns the complex conjugate of the input on an element-by-element basis.

### Examples

#### Sorting the roots of a polynomial according to magnitude.

```
// Order the roots returned from the polynomial root solver in
// descending order according to the root magnitudes.

// Create an example polynomial used to generate the roots.
poly = {poly: "x^5 + x^3 - 2x - 5"};

// Compute the roots of the polynomial.
proots = roots(poly);

// Generate the sorting index based on the root magnitudes.
// Designate the object rootsAbs as local so it will be freed
// after execution is complete.
local rootsAbs;
[rootsAbs,index] = sort(abs(proots));

// Sort the original set of roots based on the sort index.
proots = sort(proots, index);
```

```
// Now make sure that the complex root pairs are ordered by
// ..., a - bi, a + bi, ...
i = 1;
while i < rootsAbs.size do
   // Check the ordering of a root pair.
   if abs(rootsAbs[i] - rootsAbs[i+1]) < <epsilon> then
      local proot = proots[i];

      // If the order is incorrect, swap them.
      // Otherwise, jump to the next potential pair.
      if (sign(proot.i) > 0) then
         proots[i] = conj(proots[i]);
         proots[i+1] = conj(proots[i+1]);
      else
         i = i + 2;
      end if;
   // Look for the next pair starting with the next root.
   else
      i = i + 1;
   end if;
end while;
```

## See Also

trans

## convert

### Purpose

Converts a numeric object to another object type or converts the structure of a matrix object.

### Usage

Converts a vector object to a matrix object.

```
B = convert(a, m, n)
```

Converts a matrix object to a vector object.

```
b = convert(A)
```

Converts the structure of a matrix object to the specified structure.

```
B = convert(A, mType)
```

Converts the structure of a matrix object to banded structure.

B = convert(A, <band>, *mb, nb*)

### Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Vector | The input vector. |
| `m` | Integer Scalar | The number of rows to create. |
| `n` | Integer Scalar | The number of columns to create. |
| `A` | Matrix | The input matrix. |
| `mType` | HiQ Constant | The storage type of the resulting matrix.<br>`<rect>`<br>`<upperTri>`<br>`<lowerTri>`<br>`<symmetric>`<br>`<hermitian>`<br>`<band>` |
| *mb* | Integer Scalar | The lower bandwidth dimension of a banded matrix. (Optional. Default = `0`) |
| *nb* | Integer Scalar | The upper bandwidth dimension of a banded matrix. (Optional. Default = `0`) |
| `B` | Matrix | The resulting matrix. |
| `b` | Vector | The resulting vector. |

## Comments

When you convert an $m \times n$ matrix **A** to a vector **b**, the vector contains *mn* elements. HiQ creates the vector using the row elements of the matrix as in the following equation.

$$b_{n(i-1)+j} = A_{ij},\ i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n$$

When you convert a *k*-element vector **b** to an $m \times n$ matrix **A**, HiQ creates the matrix row-by-row using the elements of the vector as in the following equation.

$$A_{ij} = b_{n(i-1)+j},\ i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n$$

If $k < mn$, the remaining elements of the matrix are set to zero. If $k > mn$, the extra elements in the vector are not used.

You can use the function `convert` to change the structural properties of a matrix. This function sets the values of the appropriate matrix elements to reflect the desired structure. When possible, HiQ stores the matrix more efficiently and uses faster algorithms for built-in functions. This function supports the following matrix structures.

| HiQ Constant | Structure | Comments |
|---|---|---|
| `<rect>` | | Rectangular. No special structure. |
| `<symmetric>` | $\begin{bmatrix} a_{11} & a_{21} & \cdots & a_{n1} \\ a_{21} & a_{22} & & a_{n2} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$ | Symmetric. The lower triangle of the matrix is used to create the symmetric matrix. |
| `<hermitian>` | $\begin{bmatrix} a_{11} & a_{21}^* & \cdots & a_{n1}^* \\ a_{21} & a_{22} & & a_{n2}^* \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$ | Hermitian. The lower triangular elements are used to create the Hermitian matrix. |

| HiQ Constant | Structure | Comments |
|---|---|---|
| `<lowerTri>` | $\begin{bmatrix} a_{11} & 0 & \dots & 0 \\ a_{21} & a_{22} & & 0 \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$ | Lower triangular. The upper triangular elements are set to zero. |
| `<upperTri>` | $\begin{bmatrix} a_{11} & a_{21} & \dots & a_{n1} \\ 0 & a_{22} & & a_{n2} \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \dots & a_{nn} \end{bmatrix}$ | Upper triangular. The lower triangular elements are set to zero. |
| `<band>` | $\begin{bmatrix} a_{11} & \dots & a_{1u} & 0 & \dots & 0 \\ \vdots & & & \ddots & \ddots & \vdots \\ a_{l1} & & \ddots & & & 0 \\ 0 & \ddots & & & & \\ \vdots & \ddots & & & & \vdots \\ 0 & \dots & 0 & & \dots & a_{nn} \end{bmatrix}$ | Banded. The diagonal elements above the upper diagonal and below the lower diagonal are set to zero. |

Some linear algebra operations and built-in functions do not maintain the structural properties of a matrix. For example, if you assign a non-zero value to an element in the upper triangular portion of a matrix with lower triangular properties, the matrix loses its lower triangular structure.

You can use the function `bandwidth` to compute the upper and lower bandwidths of a matrix before converting the matrix to banded structure as in the following script.

```
[mb, nb] = bandwidth(A, tolr);
B = convert(A, <band>, mb, nb);
```

## Examples

### Determining the most efficient matrix storage type.

```
// Given a real matrix A storing all elements, convert the
// matrix to the storage type that is most efficient.
project A;
```

```
// Compute the current bandwidths of the adjusted matrix.
// The second input treats elements within an epsilon
// neighborhood of zero as zero.
[mb, nb] = bandwidth(A, <epsilon>);

// To compute the number of stored elements in the matrix,
// get the matrix dimensions.
[m, n] = dim(A);

// Select the storage type that would be most efficient.
if (m == n  && (mb == 0 || nb == 0)) then
   // The most efficient matrix type could be triangular...
   if (.5*(m+1) < mb+nb+1) then
      if (mb == 0) then
         matrixType = <upperTri>;
      else
         matrixType = <lowerTri>;
      end if;
   else if (mb+nb+1 < m) then
      matrixType = <band>;
   else
      matrixType = <rect>;
   end if;
else if (mb+nb+1 < m) then
   matrixType = <band>;
else
   matrixType = <rect>;
end if;

// Now that the optimal storage type is known, convert
// the matrix.
if matrixType == <band> then
   A = convert(A, matrixType, mb, nb);
else
   A = convert(A, matrixType);
end if;
```

## See Also

createMatrix

## cor

### Purpose

Computes the correlation of two data samples.

### Usage

```
z = cor(x, y, xMean, yMean)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The first data set. |
| `y` | Real Vector | The second data set. |
| *`xMean`* | Real Scalar | The mean of the first data set. (Optional.) |
| *`yMean`* | Real Scalar | The mean of the second data set. (Optional.) |
| `z` | Real Scalar | The correlation of the two data sets. |

### Comments

The correlation of two data sets **x** and **y** is defined as

$$\frac{\mathrm{cov}(\mathbf{x}, \mathbf{y})}{\sigma_x \sigma_y}$$

where $\sigma$ represents the standard deviation.

This function executes faster if you provide the mean of the data samples in the parameters `xMean` and `yMean`.

### See Also

`cov`, `mean`, `stdDev`

## cos

### Purpose

Computes the cosine.

### Usage

```
y = cos(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input angle in radians. |
| `y` | Real or Complex Scalar | The cosine of the input. |

### Comments

The cosine is defined for the real domain $(-\infty, \infty)$.

### See Also

`arccos`, `cosh`, `sin`

## cosh

### Purpose

Computes the hyperbolic cosine.

### Usage

```
y = cosh(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The hyperbolic cosine of the input. |

### Comments

The hyperbolic cosine is defined for the real domain $(-\infty, \infty)$.

### Examples

#### Computing the shape of a rope hanging between two points.

```
// When a heavy rope or chain is hung between two points
// with equivalent horizon, the shape made by the rope or
// chain is known as a catenary. To construct this shape,
// only two basic elements are required: the length of the
// rope or chain and the distance between the hanging points.

// Provide a sample length and distance for a catenary.
L = 3;
h = 1;

// The formula used to compute the catenary is based on a
// single constant b related to L and h by bL = 2*sinh(bh/2).
// Solving for b is not direct, so optimization is used to
// compute it. Define the function to optimize.
bFct = {f:x:"x[1]*L - 2*sinh(.5*x[1]*h)"};

// Find b within a tolerance of 1e-4. Make an initial guess
// for b of 1.
b = optimize(bFct, {v: L - 2*sinh(.5*h)});
```

```
// Use the computed b constant to define the catenary
// function. We define the catenary so that the lowest
// point corresponds with x = 0.
function catenary(x)
  // Let the function know that b and h, which are defined outside this
  // function, will be used.
   project b, h;

   // By our definition, the catenary is only defined
   // between the hanging points, i.e., [-.5*h, .5*h]
   if (abs(x) > .5*h) then
      return <nan>;

   // Compute the catenary at point x.
   else
      return (cosh(b*x) - cosh(b*h))/b;
   end if;
end function;

// Generate a temporary set of evaluation points for the domain.
// Defining it as local frees it up after execution.
local domain = seq(-.5*h, .5*h, 100, <pts>);

// Graph the catenary over the provided domain.
catenaryGraph = createGraph(domain, catenary);

// Make the graph reflect the physical nature of the problem.
catenaryGraph.axis.y.range.inverted = true;
catenaryGraph.border.visible = <off>;
catenaryGraph.axes.majorgrid.visible = <off>;
catenaryGraph.plots.style = <point>;
catenaryGraph.plots.point.style = <emptycircle>;
catenaryGraph.plots.point.size = 6;
```

## See Also

arccosh, cos, sinh

# coshI

## Purpose

Computes the hyperbolic cosine integral function.

## Usage

```
y = coshI(x)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The value of the hyperbolic cosine integral. |

## Comments

The hyperbolic cosine integral is defined by the following equation where $\gamma$ represents Euler's constant.

$$\mathrm{coshI}(x) = \gamma + \ln x + \int_0^x \frac{\cosh(t) - 1}{t} dt$$

## See Also

`cosI`, `sinhI`

## cosI

### Purpose

Computes the cosine integral function.

### Usage

```
y = cosI(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument (x > 0). |
| `y` | Real Scalar | The value of the cosine integral. |

### Comments

The cosine integral is defined by the following equation where $\gamma$ represents Euler's constant.

$$\cos\mathrm{I}(x) = \gamma + \ln x + \int_0^x \frac{\cos(t) - 1}{t} dt$$

### See Also

`coshI`, `expI`, `sinI`

## cot

### Purpose

Computes the cotangent.

### Usage

```
y = cot(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input angle in radians. |
| `y` | Real or Complex Scalar | The cotangent of the input. |

### Comments

The cotangent is defined for the domain $(-\infty, \infty)$, $x \neq \pm n\pi$.

### See Also

`arccot`, `coth`, `tan`

## coth

### Purpose

Computes the hyperbolic cotangent.

### Usage

```
y = coth(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The hyperbolic cotangent of the input. |

### Comments

The hyperbolic cotangent is defined for the domain $(-\infty, \infty)$, $x \neq 0$.

### See Also

`arccoth`, `cot`, `tanh`

## cov

### Purpose

Computes the covariance of two data samples.

### Usage

```
z = cov(x, y, xMean, yMean)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The first data set. |
| `y` | Real Vector | The second data set. |
| *`xMean`* | Real Scalar | The mean of the first data set. (Optional.) |
| *`yMean`* | Real Scalar | The mean of the second data set. (Optional.) |
| `z` | Real Scalar | The covariance of the two data sets. |

### Comments

The covariance of two *n*-element sample sets **u** and **v** is defined as

$$\mathrm{cov}(\mathbf{x}, \mathbf{y}) = \sum_{i=1}^{n} \frac{(x_i - \bar{\mathbf{x}})(y_i - \bar{\mathbf{y}})}{n-1}$$

This function executes faster if you provide the mean of the data samples in the parameters *`xMean`* and *`yMean`*.

### See Also

`cov`, `mean`, `var`

## createGraph

### Purpose

Creates a new 2D or 3D graph.

### Usage

Creates an empty 2D or 3D graph.

```
graph = createGraph(graphType)
```

Creates a 2D graph with a curve plot.

```
[graph, plotID] = createGraph(y)
[graph, plotID] = createGraph(x, y)
[graph, plotID] = createGraph(x, yFct)
```

Creates a 3D graph with a surface plot.

```
[graph, plotID] = createGraph(Z, colorMap)
[graph, plotID] = createGraph(x, y, Z, colorMap)
[graph, plotID] = createGraph(x, y, ZFct, colorMap)
```

Creates a 3D graph with a parametric curve plot.

```
[graph, plotID] = createGraph(x, y, z, colorMap)
[graph, plotID] = createGraph(tParam, xFct, yFct, zFct, colorMap)
```

Creates a 3D graph with a parametric surface plot.

```
[graph, plotID] = createGraph(X, Y, Z, colorMap)
[graph, plotID] = createGraph(uParam, vParam, XFct, YFct, ZFct,
colorMap)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `graphType` | HiQ Constant | The graph dimension.<br><`graph2D`>—2D graph.<br><`graph3D`>—3D graph. |
| `y` | Real Vector | The y data set for a 2D or 3D curve or a 3D surface plot. |
| `x` | Real Vector | The x data set for a 2D or 3D curve or a 3D surface plot. |
| `yFct` | Function | The y function to evaluate for a 2D curve or 3D parametric curve plot. |

| Name | Type | Description |
|---|---|---|
| `Z` | Real Matrix | The z data set for a 3D surface or parametric surface plot. |
| *`colorMap`* | Real Matrix | Set of data defining the color map values to use. Must have the same dimensions as the 3D z data. (Optional.) |
| `ZFct` | Function | The z function for a 3D surface or parametric surface plot. |
| `z` | Real Vector | The z data set for a 3D curve. |
| `tParam` | Real Vector | The parametric data for a 3D parametric curve. |
| `xFct` | Function | The x function to evaluate for a 3D parametric curve plot. |
| `zFct` | Function | The z function to evaluate for a 3D parametric curve plot. |
| `X` | Real Matrix | The x data set for a 3D parametric surface plot. |
| `Y` | Real Matrix | The y data set for a 3D parametric surface plot. |
| `uParam` | Real Vector | The u parametric data for a 3D parametric surface. |
| `vParam` | Real Vector | The v parametric data for a 3D parametric surface. |
| `XFct` | Function | The x function for a 3D parametric surface plot. |
| `YFct` | Function | The y function for a 3D parametric surface plot. |
| `graph` | 2D or 3D Graph | The new graph. |
| `plotID` | Integer Scalar | A handle representing the plot in the graph. |

## Comments

When used to create a graph containing a plot, `createGraph` adds the plot directly into the graph without creating a separate plot object. To add another plot directly into an existing graph, use `addPlot`. To create a plot object and add it to the graph, use `createPlot` and `addPlot.` Use `removePlot` to remove any or all plots from the graph.

When the x-axis data is not supplied in a 2D plot or the x-axis and y-axis data are not supplied in a 3D plot, HiQ uses the positive integers.

For 3D plots, the **z** data set, or the color map if provided, is used to determine the color of the plot. Use the `colorMap.style` property of the plot to define the color palette.

## Examples

### 1. Creating a 2D graph with a data plot (HiQ-Script).

This example demonstrates how to quickly graph a vector of data.

```
//Create a vector of x data.
x = seq(-<pi>,<pi>,.1);

//Create a vector of y data.
y = cos(x);

//Create a new graph with a new plot of the vector y.
myGraph = createGraph(x,y);
```

### 2. Creating a 2D graph with a function plot (HiQ-Script).

This example demonstrates how to quickly graph a function.

```
//Create a vector of x data with 100 points.
x = seq(-<pi>,<pi>,2*<pi>/100);

//Create a new graph with a new plot of the function sinh.
//Any function parameter (like sinh) must be a
//single-input, single-output function.
myGraph = createGraph(x,sinh);
```

## See Also

`addPlot`, `createPlot`, `removePlot`

## createInterface

### Purpose

Creates an ActiveX Interface object.

### Usage

```
object = createInterface(type)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `type` | Text | The type of object to create. |
| `object` | Object | The interface to an ActiveX object. |

### Comments

The parameter `type` consists of two parts:

*`Application.object`*

*`Application`* refers to an ActiveX application that exposes one or more top-level object classes. *`Object`* refers to one of the applications object classes. For example, Microsoft Word exposes an application object you can use from HiQ. The following HiQ-Script creates an interface to a Word applications object.

```
word = createInterface(“word.application”)
```

You then can access the methods and properties using the object `word`.

## createMatrix

### Purpose

Creates a variety of special matrices.

### Usage

Creates a matrix initialized with specific values.

```
A = createMatrix(m, n, mType)
A = createMatrix(m, n, <fill>, a)
A = createMatrix(m, n, <random>, a, b, <uniform>)
A = createMatrix(m, n, <random>, xMean, xStddev, <normal>)
A = createMatrix(m, n, <random>, k, <exp>)
A = createMatrix(m, n, <random>, p, <bernoulli>)
```

Creates a matrix with a specified storage type.

```
A = createMatrix(m, n, stType)
A = createMatrix(m, n, <band>, mb, nb)
```

Creates the specified matrix.

```
A = createMatrix(n, n, spType)
A = createMatrix(n, n, <toeplitz>, v)
A = createMatrix(n, n, <vandermonde>, v)
A = createMatrix(n, n, <hankel>, v)
A = createMatrix(n, n, <gram>, M)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `m` | Integer Scalar | The number of rows to create. |
| `n` | Integer Scalar | The number of columns to create. |
| `mType` | HiQ Constant | Specifies how to initialize the matrix.<br>`<seq>`<br>`<random>`<br>`<ident>`<br>`<fill>` |
| `a` | Scalar | The fill value used to initialize the elements of the matrix or the lower range of the uniform distribution. |
| `b` | Scalar | The upper range of the uniform distribution. |

| Name | Type | Description |
|---|---|---|
| `xMean` | Real Scalar | The mean of the normal distribution. |
| `xStddev` | Real Scalar | The standard deviation of the normal distribution. |
| `k` | Real Scalar | The reciprocal of the average of the exponential distribution. |
| `p` | Real Scalar | The probability of ones occurring in the distribution. |
| `stType` | HiQ Constant | The storage type of the matrix.<br>`<rect>`<br>`<band>`<br>`<lowerTri>`<br>`<upperTri>`<br>`<symmetric>` |
| `mb` | Integer Scalar | The upper bandwidth of the band matrix. |
| `nb` | Integer Scalar | The lower bandwidth of the band matrix. |
| `spType` | HiQ Constant | Specifies what kind of real matrix to generate.<br>`<hilbert>`<br>`<kahanU>`<br>`<kahanL>`<br>`<frank>`<br>`<moler>`<br>`<dingdong>`<br>`<bordered>`<br>`<wilkMinus>`<br>`<wilkPlus>` |
| `v` | Real Vector | Additional input required for types `<toeplitz>`, `<vandermonde>`, and `<hankel>`. |
| `M` | Real Matrix | Additional input required for type `<gram>`. |
| `A` | Matrix | The resulting matrix. |

## Comments

The function `createMatrix` performs faster than HiQ-Script for creating a matrix containing constant, random, or special values.

In some cases you can improve memory usage and increase the performance of matrix operations by creating a matrix that takes advantage of certain structural properties. When possible, HiQ stores the matrix more efficiently and uses faster algorithms for built-in functions. Some linear algebra operations and built-in functions do not maintain the structural properties of a matrix. For example, if you assign a value to an element in the upper triangular portion of a matrix with lower triangular properties, the matrix loses its lower triangular structure.

This function can create a variety of matrices containing special values. The available special matrix values appear in the following table:

| Constant Name | Expression | Description |
|---|---|---|
| `<bordered>` | $a_{ij} = \begin{cases} 1 & \text{if } i = j \\ 2^{1-i} & \text{if } i = n, j = n, i \neq j \\ 0 & \text{otherwise} \end{cases}$ | Arrow-headed, symmetric, degenerate. |
| `<diagonal>` | $a_{ij} = \begin{cases} i & \text{if } i = j \\ 0 & \text{otherwise} \end{cases}$ | eigenvalues = 1, 2, 3, …, n |
| `<dingdong>` | $a_{ij} = \frac{0.5}{n - i - j + 1.5}$ | Symmetric, eigenvalues cluster. |
| `<frank>` | $a_{ij} = \min(i, j)$ | Relatively well-conditioned. |
| `<gram>` | $a_{ij} = \mathbf{b}_i^T \mathbf{b}_j$ | $\mathbf{b}_i$ and $\mathbf{b}_j$ are the ith and jth columns of the input matrix **B**. |
| `<hankel>` | $a_{ij} = \mathbf{b}_{i+j-1}$ | dim(**b**) = $2n-1$, vector **b** is given. |
| `<hilbert>` | $a_{ij} = \frac{1}{i + j - 1}$ | Positive definite, very ill-conditioned. |
| `<kahanU>` | $a_{ij} = \begin{cases} 1 & \text{if } i = j \\ -1 & \text{if } i < j \\ 0 & \text{otherwise} \end{cases}$ | Ill-conditioned, upper triangular. |

| Constant Name | Expression | Description |
|---|---|---|
| `<kahanL>` | $a_{ij} = \begin{cases} 1 & \text{if } i = j \\ -1 & \text{if } i > j \\ 0 & \text{otherwise} \end{cases}$ | Ill-conditioned, lower triangular. |
| `<moler>` | $a_{ij} = \begin{cases} i & \text{if } i = j \\ \min(i, j) - 2 & \text{otherwise} \end{cases}$ | Positive definite, one small eigenvalue. |
| `<toeplitz>` | $a_{ij} = \mathbf{b}_{n+i-j}$ | Toeplitz matrix, vector b is given. |
| `<vandermonde>` | $a_{ij} = \mathbf{b}_j^{i-1}$ | Ill-conditioned, $\dim(\mathbf{b}) = n$, vector **b** is given. |
| `<wilkPlus>` | $a_{ij} = \begin{cases} \frac{n}{2} + 1 - \min(i, n-i+1) & \text{if } i = j \\ 1 & \text{if } \lvert i-j \rvert = 1 \\ 0 & \text{otherwise} \end{cases}$ | Symmetric, tri-diagonal, for odd $n$ has pairs of close eigenvalues. |
| `<wilkMinus>` | $a_{ij} = \begin{cases} \frac{n}{2} + 1 - i & \text{if } i = j \\ 1 & \text{if } \lvert i-j \rvert = 1 \\ 0 & \text{otherwise} \end{cases}$ | Symmetric, tri-diagonal, for odd $n$ has pairs of close eigenvalues. |

## Examples

### Creating a special matrix (HiQ-Script).

This example shows how to solve a symmetric, positive definite linear system.

```
//Solving a symmetric, positive definite linear system.

//Create a 5x5 Moler matrix. The Moler matrix is
//symmetric and positive definite.
A = createMatrix(5,5,<moler>);
```

```
//Create the vector b from 1 to 5.
b = seq(5);

//Compute the decomposition (LL') of the
//symmetric, positive definite matrix A.
L = choleskyD(A);

//Solve the system Ax = b using the symmetric, positive
//definite decomposition matrix L.
x = solve(L,b,<choleskyD>);
```

## See Also

`createVector`, `diag`, `ident`, `ones`

## createPlot

### Purpose

Creates a new 2D or 3D plot object.

### Usage

Creates a 2D curve plot.

```
plot = createPlot(y)
plot = createPlot(x, y)
plot = createPlot(x, yFct)
```

Creates a 3D surface plot.

```
plot = createPlot(Z, colorMap)
plot = createPlot(x, y, Z, colorMap)
plot = createPlot(x, y, ZFct, colorMap)
```

Creates a 3D parametric curve plot.

```
plot = createPlot(x, y, z, colorMap)
plot = createPlot(xFct, yFct, zFct, tParam, colorMap)
```

Creates a 3D parametric surface plot.

```
plot = createPlot(X, Y, Z, colorMap)
plot = createPlot(XFct, YFct, ZFct, uParam, vParam, colorMap)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `y` | Real Vector | The y data set for a 2D or 3D curve or a 3D surface plot. |
| `x` | Real Vector | The x data set for a 2D or 3D curve or a 3D surface plot. |
| `yFct` | Function | The y function to evaluate for a 2D curve or a 3D parametric curve plot. |
| `Z` | Real Matrix | The z data set for a 3D surface or parametric surface plot. |
| *`colorMap`* | Real Matrix | Set of data defining the color map values to use. Must have the same dimensions as the 3D z data. (Optional.) |

| Name | Type | Description |
|---|---|---|
| `ZFct` | Function | The z function for a 3D surface or parametric surface plot. |
| `z` | Real Vector | The z data set for a 3D curve. |
| `xFct` | Function | The x function to evaluate for a 3D parametric curve plot. |
| `zFct` | Function | The z function to evaluate for a 3D parametric curve plot. |
| `tParam` | Real Vector | The parametric data for a 3D parametric curve. |
| `X` | Real Matrix | The x data set for a 3D parametric surface plot. |
| `Y` | Real Matrix | The y data set for a 3D parametric surface plot. |
| `XFct` | Function | The x function for a 3D parametric surface plot. |
| `YFct` | Function | The y function for a 3D parametric surface plot. |
| `uParam` | Real Vector | The u parametric data for a 3D parametric surface. |
| `vParam` | Real Vector | The v parametric data for a 3D parametric surface. |
| `plot` | 2D or 3D Plot | The handle to the newly created plot. |

## Comments

You can use the output parameter `plot` as an input to the function `addPlot` to add the plot to a graph.

When the x-axis data is not supplied in a 2D plot or the x-axis and y-axis data are not supplied in a 3D plot, HiQ uses the positive integers.

For 3D plots, the **z** data set, or the color map if provided, is used to determine the color of the plot. Use the `colorMap.style` property of the plot to define the color palette.

## See Also

`addPlot`, `changePlotData`, `removePlot`

## createPoly

### Purpose

Creates a polynomial.

### Usage

Creates a polynomial with the given roots.

```
p = createPoly(pRoots)
```

Creates a polynomial with the given coefficients.

```
p = createPoly(coefs, order)
```

Creates an orthogonal polynomial of a specified degree.

```
p = createPoly(degree, type)
p = createPoly(degree, <gegenbauer>, a)
p = createPoly(degree, <aLaguerre>, a)
```

Creates the characteristic polynomial of a matrix.

```
p = createPoly(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `pRoots` | Real or Complex Vector | The roots of the polynomial. |
| `coefs` | Real or Complex Vector | The coefficients of the polynomial. |
| `order` | HiQ Constant | The order of the coefficients based on the degree of the polynomial.<br>`<ascending>`<br>`<descending>` |
| `degree` | Integer Scalar | The degree of the polynomial. |
| `type` | HiQ Constant | The type of orthogonal polynomial to create.<br>`<chebyshev1>`<br>`<chebyshev2>`<br>`<hermite>`<br>`<laguerre>`<br>`<legendre>` |

| Name | Type | Description |
|---|---|---|
| a | Real Scalar | Additional parameter for polynomial type `<gegenbauer>` and `<aLaguerre>`. |
| A | Matrix | The matrix used to create the characteristic polynomial. |
| p | Polynomial | The resulting polynomial. |

## Comments

The usage `createPoly(pRoots)` where `pRoots` is an *n*-element vector containing the desired polynomial roots creates a normalized polynomial of degree *n*.

A family of polynomials $p_i(x)$ are called orthogonal polynomials over the interval $a < x < b$ if each polynomial in the family satisfies the following equations.

$$\int_a^b w(x)p_n(x)p_m(x)dx = 0 \quad \text{if } n \neq m$$

$$\int_a^b w(x)p_n(x)p_n(x)dx = h_n \neq 0$$

The interval ($a$, $b$) and the weighting function $w(x)$ vary depending on the family of orthogonal polynomials.

Chebyshev orthogonal polynomials of the first kind, $T_n(x)$, are defined by the integral

$$\int_{-1}^{1} \frac{1}{\sqrt{1-x^2}} T_n(x)T_n(x)dx = \begin{cases} \dfrac{\pi}{2} & \text{if } n \neq 0 \\ \pi & \text{if } n = 0 \end{cases}$$

and follow the recurrence relationship

$$T_0(x) = 1$$

$$T_1(x) = x$$

$$T_n(x) = 2xT_{n-1}(x) - T_{n-2}(x) \quad \text{where } n = 2, 3, \ldots$$

Chebyshev orthogonal polynomials of the second kind, $U_n (x)$, are defined by the integral

$$\int_{-1}^{1} \sqrt{1-x^2}\, U_n(x) U_n(x) dx = \frac{\pi}{2}$$

and follow the recurrence relationship

$$U_0(x) = 1$$

$$U_1(x) = 2x$$

$$U_n(x) = 2xU_{n-1}(x) - U_{n-2}(x) \qquad \text{where } n = 2, 3, \ldots$$

Gegenbauer orthogonal polynomials (ultraspherical polynomials), $C_n^a(x)$, are defined by the integral

$$\int_{-1}^{1} (1-x^2)^{a-\frac{1}{2}} C_n^a(x) C_n^a(x) dx = \begin{cases} \dfrac{\pi 2^{1-2a}\Gamma(n+2a)}{n!(n+a)\Gamma^2(a)} & \text{if } a \neq 0 \\ \dfrac{2\pi}{n^2} & \text{if } a = 0 \end{cases}$$

and follow the recurrence relationship

$$C_0^a(x) = 1$$

$$C_1^a(x) = 2ax$$

$$C_n^a(x) = \frac{2(n+a)}{n+1} C_{n-1}^a(x) - \frac{n+2a-1}{n+1} C_{n-2}^a \qquad \text{where } n = 2, 3, \ldots \text{ for } a \neq 0$$

Hermite orthogonal polynomials, $H_n(x)$, are defined by the integral

$$\int_{-\infty}^{\infty} e^{-x^2} H_n(x) H_n(x) dx = \sqrt{\pi} 2^n n!$$

and follow the recurrence relationship

$$H_0(x) = 1$$

$$H_1(x) = 2x$$

$$H_n(x) = 2xH_{n-1}(x) - 2(n-1)H_{n-2}(x) \quad \text{where } n = 2, 3, \ldots$$

Laguerre orthogonal polynomials, $L_n(x)$, are defined by the integral

$$\int_{0}^{\infty} e^{-x} L_n(x) L_n(x) dx = 1$$

and follow the recurrence relationship

$$L_0(x) = 1$$

$$L_1(x) = -x + 1$$

$$L_n(x) = \frac{2n-1-x}{n} L_{n-1}(x) - \frac{n-1}{n} L_{n-2} \quad \text{where } n = 2, 3, \ldots$$

Associated Laguerre orthogonal polynomials, $L_n^a(x)$, are defined by the integral

$$\int_0^{\infty} e^{-x} x^a L_n^a(x) L_n^a(x) dx = \frac{\Gamma(a+n+1)}{n!}$$

and follow the recurrence relationship

$$L_n^a(x) = 1$$

$$L_n^a(x) = -x + a + 1$$

$$L_n^a(x) = \frac{2n+a-1-x}{n} L_{n-1}^a(x) - \frac{n+a-1}{n} L_{n-2}^a \quad \text{where } n = 2, 3, \ldots$$

Legendre orthogonal polynomials, $P_n(x)$, are defined by the integral

$$\int_{-1}^{1} P_n(x) P_n(x) dx = \frac{2}{2n+1}$$

and follow the recurrence relationship

$$P_0(x) = 1$$

$$P_1(x) = x$$

$$P_n(x) = \frac{2n-1}{n} x P_{n-1}(x) - \frac{n-1}{n} P_{n-2} \quad \text{where } n = 2, 3, \ldots$$

## See Also

`evalPoly`

## createVector

### Purpose

Creates a variety of special vectors.

### Usage

Creates a vector initialized with a specified value.

```
y = createVector(n, <fill>, a)
```

Creates a vector initialized with the sequence of whole numbers starting at 1.

```
y = createVector(n, <seq>)
```

Creates the specified basis vector.

```
y = createVector(n, <kronecker>, i)
y = createVector(n, <heaviside>, i)
```

Creates a vector initialized with random numbers of the given distribution.

```
y = createVector(n, <random>)
y = createVector(n, <random>, a, b, <uniform>)
y = createVector(n, <random>, xMean, xStddev, <normal>)
y = createVector(n, <random>, k, <exp>)
y = createVector(n, <random>, p, <bernoulli>)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `n` | Integer Scalar | The number of elements in the vector. |
| `a` | Scalar | The fill value used to initialize the elements of the vector or the lower range of the uniform distribution. |
| *`i`* | Integer Scalar | The basis index. (Optional. Default = `1`) |
| `b` | Real Scalar | The upper range of the uniform distribution. |
| `xMean` | Real Scalar | The mean of the normal distribution. |
| `xStddev` | Real Scalar | The standard deviation of the normal distribution. |
| `k` | Real Scalar | The reciprocal of the average of the exponential distribution. |

| Name | Type | Description |
|---|---|---|
| p | Real Scalar | The probability of ones occurring in the distribution. |
| y | Vector | The new vector. |

## Comments

The function `createVector` performs faster than HiQ-Script for creating a vector containing constant, random, or sequence values.

The Kronecker and Heaviside vectors are used to form a basis in *n*-dimensional vector space. The Kronecker vector is defined as

$$\mathbf{a}_k = \begin{cases} 1 & \text{if } k = i \\ 0 & \text{if } k \neq i \end{cases}$$

The Heaviside vector is defined as

$$\mathbf{a}_k = \begin{cases} 1 & \text{if } k \leq i \\ 0 & \text{if } k > i \end{cases}$$

This function returns a zero vector if the optional input parameter *`i`* is zero.

## See Also

`basis`, `createMatrix`, `fill`, `seq`

## createView

### Purpose

Creates a view of an object in a separate window.

### Usage

`createView(x, `*`pause`*`)`

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Object | The object to be viewed. |
| *`pause`* | HiQ Constant | Specifies whether to pause the current script while the view is still visible. (Optional. Default = `false`)<br>`true`<br>`false` |

### Comments

If *`pause`* is `false`, the script continues to execute. If *`pause`* is `true`, the view has a **continue** button and the script pauses execution until the **continue** button is pressed. The view closes when the **continue** button is pressed.

### See Also

`wait`

## cross

### Purpose

Computes the cross product of two three-element vectors.

### Usage

```
[z, theta] = cross(x, y)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The first input vector. |
| `y` | Real Vector | The second input vector. |
| `z` | Real Vector | The cross product vector of the inputs. |
| `theta` | Real Scalar | The angle between the two input vectors (in radians.) |

### Comments

The cross product of two vectors is defined only for three-dimensional (three-element) vectors.

### See Also

`dot`

## csc

### Purpose

Computes the cosecant.

### Usage

```
y = csc(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real or Complex Scalar | The input angle in radians. |
| y | Real or Complex Scalar | The cosecant of the input. |

### Comments

The cosecant is defined for the real domain $(-\infty, \infty)$, $x \neq \pm n\pi$ .

### See Also

`arccsc`, `csch`, `sec`

## csch

### Purpose

Computes the hyperbolic cosecant.

### Usage

```
y = csch(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The hyperbolic cosecant of the input. |

### Comments

The hyperbolic cosecant is defined for the real domain $(-\infty, \infty)$, $x \neq 0$.

### See Also

`arccsch`, `csc`, `sech`

## curl

### Purpose

Computes the curl of a three-dimensional vector field.

### Usage

```
y = curl(fct, x0, h, method)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function | The input function. |
| `x0` | Real Scalar | The point at which to calculate the curl. |
| *`h`* | Real Scalar | The step size to use. (Optional.) |
| *`method`* | HiQ Constant | The finite difference method to use. (Optional. Default = `<central>`)<br>`<extended>`<br>`<central>`<br>`<forward>` |
| `y` | Real Vector | The curl of the function. |

### Comments

Given a vector field **v** defined in three-dimensional space

$$\mathbf{v} = \mathbf{v}(x, y, z) = v_x(x, y, z)\mathbf{i} + v_y(x, y, z)\mathbf{j} + v_z(x, y, z)\mathbf{k}$$

the curl of the vector field **v** is defined by the following equation.

$$\text{curl } \mathbf{v} = \nabla \times \mathbf{v} = \left(\frac{\partial v_z}{\partial y} - \frac{\partial v_y}{\partial z}\right)\mathbf{i} + \left(\frac{\partial v_x}{\partial z} - \frac{\partial v_z}{\partial x}\right)\mathbf{j} + \left(\frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y}\right)\mathbf{k}$$

If the step size is equal to zero, HiQ chooses an appropriate step size based on the precision of your computer.

The forward, central, and extended central difference methods result in finite difference approximations of order one, two, and four respectively.

## Examples

### Computing the local angular velocity in a moving fluid.

```
// Compute the local angular velocity at point P in a fluid
// moving with velocity field v.

// Define the velocity field.
v = {f:x:"x[1]*basis(3, <kronecker>, 2)"};

// Generate a computation point for the angular velocity.
point = createVector(3, <random>, -5, 5);

// Compute the angular velocity.
velocity = .5*curl(v, point);
```

## See Also

`div`, `gradient`, `laplacian`

## date

### Purpose

Returns the current date.

### Usage

```
[today, year, month, day, dayOfWeek, dayOfYear] = date(format)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| *`format`* | HiQ Constant | The date format. (Optional. Default = `<short>`)<br>`<short>`<br>`<long>` |
| `today` | Text | The current date. |
| `year` | Integer Scalar | The current year. |
| `month` | Integer Scalar | The current month. |
| `day` | Integer Scalar | The current day. |
| `dayOfWeek` | Integer Scalar | The current day of the week. |
| `dayOfYear` | Integer Scalar | The current day of the year. |

### Comments

This function creates a text object containing the current month, day, and year formatted in either a short or long form. For example, the following script returns the short formatted text `11/19/1996`.

```
today = date();
```

The following script returns the long formatted text `Tuesday, November 19, 1996`.

```
today = date(<long>);
```

### See Also

`time`, `timer`, `wait`

## dawson

### Purpose

Computes the Dawson integral.

### Usage

```
y = dawson(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The value of the Dawson integral. |

### Comments

The Dawson's integral function is defined as

$$e^{-x^2}\int_0^x e^{t^2}\,dt$$

### Examples

#### Computing the error function of a purely imaginary value.

```
// Compute the error function of a purely imaginary value using
// the Dawson integral.

// Create the imaginary scalar.
z.i = random(-5, 5);

// Compute the exponential component to the formula.
erfz.i = 2*exp(z.i*z.i)/sqrt(<pi>);

// Factor in the Dawson component to get the result.
erfz.i = erfz.i*dawson(z.i);
```

### See Also

`erf`, `erfc`, `fCosI`, `fSinI`

## degree

### Purpose

Computes the effective degree of a polynomial.

### Usage

```
n = degree(p, tolr)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `p` | Polynomial | The input polynomial. |
| *`tolr`* | Real Scalar | The tolerance to use. (Optional.) |
| `n` | Integer Scalar | The effective degree of the polynomial. |

### See Also

`inv`, `compose`, `pow`

## deleteFile

### Purpose

Deletes a file from hard disk.

### Usage

```
deleteFile(fileName)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fileName` | Text | The name of the file to delete. |

### Comments

You can include the path name to fully specify the location. If you do not specify the path name then HiQ uses the current directory.

### See Also

`close`, `open`, `renameFile`

## derivative

### Purpose

Computes the derivative of a function or polynomial.

### Usage

Computes the *n*-th derivative of a function.

```
y = derivative(fct, x, n, h)
```

Computes the first derivative of a function using the specified difference method.

```
y = derivative(fct, x, 1, h, method)
```

Creates the *n*-th derivative polynomial object of another polynomial object.

```
yPoly = derivative(xPoly, n)
```

Computes the derivative of a signal.

```
w = derivative(v, h, vInit, vFinal)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function or Polynomial | The input function. |
| `x` | Scalar | The point at which to calculate the derivative. |
| *`n`* | Integer Scalar | The order of the derivative. (Optional. Default = `1`) |
| *`h`* | Scalar | The step size to use. (Optional.) |
| *`method`* | HiQ Constant | The finite difference method to use. (Optional. Default = `<central>`)<br>`<extended>`<br>`<central>`<br>`<forward>` |
| `xPoly` | Polynomial | The input polynomial. |
| `v` | Real Vector | An *n*-element vector representing a signal or waveform. |
| `vInit` | Real Scalar | The value represented by `v`[0]. |
| `vFinal` | Real Scalar | The value represented by `v`[n+1]. |

| Name | Type | Description |
|---|---|---|
| `y` | Scalar | The numeric derivative of the function. |
| `yPoly` | Polynomial | The polynomial object representing the derivative of the input polynomial. |
| `w` | Real Vector | An *n*-element vector representing the derivative of the input signal. |

## Comments

HiQ uses different methods for computing the derivative depending on how you use the function.

```
y = derivative(fct, x, n);
```

HiQ computes the n$^{th}$ derivative as accurately as possible using an extrapolation to a limit. This method uses several different step sizes to calculate intermediate derivatives and relies on the convergence of these derivatives to the final answer.

```
y = derivative(fct, x, n, stepsize);
```

HiQ computes the n$^{th}$ derivative using the central difference method. If the step size is equal to zero, HiQ chooses an appropriate step size based on the precision of your computer.

```
y = derivative(fct, x, 1, stepsize, method);
```

HiQ computes the first derivative using the specified difference method. If the step size is equal to zero, HiQ chooses an appropriate step size based on the precision of your computer.

The forward, central, and extended central difference methods result in finite difference approximations of order one, two, and four respectively.

## Examples

### Illustrating the second derivative relationships of the Airy function.

```
// Show the second derivative relationships for the airy function,
// i.e., d2f/dx2 = x*F where F = Ai(x) or Bi(x).

// Grab a random evaluation point.
x = random(-5, 5);

// Compute the airy functions at the evaluation point.
[ai, bi] = airy(x);
```

```
// Generate an individual function to compute the second derivatives.
Ai = {f:x:"airy(x)"};
Bi = {f:x:"[,bix] = airy(x); return bix;"};

// Compute the second derivative for each at the evaluation point.
d2Ai = derivative(Ai, x, 2);
d2Bi = derivative(Bi, x, 2);

// Compute the difference in the two computations.
diffAi = d2Ai - ai*x;
diffBi = d2Bi - bi*x;

// Show the results.
message("Difference in Ai(x) = " + totext(diffAi));
message("Difference in Bi(x) = " + totext(diffBi));
```

## See Also

`gradient`, `hessian`, `integrate`, `jacobian`, `laplacian`, `partial`

## det

### Purpose

Computes the determinant of a matrix.

### Usage

```
y = det(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real or Complex Matrix | A square matrix. |
| `y` | Real or Complex Scalar | The determinant of the matrix A. |

### Comments

HiQ uses various algorithms to compute the determinant depending on the structural properties of **A**. Computing the determinant of lower or upper triangular matrices is faster than computing the determinant of a matrix having rectangular structure.

Although the determinant of a matrix is the most important invariant of a square matrix, you should not use it as a measure of matrix singularity or matrix conditioning. For example, a well-conditioned matrix may have a small determinant. You should use functions `rank` and `cond` to determine these properties.

### See Also

`rank`, `trace`

# diag

## Purpose

Creates a diagonal matrix or extracts diagonal elements from a matrix.

## Usage

Creates a matrix containing the specified diagonal elements.

```
D = diag(a, p)
```

Returns the specified diagonal of a matrix.

```
d = diag(A, p)
```

Sets the values of the specified diagonal of a matrix.

```
D = diag(A, a, p)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Vector | The vector of values to assign to the diagonal. |
| `p` | Integer Scalar | The desired diagonal. (Optional. Default = `0` (main diagonal)) |
| `A` | Matrix | The matrix from which to extract the diagonal or the matrix containing the diagonal to set. |
| `D` | Matrix | Diagonal matrix containing the desired values. |
| `d` | Vector | Contains the diagonal values of the input matrix. |

## Comments

For the cases where the optional parameter *p* is specified, a positive *p* indicates a superdiagonal and a negative *p* indicates a sub-diagonal. For example, `p=-1` indicates the diagonal immediately below the main diagonal.

## See Also

`createMatrix`, `createVector`

## digamma

### Purpose

Computes the digamma (psi) function.

### Usage

```
y = digamma(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real Scalar | The input argument. |
| y | Real Scalar | The value of the digamma function. |

### Comments

The `digamma` function (psi function) is defined by the following equation.

$$\psi(x) = \frac{d\ \ln(\Gamma(x))}{dx} = \frac{1}{\Gamma(x)}\frac{d\Gamma(x)}{dx}$$

### Examples

#### Computing the Bateman's G function and the derivative of the gamma function.

```
// Use the digamma function to compute the Bateman's G function
// and the derivative of the gamma function.

// Choose the evaluation point for the Bateman's G function.
x = random(-5, 5);

// Define the G function in terms of digamma().
G = {f:x:"digamma(.5*(x+1.0)) - digamma(.5*x)"};

// Compute the Bateman's G function at the evaluation point.
y = G(x);

// Compute the derivative of the gamma function at x.
dGamma = gamma(x)*digamma(x);
```

### See Also

`beta`, `gamma`

## diln

### Purpose

Computes the dilogarithm function (Spence's Integral).

### Usage

```
y = diln(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real Scalar | The input argument. |
| y | Real Scalar | The value of the dilogarithm function. |

### Comments

The dilogarithm (Spence's integral) function is defined by the following equation.

$$\operatorname{diln}(x) = -\int_1^x \frac{\ln(t)}{t-1}\,dt$$

### See Also

`ln`

## dim

### Purpose

Returns the dimensions of a vector or matrix.

### Usage

Returns the size of a vector.

```
m = dim(a)
```

Returns the row, column, and lower and upper bandwidth dimensions of a matrix.

```
[m, n, mb, nb] = dim(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Vector | The input vector. |
| `A` | Matrix | The input matrix. |
| `m` | Integer Scalar | The row dimension of the matrix or size of the vector. |
| `n` | Integer Scalar | The column dimension of the matrix. |
| `mb` | Integer Scalar | The lower bandwidth dimension of the matrix. |
| `nb` | Integer Scalar | The upper bandwidth dimension of the matrix. |

### Comments

If **a** is a vector, the column dimension, upper bandwidth, and lower bandwidth are returned as 0.

The function `dim` returns the lower and upper bandwidths of the matrix based on the structural properties of the matrix, not the values of the elements. To compute the lower and upper bandwidths of the matrix based on the values of the elements, use the function `bandwidth`.

### Examples

#### Determining the most efficient matrix storage type.

```
// Given a real matrix A storing all elements, convert the
// matrix to the storage type that is most efficient.
project A;
```

```
// Compute the current bandwidths of the adjusted matrix.
// The second input treats elements within an epsilon
// neighborhood of zero as zero.
[mb, nb] = bandwidth(A, <epsilon>);

// To compute the number of stored elements in the matrix,
// get the matrix dimensions.
[m, n] = dim(A);

// Select the storage type that would be most efficient.
if (m == n  && (mb == 0 || nb == 0)) then
   // The most efficient matrix type could be triangular...
   if (.5*(m+1) < mb+nb+1) then
      if (mb == 0) then
         matrixType = <upperTri>;
      else
         matrixType = <lowerTri>;
      end if;
      else if (mb+nb+1 < m) then
         matrixType = <band>;
      else
         matrixType = <rect>;
      end if;
   else if (mb+nb+1 < m) then
      matrixType = <band>;
   else
      matrixType = <rect>;
   end if;

   // Now that the optimal storage type is known, convert
   // the matrix.
   if matrixType == <band> then
      A = convert(A, matrixType, mb, nb);
   else
      A = convert(A, matrixType);
   end if;
```

## See Also

`bandwidth`, `createMatrix`, `createVector`

# dist

## Purpose

Computes the distance between two vectors or matrices.

## Usage

Computes the distance between two vectors.

```
x = dist(a, b, vType)
```

Computes the distance between two vectors using the p-norm.

```
x = dist(a, b, <Lp>, p)
```

Computes the distance between two vectors using the weighted Euclidean norm.

```
x = dist(a, b, <Lw>, w)
```

Computes the distance between two matrices.

```
x = dist(A, B, mType)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Real or Complex Vector | The first input vector. |
| `b` | Real or Complex Vector | The second input. |
| *`vType`* | HiQ Constant | Type of vector norm to use. (Optional. Default = `<L2>`)<br>`<Lp>`<br>`<L1>`<br>`<Li>`<br>`<Lw>`<br>`<L2sq>`<br>`<L2>` |
| `p` | Integer Scalar | Parameter for *`vType`* `<Lp>`. |
| `w` | Real Vector | Weighting vector for *`vType`* `<Lw>`. |
| `A` | Real or Complex Matrix | The first input matrix. |
| `B` | Real or Complex Matrix | The second input matrix |

| Name | Type | Description |
|---|---|---|
| *`mType`* | HiQ Constant | Type of matrix norm to use. (Optional. Default = `<L2>`)<br>`<L1>`<br>`<Li>`<br>`<L2sq>`<br>`<L2>`<br>`<frob>` |
| `x` | Real Scalar | The distance between the two inputs. |

## Comments

In a Euclidean vector space, distance between two points (vectors) in the space is often defined as the Euclidean norm of the difference between the two points (vectors).

$$\mathrm{dist}(a, b) = \|\mathbf{a} - \mathbf{b}\|_2$$

You can extend this concept by choosing different types of norms or different objects for the elements of the space. For example, an element in an $m \times n$ vector space is an $m \times n$ matrix and you can define the notion of distance as the Frobenius norm of the difference between two matrices. Refer to the description of the function `norm` for more information.

## See Also

`cond`, `norm`

## div

### Purpose

Computes the divergence of a three-dimensional vector field.

### Usage

```
y = div(fct, x0, h, method)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function | The input function representing the three-dimensional vector field. |
| `x0` | Real Vector | The point at which to calculate the divergence. |
| *`h`* | Real Scalar | The step size to use. (Optional.) |
| *`method`* | HiQ Constant | The finite difference method to use. (Optional. Default = `<central>`)<br>`<central>`<br>`<forward>`<br>`<extended>` |
| `y` | Real Scalar | The divergence of the function. |

### Comments

Given a vector field **v** defined in three-dimensional space

$$\mathbf{v} = \mathbf{v}(x, y, z) = v_x(x, y, z)\mathbf{i} + v_y(x, y, z)\mathbf{j} + v_z(x, y, z)\mathbf{k}$$

the divergence of the vector field **v** is defined by the following equation.

$$\mathrm{div}\ \mathbf{v} = \nabla \cdot \mathbf{v} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}$$

If the step size is equal to zero, HiQ chooses an appropriate step size based on the precision of your computer. The forward, central, and extended central difference methods result in finite difference approximations of order one, two, and four respectively.

### See Also

`curl`, `gradient`, `laplacian`

# divide

## Purpose

Computes the ratio of two polynomials.

## Usage

```
[quotient, remainder] = divide(p, q)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `p` | Polynomial | The polynomial numerator. |
| `q` | Polynomial | The polynomial denominator. |
| `quotient` | Polynomial | The resulting quotient. |
| `remainder` | Polynomial | The remainder. |

## Comments

This function returns the remainder while the division operator does not.

## See Also

`compose`, `inv`

## dot

### Purpose

Computes the dot product of two vectors.

### Usage

Computes dot product of two vectors.

```
    z = dot(x, y)
```

Computes the weighted dot product of two vectors.

```
    z = dot(x, A, y)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Vector | An *m*-element input vector. |
| `y` | Real or Complex Vector | An *n*-element input vector. |
| `A` | Real or Complex Matrix | An *mxn* weighting matrix. |
| `z` | Real Scalar | The dot product of the two input vectors. |

### Comments

The dot product (scalar product or inner product) of two *n*-element vectors **a** and **b** is defined by the following equation.

$$\mathbf{a} \cdot \mathbf{b} = \sum_{i=1}^{n} a_i b_i$$

### See Also

`cross`

## eigen

### Purpose

Computes the eigenvalues and eigenvectors of a matrix.

### Usage

Computes the eigenvalues and eigenvectors of a matrix.

```
   [e, V] = eigen(A, aType)
```

Computes the generalized eigenvalues and eigenvectors of a matrix.

```
   [e, V] = eigen(A, B)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real or Complex Matrix | The square *n*x*n* input matrix. |
| *`aType`* | HiQ Constant | Describes the structural properties of the input matrix. (Optional.)<br>`<hermitian>`<br>`<symmetric>` |
| `B` | Real Matrix | The square *n*x*n* generalized input matrix. |
| `e` | Complex Vector | A *k*-element vector containing the eigenvalues of `A` in descending order. |
| `V` | Complex Matrix | An *n*x*k* matrix whose columns contain the eigenvectors of `A`. |

### Comments

A scalar $\lambda$ is an eigenvalue of the $n \times n$ matrix **A** if there exists a nonzero vector **x** such that,

$$\mathbf{Ax} = \boldsymbol{\lambda}\mathbf{x}$$

The nonzero vector **x** is called an eigenvector of **A** and is associated with the eigenvalue $\lambda$. The set of *n* eigenvalues is called the spectrum of **A**. If **A** is a real matrix, complex eigenvalues always occur in complex conjugate pairs and the eigenvectors are complex. If **A** is a real symmetric matrix, the eigenvalues and eigenvectors are real. If **A** is a complex Hermitian matrix, the eigenvalues are real and the eigenvectors are real or complex. The columns of the return matrix **X** contain the *n* normalized eigenvectors corresponding to the *n* eigenvalues.

If the eigenvalues are distinct, the matrix of eigenvectors **X** can be used to perform the similarity transformation

$$\mathbf{X}^{-1}\mathbf{A}\mathbf{X} = \Lambda$$

where $\Lambda$ is a diagonal matrix containing the eigenvalues along the main diagonal. If some eigenvalues are repeated but the eigenvectors are distinct, the above similarity transformation is still valid.

If some of the eigenvalues and eigenvectors are repeated, the matrix of eigenvectors **X** can be used to perform the similarity transformation

$$\mathbf{X}^{-1}\mathbf{A}\mathbf{X} = \mathbf{J}$$

where **J** is a block-diagonal matrix in the Jordan form

$$\begin{bmatrix} \mathbf{J}_1 & 0 & \dots & 0 \\ 0 & \mathbf{J}_2 & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \dots & 0 & \mathbf{J}_p \end{bmatrix}$$

$\mathbf{J}_i$ are Jordan blocks in the form

$$\begin{bmatrix} \lambda_j & 1 & \dots & 0 \\ 0 & \lambda_j & \ddots & \vdots \\ \vdots & & \ddots & 1 \\ 0 & \dots & 0 & \lambda_j \end{bmatrix}$$

and $p$ is the number of distinct eigenvalues.

HiQ uses a QR algorithm with balancing, Hessenberg reduction, and implicit double shifting to solve the eigenvalue problem. The algorithm is iterative and may generate an error if convergence is poor.

If you specify a value of `<symmetric>` or `<hermitian>` for the parameter `aType`, HiQ uses the lower triangular portion of the matrix to compute the eigenvalues.

The generalized eigenvalue problem is defined as

$$\mathbf{Ax} = \lambda\mathbf{Bx}$$

where **B** is an $n \times n$ matrix. The matrix **A** has *n* eigenvalue and eigenvector pairs only if **B** has full rank. If **B** is rank deficient, the actual number of eigenvalues computed might be less than *n*. HiQ uses a QZ algorithm to solve the generalized eigenvalue problem.

This function executes significantly faster when you request only the eigenvalues as in the following script.

```
z = eigen(A);
```

## See Also

`eigenDom`, `eigenSel`, `SVD`

## eigenDom

### Purpose

Computes the dominant eigenvalue and eigenvector of a matrix.

### Usage

```
[e, x, nIter] = eigenDom(A, tolr, iterMax, aType)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real or Complex Matrix | The square *n*x*n* input matrix. |
| *`tolr`* | Real Scalar | The eigenvalue tolerance. (Optional.) |
| *`iterMax`* | Integer Scalar | The maximum number of iterations to perform. (Optional. Default = `32`) |
| *`aType`* | HiQ Constant | Describes the structural properties of the input matrix. (Optional.)<br>`<hermitian>`<br>`<symmetric>` |
| `e` | Real Scalar | The dominant eigenvalue. |
| `x` | Real or Complex Vector | The eigenvector associated with the dominant eigenvalue. |
| `nIter` | Integer Scalar | The number of iterations performed. |

### Comments

An eigenvalue$\lambda_d$ is the dominant (or principle) eigenvalue of the $n \times n$ matrix **A** if

$$|\lambda_d| > |\lambda_i|, i = 1, n; i \neq d$$

where $\lambda_i$is an eigenvalue of **A**. This function uses the iterative power method for calculating the dominant eigenvalue and returns after the maximum number of iterations has occurred or the specified tolerance has been achieved. The tolerance is a measure of how the eigenvalue solution is changing between each iteration, not a measure of closeness to the actual value of the dominant eigenvalue. If HiQ generates an error message about a convergence problem, the tolerance and maximum iteration values might be too restrictive, the matrix **A** might lack a dominant eigenvalue, or the dominant eigenvalue might be too close to the other eigenvalues. The output parameter `nIter` gives an indication of the rate of convergence.

Calling this function several times might produce different results because the algorithm uses random numbers. You can use the function `seed` to control the random sequence and ensure repeatable results.

If **A** is real symmetric or complex Hermitian, HiQ uses the symmetric power method. If **A** is real, the dominant eigenvalue and eigenvector are real. The symmetric power method uses Rayleigh quotients

$$\lambda_i = \frac{(Av_i, v_i)}{\|v_i\|}$$

to estimate the dominant eigenvalue. Although each iteration requires more memory than the power method, the rate of convergence is twice as fast. This method also works for non-symmetric matrices, but the rate of convergence is the same as the power method.

## See Also

`eigen`, `eigenSel`

## eigenSel

### Purpose

Computes the eigenvalue closest to a specified value and its corresponding eigenvector.

### Usage

Computes the eigenvalue and associated eigenvector closest to a specified value.

`[e, v, nIter] = eigenSel(A, e0, tolr, iterMax, nLUD)`

Computes the generalized eigenvalue and associated eigenvector closest to a specified value.

`[e, v, nIter] = eigenSel(A, B, e0, tolr, iterMax, nLUD)`

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real Matrix | A square *n*x*n* input matrix. |
| `e0` | Real Scalar | The initial eigenvalue guess. |
| *`tolr`* | Real Scalar | The solution tolerance. (Optional. Default = `.01`) |
| *`iterMax`* | Integer Scalar | The maximum number of iterations. (Optional. Default = `128`) |
| *`nLUD`* | Integer Scalar | The number of iterations between recalculation of the LU decomposition. (Optional. Default = `8`) |
| `B` | Real Matrix | A square *n*x*n* generalized input matrix. |
| `e` | Real Scalar | The computed eigenvalue. |
| `v` | Real Vector | The computed eigenvector. |
| `nIter` | Integer Scalar | The number of iterations performed. |

### Comments

This function uses the inverse iteration method to find the real eigenvalue in the neighborhood of the initial guess and returns after the maximum number of iterations has occurred or the specified tolerance has been achieved. Each time HiQ updates the eigenvalue guess, the algorithm performs an LU decomposition to obtain the corresponding eigenvector. The algorithm might converge more quickly if the LUD decomposition is not performed at each iteration. You control how often the LUD decomposition occurs with the input parameter *`nLUD`*. An update rate of eight $k=8$ should provide good performance and quicker convergence. The results could be different on subsequent runs because the algorithm depends on a random number generator. You can use the function `seed` to control the random sequence and ensure repeatable results.

Refer to the function `eigen` for more information about the eigenvalue and generalized eigenvalue problem.

## See Also

`eigen`, `eigenDom`

## elliptic1

### Purpose

Computes the elliptic integral of the first kind.

### Usage

```
y = elliptic1(k, a)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `k` | Real Scalar | The modulus argument. |
| *`a`* | Real Scalar | The amplitude of the function (the upper limit of the integral). (Optional. Default = `<pi>`/2) |
| `y` | Real Scalar | The value of the elliptic integral of the first kind. |

### Comments

The elliptic integral of the first kind is defined by the following equation.

$$F(k, a) = \int_0^a \frac{1}{\sqrt{1 - k\sin^2\theta}} d\theta$$

The parameter *k* is called the modulus and the upper limit of the integral *a* is called the amplitude. The complete elliptic integral of the first kind is defined by the previous equation when the amplitude $a = \pi/2$ .

### See Also

`elliptic2`, `ellipticJ`

## elliptic2

### Purpose

Computes the elliptic integral of the second kind.

### Usage

```
y = elliptic2(k, a)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `k` | Real Scalar | The modulus argument. |
| *`a`* | Real Scalar | The amplitude of the function (the upper limit of the integral). (Optional. Default = `<pi>/2`) |
| `y` | Real Scalar | The value of the incomplete elliptic integral of the second kind. |

### Comments

The elliptic integral of the second kind is defined by the following equation.

$$F(k, a) = \int_0^a \sqrt{1 - k\ \sin^2\theta}\, d\theta$$

The parameter *k* is called the modulus and the upper limit of the integral *a* is called the amplitude. The complete elliptic integral of the second kind is defined by the previous equation when the amplitude $a = \pi/2$ .

### See Also

`elliptic1`, `ellipticJ`

# ellipticJ

## Purpose

Computes the Jacobi elliptic functions.

## Usage

```
[cn, dn, sn] = ellipticJ(x, k)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `k` | Real Scalar | The integrand parameter. |
| `cn` | Real Scalar | The value of the Jacobi elliptic function `cn`. |
| `dn` | Real Scalar | The value of the Jacobi elliptic function `dn`. |
| `sn` | Real Scalar | The value of the Jacobi elliptic function `sn`. |

## Comments

The three Jacobi elliptic functions are defined by the following equations.

$$\left.\begin{aligned} cn(x,k) &= \cos(\phi) \\ sn(x,k) &= \sin(\phi) \\ dn(x,k) &= \sqrt{1-k\sin^2\phi} \end{aligned}\right\} \quad \text{where } x = \int_0^{\phi} \frac{1}{\sqrt{1-k\sin^2\theta}}\,d\theta$$

## See Also

`elliptic1`, `elliptic2`

## erf

### Purpose

Computes the error function.

### Usage

```
y = erf(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The value of the error function. |

### Comments

The error function is defined by the following equation.

$$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt$$

### See Also

`dawson`, `erfc`, `fCosI`, `fSinI`

## erfc

### Purpose

Computes the complementary error function.

### Usage

```
y = erfc(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The value of the complementary error function. |

### Comments

The complement error function is defined by the following equation.

$$\mathrm{erfc}(x) = 1 - \mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \int_{x}^{\infty} e^{-t^2}\, dt$$

### See Also

`dawson`, `erf`, `fCosI`, `fSinI`

## error

### Purpose

Displays an error dialog box and terminates a HiQ-Script.

### Usage

```
error(text)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `text` | Text | Error message to display in the dialog box. |

### Comments

The `error` function displays a run-time error dialog box containing the script name and line number where the `error` function was called, and the input text. The script terminates after the user clicks on the OK button.

### See Also

`message`, `warning`

## eval

### Purpose

Evaluates a polynomial or single-valued function at the given input value.

### Usage

Evaluate a polynomial at the given input value.

```
Z = eval(poly, X)
```

Evaluate a single-valued function at the given input values on an element-by-element basis.

```
Z = eval(fct, Y1, Y2, Y3)
```

Evaluate a single-valued function at the given matrix object.

```
Z = eval(fctS, Y, <object>)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `poly` | Polynomial | The polynomial to evaluate. |
| `X` | Scalar or Matrix | The number or matrix at which to evaluate the polynomial. |
| `fct` | Function | The function to evaluate. |
| `Y1` | Vector or Matrix | The values of the first parameter at which to evaluate the function. |
| `Y2` | Vector or Matrix | The values of the second parameter at which to evaluate the function. |
| `Y3` | Vector or Matrix | The values of the third parameter at which to evaluate the function. |
| `fctS` | Function | The single-valued function used to evaluate a matrix object. |
| `Y` | Matrix | The matrix object at which to compute the single-valued function. |
| `Z` | Scalar, Vector, or Matrix | The value of the polynomial or function. |

## Comments

For built-in functions or user-defined functions, `eval` computes the element-by-element result for any combinations of up to three function parameters. For example, the following script computes the first order Bessel function of the first kind at several different arguments.

```
x = {v:1.1, 1.5, 1.9, 2.8, 3.7};
a = {v:1, 1, 1, 1, 1};
y = eval(besselJ, x, a);
```

The evaluation of a single-valued function at a matrix object is performed based on the following formula.

```
[D, V] = eigen(Y);
Z = V*diag(eval(fct,D))*V^-1;
```

## See Also

`evalPoly`

## evalPoly

### Purpose

Evaluates a polynomial.

### Usage

Evaluates a polynomial object at the desired value.

```
y = evalPoly(p, x)
```

Evaluates a polynomial of a specific type at a given point.

```
y = evalPoly(x, degree, type)
y = evalPoly(x, degree, <aLaguerre>, m)
y = evalPoly(x, degree, <jacobi>, r1, r2)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `p` | Polynomial | The input polynomial. |
| `x` | Scalar or Matrix | The input value. |
| `degree` | Integer Scalar | The order of the polynomial. |
| `type` | HiQ Constant | The orthogonal polynomial type.<br>`<chebyshev1>`<br>`<chebyshev2>`<br>`<hermite>`<br>`<laguerre>`<br>`<legendre>` |
| `m` | Real Scalar | Additional parameter for associated Laguerre `<aLaguerre>` orthogonal polynomial type. |
| `r1` | Real Scalar | Additional parameter for the Jacobi `<jacobi>` orthogonal polynomial type. |
| `r2` | Real Scalar | Additional parameter for the Jacobi `<jacobi>` orthogonal polynomial type. |
| `y` | Scalar, Vector, or Matrix | The output values. |

## Comments

Polynomial evaluation using matrices is performed using linear algebra, not on an element-by-element basis.

This function evaluates orthogonal polynomials numerically without creating a polynomial object. Only real scalar objects are valid.

A family of polynomials $p_i(x)$ are called orthogonal polynomials over the interval $a < x < b$ if each polynomial in the family satisfies the following equations.

$$\int_a^b w(x)p_n(x)p_m(x)dx = 0 \qquad \text{if } n \neq m$$

$$\int_a^b w(x)p_n(x)p_n(x)dx = h_n \neq 0$$

The interval, $(a, b)$, and the weighting function, $w(x)$, vary depending on the family of orthogonal polynomials.

Chebyshev orthogonal polynomials of the first kind, $T_n(x)$, are defined by the integral

$$\int_{-1}^{1} \frac{1}{\sqrt{1-x^2}} T_n(x)T_n(x)dx = \begin{cases} \dfrac{\pi}{2} & \text{if } n \neq 0 \\ \pi & \text{if } n = 0 \end{cases}$$

and follow the recurrence relationship

$$T_0(x) = 1$$

$$T_1(x) = x$$

$$T_n(x) = 2xT_{n-1}(x) - T_{n-2}(x) \qquad \text{where } n = 2, 3, \ldots$$

Chebyshev orthogonal polynomials of the second kind, $U_n(x)$, are defined by the integral

$$\int_{-1}^{1} \sqrt{1-x^2}\, U_n(x) U_n(x)\, dx = \frac{\pi}{2}$$

and follow the recurrence relationship

$$U_0(x) = 1$$

$$U_1(x) = 2x$$

$$U_n(x) = 2xU_{n-1}(x) - U_{n-2}(x) \quad \text{where } n = 2, 3, \ldots$$

Jacobi orthogonal polynomials (hypergeometric polynomials), $P_n^{\mu, v}(x)$, are defined by the integral

$$\int_{-1}^{1} (1-x)^{\mu}(1+x)^{v} P_n^{\mu, v}(x) P_n^{\mu, v}(x)\, dx = \frac{2^{\mu+v+1}}{2n+\mu+v+1} \frac{\Gamma(n+\mu+1)\Gamma(n+v+1)}{n!\Gamma(n+\mu+v+1)}$$

and follow the recurrence relationship

$$P_0^{\mu, v}(x) = 1$$

$$P_1^{\mu, v}(x) = \frac{(\mu+v+2)}{2}x + \frac{v-\mu}{2}$$

$$P_n^{\mu, v}(x) = \frac{(2n+\mu+v-1)[(2n+\mu+v-2)(2n+\mu+v)x-\mu^2+v^2]}{2n(n+\mu+v)(2n+\mu+v-2)} P_{n-1}^{\mu, v}(x) -$$

$$\frac{(n+v-1)(n+\mu-1)(2n+\mu+v)}{n(n+\mu+v)(2n+\mu+v-2)} P_{n-2}^{\mu, v}(x) \quad \text{where } n = 2, 3, \ldots$$

Hermite orthogonal polynomials, $H_n\ (x)$, are defined by the integral

$$\int_{-\infty}^{\infty} e^{-x^2} H_n(x) H_n(x)\, dx = \sqrt{\pi}\, 2^n n!$$

and follow the recurrence relationship

$$H_0(x) = 1$$

$$H_1(x) = x$$

$$H_n(x) = 2xH_{n-1}(x) - 2nH_{n-2}(x) \quad \text{where } n = 2, 3, \ldots$$

Laguerre orthogonal polynomials, $L_n\ (x)$, are defined by the integral

$$\int_{0}^{\infty} e^{-x} L_n(x) L_n(x)\, dx = 1$$

and follow the recurrence relationship

$$L_0(x) = 1$$

$$L_1(x) = -x + 1$$

$$L_n(x) = \frac{2n-1-x}{n} L_{n-1}(x) - \frac{n-1}{n} L_{n-2} \quad \text{where } n = 2, 3, \ldots$$

Associated Laguerre orthogonal polynomials, $L_n^a(x)$, are defined by the integral

$$\int_0^\infty e^{-x} x^a L_n^a(x) L_n^a(x) dx = \frac{\Gamma(a+n+1)}{n!}$$

and follow the recurrence relationship

$$L_n^a(x) = 1$$

$$L_n^a(x) = -x + a + 1$$

$$L_n^a(x) = \frac{2n+a-1-x}{n} L_{n-1}^a(x) - \frac{n+a-1}{n} L_{n-2}^a \quad \text{where } n = 2, 3, \ldots$$

Legendre orthogonal polynomials, $P_n(x)$, are defined by the integral

$$\int_{-1}^{1} P_n(x) P_n(x) dx = \frac{2}{2n+1}$$

and follow the recurrence relationship

$$P_0(x) = 1$$

$$P_1(x) = -x + 1$$

$$P_n(x) = \frac{2n-1}{n} P_{n-1}(x) - \frac{n-1}{n} P_{n-2} \quad \text{where } n = 2, 3, \ldots$$

## See Also

createPoly

## exp

### Purpose

Computes the exponential function.

### Usage

```
y = exp(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar or Matrix | The input argument. |
| `y` | Real or Complex Scalar or Matrix | The exponential of the input. |

### Comments

The exponential function is defined by the following equation.

$$\exp(x) = e^x$$

### See Also

`ln`, `log`

# expI

## Purpose

Computes the exponential integral function.

## Usage

```
y = expI(x, n)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `n` | Integer Scalar | The exponent parameter. |
| `y` | Real Scalar | The value of the exponential integral function. |

## Comments

The exponential integral function is defined by the following equation.

$$E(x, n) = \int_1^{\infty} t^{-n} e^{-xt} dt$$

## See Also

`cosI`, `sinI`

## export

### Purpose

Exports data to a file.

### Usage

`export(fid, object, *format, progressFct*)`

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | The file ID of the target file. |
| *`object`* | Object | The numeric object to write to the file. |
| *`format`* | Text | Specifies how to write the object to the file. (Optional.) |
| *`progressFct`* | Function | A user function that monitors the progress of the export. (Optional.) |

### Comments

HiQ uses the parameter `format` to convert data from an internal source object to an external target object. For the `export` function, the source object is a HiQ object and the target object is a file. HiQ provides predefined constants for the most commonly used data format strings. If you do not provide the parameter `format`, HiQ exports the data as numeric text.

A format string is composed of three strings describing the external (target) data, the format of the data, and the internal (source) object. These strings are separated by colons (:) as follows.

```
"[ExternalDescr]:[FormatDescr]:[InternalDescr]"
```

Each string is composed of identifiers preceded by a percent sign (%). These strings and their identifiers are described in detail below for the `export` function.

#### External Description

The external description string describes how the data is to be stored in the target file. HiQ supports both big endian and little endian byte ordering. The valid identifiers for the external description string are defined in the following table.

| Source Identifier | Description |
|---|---|
| `%littleendian`<br>`%intel` | Bytes are stored in the file with the least significant byte first. Intel CPU-based computers use little endian byte ordering. (Default.) |
| `%bigendian`<br>`%motorola` | Bytes are stored in the file with the most significant byte first. Motorola CPU-based computers use big endian byte ordering. |
| `%Excel`<br>`%Excel[`*`sheet`*`]` | Source file is an Excel file. In the second form the name of the sheet to be imported is specified. If omitted the first sheet in the file is imported. |
| `%range[`*`A1style`*`]`<br>`%range[`*`HiQStyle`*`]` | For Excel files, indicates the desired cell range. If omitted all cells with data are imported. The range can be the Excel A1 style (for example, `%range[A1:C3]`) or the HiQ-Script subscript range style (for example, `%range[1:3,1:3]`). The HiQ-Script range works exactly as in script except that if the upper range is omitted it is assumed to be `*`. In other words `%range[1,1]` is the same as `%range[1:*,1:*]`. |

## Format Description

The format description string describes how HiQ writes the numeric data to the file. For example, you can specify whether the numeric data is text or binary, whether the data is integer, real, or complex, or the width and precision of a text numeric field. The export wizard **(Notebook»Export Data...)** is a convenient place to learn how the format description string works. In expert mode, you can enter and modify a format string and immediately view the results in the Preview window. The valid identifiers for the format description string are defined in the following table.

| Format Identifier | Description |
|---|---|
| `%delimiters[`*`list`*`]` | Delimiter identifier specifying the characters that separate numeric values. (Optional.) |
| *`%count type`*`[`*`modifiers`*`]` | Numeric identifier describing the repeat count and format type for integer and real numeric values. (Optional.) |
| *`%count cType`*`[`*`type`*`[`*`modifiers`*`]]` | Numeric identifier describing the repeat count and format type for complex numeric values. (Optional.) |

A format description string can have multiple numeric format identifiers but only one delimiter format identifier. The components of a format identifier string are defined in the following table.

| **Parameter** | **Description** |
|---|---|
| *`list`* | A string of characters that delimit the numeric values in a file. If *`list`* is empty, HiQ uses the tab character. For special characters, use the following.<br><br>`\t` (tab)<br>`\]` (right square bracket)<br>`\[` (left square bracket)<br>`\\` (backslash) |
| *`count`* | Indicates the number of times to apply the format identifier. A value of zero repeats the format identifier for the entire row of a matrix. A zero value is invalid with binary forms. (Optional. Default = `1`.) |
| *`type`* | Indicates whether the data is text numeric or binary numeric and integer or real. (Optional. Default = `g`)<br><br>`f` Text Decimal real. For example, `123.456`.<br>`e` Text Scientific real. For example, `1.23456e02`.<br>`g` Text General real. For example, `1.23456e02`.<br>`ee` Text Engineering real. For example, `0.123456e03`.<br>`ge` Text General engineering real. For example, `0.123456e03`.<br>`i` Text Decimal integer. For example, `123`.<br>`d` Text Decimal integer. For example, `123`.<br>`x` Text Hexadecimal integer. For example, `D4A2`.<br>`pr` Text Polynomial with ascending coefficients.<br>`pf` Text Polynomial with descending coefficients.<br>`pv`*`x`* Text Polynomial with *x* as the dependent variable.<br>`fb` Binary Real.<br>`ib` Binary Integer.<br>`ub` Binary Unsigned integer. |

| Parameter | Description |
|---|---|
| *modifiers* | Indicates the numeric field width, number of digits to the right of the decimal point, and whether to discard the data. (Optional)<br>w*n* For text destination: Specifies the width of the numeric field in number of characters.<br>For binary destination: Specifies the width of the number in number of bits.<br>p*n* Specifies the number of digits of precision to the right of the decimal point. (Default = p6.)<br>p* Tells HiQ to automatically determine the precision.<br>e*n* Specifies the number of digits in the exponent. Valid values of *n* are 1, 2 and 3.<br>d Writes a 0 formatted to the specified options for text formats. For binary formats if the write would extend the length of the file then a 0 is written according to the specified options. In binary mode if you are writing over an already written portion of the file it will simply seek past the position leaving it untouched. This allows you to do binary writes that interleave data.<br>jr Specifies to right justify the formatted number within the specified width. (Default.)<br>jl Specifies to left justify the formatted number within the specified width. (Default.)<br>wc Turns width control on. This automatically adjusts the precision to fit within the width specified by w*n*. If the formatted number does not fit, then the width is increased appropriately.<br>wc Turns width control off. (Default.)<br>wc# For width control, this fills the entire width with # signs if the formatted number does not fit.<br>wc... For width control, replaces each of the last three characters with a dot if the formatted number does not fit.<br>wce For width control, replaces the last character with the ellipses character if the formatted number does not fit.<br>zp Zero pad the width of this format.<br>zp+ Zero pad the width of this format.<br>zp- Do not zero pad the width of this format. (Default.) |

| Parameter | Description |
|---|---|
| | `tz` Removes trailing zeros. (Default.)<br>`tz+` Removes trailing zeros.<br>`tz-` Do not remove trailing zeros.<br>`~` If the formatted string results in 0 and the original number is not identically 0, then output ~0.<br>`~-` Do not format 0 strings with ~0. (Default.) |
| *`cType`* | Indicates the data is a complex number and specifies the complex format. The optional modifier for *`cType`*, *`type`*[*`modifiers`*], describes the format of each of the two components of the complex number. If you provide only one modifier *`type`*[*`modifiers`*], that modifier is used for both components. The valid values for *`cType`* are defined in the following table.<br>`co` Ordered pair `(`*`real`*, *`imaginary`*`)`. (Default.)<br>`ci` Sum, i format *`real`* + *`imaginary`* `i`.<br>`cj` Sum, j format *`real`* + *`imaginary`* `j`.<br>`cd` Polar, degrees, *`magnitude`* @ *`degrees`* `°`.<br>`cr` Polar, radians, *`magnitude`* @ *`radians`* `r`.<br>`cg` Polar, grads, *`magnitude`* @ *`grads`* `g`.<br>Each complex type can be modified by inserting the characters inside the outer modifier brackets.<br>`s` Turns space control on. This will strip extra spaces in the formatting of the complex number.<br>`s-` Turns space control off. (Default.)<br>`jr` Specifies to right justify the formatted number within the specified width. (Default for real part.)<br>`jl` Specifies to left justify the formatted number within the specified width. (Default for imaginary part.) |

Examples of valid format description strings include the following.

```
%delimiters[,]%5f%5i
%5f[w8p3]
%co[f[w6p2]]
%2cd[f[w6p2]i[w2]]
```

## Internal Description

The internal description string describes the HiQ object to export. The valid identifiers for the internal description string are defined in the following table.

| Target Identifier | Description |
|---|---|
| `%transpose` | Transpose the data while writing to the target. Reverses the meaning of row and column counts. |

## See Also

`import`

## fact

### Purpose

Computes the factorial of a number.

### Usage

```
y = fact(n)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `n` | Integer Scalar | The input argument. |
| `y` | Real Scalar | The factorial of the input. |

### Comments

The factorial function is defined by the following equation.

$$\mathrm{fact}(n) = n! = \prod_{i=1}^{n} i$$

### See Also

`gamma`

## fCosI

### Purpose

Computes the Fresnel cosine integral function.

### Usage

```
y = fCosI(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The value of the Fresnel cosine integral. |

### Comments

The Fresnel cosine integral is defined by the following equation.

$$C(x) = \int_0^x \cos\left(\frac{\pi}{2}t^2\right)dt$$

### Examples

#### Illustrating Cornu's spiral.

```
// Graph the Cornu's Spiral based on the Fresnel Integrals.

// Define the domain for the parametric curve and
// compute x and y based on the domain.
t = seq(-5, 5, 10000, <pts>);
xt = eval(fCosI, t);
yt = eval(fSinI, t);

// Generate the spiral given the computed parameters.
cornuSpiral = createGraph(xt, yt);
```

### See Also

`dawson`, `erf`, `erfc`, `fSinI`

## fill

### Purpose

Creates a vector or matrix initialized with a value.

### Usage

Creates an *m*-element vector initialized with the value *x*.

```
    a = fill(m, x)
```

Creates an *mxn* matrix initialized with the value *x*.

```
    A = fill(m, n, x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `m` | Integer Scalar | The number of rows to create. |
| `x` | Scalar | The value used to fill the matrix. |
| `n` | Integer Scalar | The number of columns to create. |
| `a` | Vector | The *m*-element output vector. |
| `A` | Matrix | The *mxn* output matrix. |

### Comments

All elements of the vector or matrix are set to the fill value.

### See Also

`createMatrix`, `createVector`, `ident`, `ones`, `seq`

## find

### Purpose

Finds the occurrences of an element in a vector or matrix.

### Usage

Finds the occurrences of a scalar in a vector or matrix.

```
[found, foundIndices, nFound] = find(x, value)
```

Finds the occurrences of a set of scalars in a vector or matrix.

```
[found, foundIndices, nFound, valIndices] = find(x, values,
<elements>)
```

Finds the occurrences of a subvector or submatrix in a vector or matrix.

```
[found, foundIndices, nFound] = find(x, xSub)
```

Finds the occurrences of a subvector in a matrix.

```
[found, foundIndices, nFound] = find(X, Xsub, direction)
```

Finds the occurrences of elements satisfying a predefined condition in a vector or matrix.

```
[found, foundIndices, nFound] = find(x, operator, base)
```

Finds the occurrences of elements satisfying a user defined condition in a vector or matrix.

```
[found, foundIndices, nFound] = find(x, findFct)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Vector or Matrix | The input vector or matrix to search. |
| `value` | Scalar | The element to find. |
| `values` | Vector or Matrix | The elements to find. |
| `xSub` | Vector or Matrix | The subvector or submatrix to find. |
| `X` | Matrix | The input matrix to search. |
| `Xsub` | Vector | The subvector to find. |
| *`direction`* | HiQ Constant | Specifies whether to search rows or columns. (Optional. Default = `<row>`)<br>`<row>`<br>`<column>` |

| Name | Type | Description |
|---|---|---|
| `operator` | HiQ Constant | A predefined operator with which to compare values.<br>`<GT>`<br>`<LT>`<br>`<GE>`<br>`<LE>`<br>`<NE>` |
| `base` | Scalar | An additional parameter for use with the predefined operator. |
| `findFct` | Function | A user function that determines which values to find. |
| `found` | Vector or Matrix | The found elements. |
| `foundIndices` | Integer Vector or Matrix | The indices of the found elements. |
| `nFound` | Integer Scalar | The number of matches found. |
| `valIndices` | Integer Vector or Matrix | The indices into the input set of values corresponding to the actual values found. |

## Comments

The search in vectors is performed from first element to last. The search in matrices is performed row-wise, first column to last. If you are searching for a set of elements and the set of elements contains duplicate values, only the first value is used to find a match.

When searching for scalars (or sets of scalars), each occurrence of a scalar is returned in the object `found`. When searching for a subvector or a submatrix, the object `found` contains only one instance of the subvector or submatrix found.

The object type and size of `foundIndices` is directly related to the type of objects being searched and found.

| Search Object | Find Object | Options | Indices |
|---|---|---|---|
| vector | scalar | | vector |
| vector | subvector | | *n*x2 matrix |
| vector | vector | <elements> | vector |
| matrix | scalar | | *n*x2 matrix |
| matrix | subvector | <row> or <column> | *n*x4 matrix |
| matrix | submatrix | | *n*x4 matrix |
| matrix | matrix | <elements> | *n*x2 matrix |

If searching for a subvector, each row of an *n*x2 matrix represents the range of the subvector found. Otherwise, each row of an *n*x2 matrix represents the row and column index of the scalar found. Each row of an *n*x4 matrix represents the row and column indices of the upper left (the first two elements of the row) and lower right (the last two elements of the row) corners of the occurrence of the found object in the matrix.

If the input parameter `values` is a vector, the return object `valIndices` is a vector of indices. If the input parameter `values` is a matrix, the return object `valIndices` is a matrix of row and column indices.

When no items are found, this function returns 0 for integer, `<nan>` for reals and (`<nan>`, `<nan>`) for complex. For indices, a 1-element vector, a 1x2 matrix, or a 1x4 matrix will be returned containing zeros.

The user-defined find function, `findFct`, for the usage above has the following definitions:

```
// Function definition for searches performed on vectors.
function findFct(x, i)
   // x - The current vector element under inspection
   // i - The index of the current vector element

   // return options:
   //  true  - x meets the user-defined condition
   //  false - x does not meet the user-defined condition
end function;
```

```
// Function definition for searches performed on matrices.
function findFct(x, i, j)
   // x - is the current matrix element under inspection
   // i - is the row index of the current matrix element
   // j - is the column index of the current matrix element

   // return options:
   //   true  - x meets the user-defined condition
   //   false - x does not meet the user-defined condition
end function;
```

## See Also

`remove`, `replace`, `subrange`

## fit

### Purpose

Computes the parameters of a function that best fit a data set.

### Usage

Computes the parameters of a pre-defined function that best fit a data set.

```
[a, res, q, aVar, yFit] = fit(x, y, <line>, w)
[a, res, q, aVar, yFit] = fit(x, y, <exp>, w)
[a, res, q, aVar, yFit] = fit(x, y, <gauss>, a0, method, tolr, w)
```

Creates the polynomial object that best fits a data set.

```
yPoly = fit(x, y, <poly>, n, w)
```

Computes the parameters of a single-variable nonlinear function that best fit a data set.

```
[a, res, q, aVar, yFit] = fit(x, y, sFct, a0, method, tolr, iterMax,
w, rhoFct)
```

Computes the parameters of a multi-variable nonlinear function that best fit a data set.

```
[a, res, q, aVar, yFit] = fit(X, y, mFct, a0, method, tolr, iterMax,
w, rhoFct)
```

Computes the linear combination of a set of basis functions that best fit a data set.

```
[a, res, q, aVar, yFit] = fit(x, y, basisFct, basisMethod, w)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | An *n*-element vector of independent data points. |
| `y` | Real Vector | An *n*-element vector of dependent data points. |
| *`w`* | Real Vector | An *n*-element vector of parameter weights. (Optional. Default = *`w`*`[i]` = `1.0`) |
| `a0` | Real Vector | The *m*-element vector of initial guesses for the function parameters. |
| *`method`* | HiQ Constant | The unconstrained optimization algorithm to use. (Optional. Default = `<marquardt>`)<br>`<marquardt>`<br>`<quasiNewton>`<br>`<conjGrad>` |

| Name | Type | Description |
|---|---|---|
| *`tolr`* | Real Scalar | The tolerance to use.<br>(Optional. Default = `.0001`) |
| `n` | Integer Scalar | The order of the polynomial to fit. |
| `sFct` | Function | The single-dimension nonlinear function to fit. |
| *`iterMax`* | Integer Scalar | The maximum number of iterations to allow.<br>(Optional. Default = `32`) |
| *`rhoFct`* | Function | A robust estimation function. (Optional.) |
| `X` | Real Matrix | An *n*x*k* matrix of independent data points. |
| `mFct` | Function | The multi-dimensional nonlinear function to fit. |
| `basisFct` | Function | The set of basis functions to use. |
| *`basisMethod`* | HiQ Constant | The algorithm to use.<br>(Optional. Default = `<housefullrank>`)<br>`<SVD>`<br>`<givensFullRank>`<br>`<houseDefRank>`<br>`<givensDefRank>`<br>`<houseFullRank>` |
| `a` | Real Vector | The parameters that best fit the function to the data. |
| `res` | Real Scalar | The residual of the resulting data fit. |
| `q` | Real Scalar | The goodness-of-fit value. |
| `aVar` | Real Scalar | The variance of the best-fit parameters. |
| `yFit` | Vector | The best fit evaluated at each of the input values in *x*. |
| `yPoly` | Polynomial | The polynomial object that best fits the data. |

## Comments

The computed best-fit parameters are returned in the vector **a**. For polynomial data fitting, this function returns the best-fit polynomial object. The coefficients of the polynomial are the best-fit parameters.

Each usage, except for the multi-variable nonlinear fit, now supports an implicit domain. For example, the following usage is valid.

```
[a, res, q, aVar, yFit] = fit(y,<line>);
```

In this usage, the domain is assumed to be the following.

```
x = seq(y.size);
```

You can choose a predefined function to fit your data or supply your own user-defined function. HiQ fits the following predefined equations.

| Usage | Equation |
|---|---|
| `a = fit(x, y, <line>);` | $y = a_1 x + a_2$ |
| `a = fit(x, y, <exp>);` | $y = a_1 e^{a_2 x}$ |
| `a = fit(x, y, <gauss>, a0);` | $y = a_3 e^{\frac{-(x-a_1)^2}{(2a_2)^2}}$ |

HiQ fits the following user-defined equations.

| Usage | Equation |
|---|---|
| `a = fit(x, y, f, a0);` | $y = f(\mathbf{a}, x) = f(a_1, a_2, \ldots, a_n, x)$ |
| `a = fit(x, y, f, a0);` | $y = f(\mathbf{a}, \mathbf{x}) = f(a_1, a_2, \ldots, a_n, x_1, x_2, \ldots, x_m)$ |
| `a = fit(x, y, f, basisMethod);` | $y = \sum_{i=1}^{n} a_i f_i(x)$ |

For the single-variable nonlinear equation, each element of the input vector `x` corresponds to the value of the independent variable for each element in `y`.

For the multi-variable nonlinear equation, each row of the input matrix X corresponds to the values of the independent variables for each element in `y`. Each column of the input matrix X corresponds to a separate independent variable. For example, a data set `y` containing 200 points that is a function of five independent variables requires an $200 \times 5$ input matrix X and a 200-element input vector `y`.

To fit the single-variable and multi-variable nonlinear equations, HiQ uses one of several available unconstrained optimization algorithms. To fit the single-variable linear combination of basis functions, HiQ uses one of several available least-squares algorithms. Refer to the functions `optimize` and `solve` for more information on these algorithms.

The computed parameters minimize the sum of the squares of the weighted differences at each data point. For example, the best-fit parameters **a** of a single-variable nonlinear equation minimizes

$$r = \sum_{i=1}^{n} \frac{(y_i - f_i(\mathbf{a}, x))^2}{w_i^2}$$

where $r$ is the residual of the fit.

The weighting parameter $w$ gives you the flexibility to modify the influence of each data point on the resulting fit. A smaller value of $w_i$ places more emphasis on the data fit for data point $y_i$. For statistical data fitting, $w_i$ represents the standard deviation of the measurement $y_i$. This function also computes two statistics at the best-fit solution. The return parameter `q` ($0 \le q \le 1$) represents the chi-square goodness-of-fit statistic of the data fit. A chi-square value of zero indicates a bad fit and a value of one indicates a good fit. The return parameter `aCov` is the matrix of covariances between each of the best-fit parameters. The diagonal elements of this matrix are the variances of each parameter and are a measure of uncertainty in each parameter. The off-diagonal elements are the covariances of the parameters. Smaller elements in this matrix indicate less uncertainty in the computed parameters.

A more flexible approach to modifying the influence of each data point on the resulting fit is to change the performance function. The default performance function is

$$r = \sum_{i=1}^{n} \frac{(y_i - f_i(\mathbf{a}, x))^2}{w_i^2} = \sum_{i=1}^{n} z^2 \qquad \text{where } z = \frac{y_i - f_i(\mathbf{a}, x)}{w_i}$$

You can modify the performance function with a user-defined robust estimation function $\rho(z)$ (parameter `rhoFct`)

$$r = \sum_{i=1}^{n} \rho(z)$$

The default estimation function is

$$\rho(z) = z^2$$

Examples of robust estimation functions include

$$\rho(z) = \ln\left(1 + \frac{z^2}{x}\right)$$

and

$$\rho(z) = |z|$$

To avoid numerical problems, you should define an estimation function that is differentiable. For example, the following script implements $\rho(z) = |z|$, avoiding problems at $z = 0$.

```
function rho(z)
   if abs(z) < 1 then
      return z^2;
   else
      return abs(z);z
end function;
```

## See Also

`fitEval`, `interp`, `optimize`, `spline`

# fitEval

## Purpose

Evaluates a fit at the given points.

## Usage

Evaluates the fit of a predefined function.
```
y = fitEval(x, fitType, a)
```

Evaluates the polynomial fit.
```
y = fitEval(x, <poly>, p)
```

Evaluates the single variable fit model at a set of values.
```
y = fitEval(x, sFct, a)
```

Evaluates the multi-variable fit model at a set of values.
```
y = fitEval(X, mFct, a)
```

Evaluates the linear combination of basis functions at a set of values.
```
y = fitEval(x, <basis>, basisFct, a)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The vector of values to evaluate the fit. |
| `fitType` | HiQ Constant | The predefined function used to define the fit model.<br>`<exp>`<br>`<gauss>`<br>`<line>` |
| `a` | Real Vector | The coefficients defining the fit model. |
| `p` | Real Polynomial | The polynomial representing the fit model. |
| `sFct` | Function | The function used to define the single-variable fit model. |
| `X` | Real Matrix | The matrix of values to evaluate a multi-variable fit. |
| `mFct` | Function | The function used to define the multi-variable fit model. |

| Name | Type | Description |
|---|---|---|
| `basisFct` | Function | The set of basis functions defining the fit model. |
| `y` | Vector | The fit evaluated at the given points. |

## Comments

The function fit computes the best-fit parameters of a fit model and evaluates the model at the values used to determine the fit. You can use the function `fitEval` to evaluate the best-fit model returned from the function fit at any set of values without having to recompute the best-fit parameters.

HiQ fits the following predefined equations.

| Usage | Equation |
|---|---|
| `y = fitEval(x, <line>, a);` | $y = a_1 x + a_2$ |
| `y = fitEval(x, <exp>, a);` | $y = a_1 e^{a_2 x}$ |
| `y = fitEval(x, <gauss>, a);` | $y = a_3 e^{\frac{-(x-a_1)^2}{(2a_2)^2}}$ |

HiQ fits the following user-defined equations.

| Usage | Equation |
|---|---|
| `y = fitEval(x, f, a);` | $y = f(\mathbf{a}, x) = f(a_1, a_2, \ldots, a_n, x)$ |
| `y = fitEval(x, f, a);` | $y = f(\mathbf{a}, \mathbf{x}) = f(a_1, a_2, \ldots, a_n, x_1, x_2, \ldots, x_m)$ |
| `y = fitEval(x, <basis>, a);` | $y = \sum_{i=1}^{n} a_i f_i(x)$ |

For the single-variable nonlinear equation, each element of the input vector *x* corresponds to the value of the independent variable for each element in *y*.

For the multi-variable nonlinear equation, each row of the input matrix *X* corresponds to the values of the independent variables for each element in *y*. Each column of the input matrix *X* corresponds to a separate independent variable. For example, a data set *y* containing 200 points that is a function of five independent variables requires an 200x5 input matrix *X* and a 200-element input vector *y*.

## See Also

`fit`, `interp`, `interpEval`, `spline`, `splineEval`

## floor

### Purpose

Rounds a number towards negative infinity.

### Usage

```
y = floor(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar, Vector, or Matrix | The input argument. |
| `y` | Real Scalar, Vector, or Matrix | The rounded value. |

### Comments

For vector and matrix objects, `floor(x)` returns the floor of the input on an element-by-element basis.

### Examples

#### Computing the floor of a vector of data.

```
// Generate two step functions that 'surround' a
// data set and graph the results.

// Create a set of 500 points in (-5, 5) sorted by size.
data = createVector(25, <random>, 1, 25, <uniform>);
data = sort(data);

// Create the graph and plot the generated data.
[graph, plotData] = createGraph(data);

// Once the graph is created, add the plots of the
// upper and lower bounds for the data.
plotTop = addPlot(graph, ceil(data));
plotBottom = addPlot(graph, floor(data));
```

```
// Change the plot color and style to make the plots
// easier to distinguish.
graph.plot(plotData).style = <point>;
graph.plot(plotData).point.size = 2;

graph.plot(plotTop).line.color = <ltblue>;
graph.plot(plotBottom).line.color = <red>;
```

## See Also

`ceil`, `round`

## flush

### Purpose

Flushes the contents of the file buffer to disk.

### Usage

```
flush(fid)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | The file ID of the file to flush. |

### Comments

Data written to a file often resides in a buffer until the buffer fills up or until the file is closed. This function forces the buffer to write any data to the file.

### See Also

`close`, `deleteFile`, `open`

# fPart

## Purpose

Computes the fractional part of a number.

## Usage

```
y = fPart(x)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, or Matrix | The input argument. |
| `y` | Scalar, Vector, or Matrix | The fractional part of the input argument. |

## Comments

The result retains the sign of the input. For example, the following script returns a value of –0.82 for `y`.

```
y = fPart(-4.82);
```

For vector and matrix inputs, `fPart(x)` returns the fractional part of the input on an element-by-element basis

## See Also

`ceil`, `floor`, `iPart`, `round`, `toInteger`

## fSinI

### Purpose

Computes the Fresnel sine integral function.

### Usage

```
y = fSinI(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The value of the Fresnel sine integral. |

### Comments

The Fresnel sine integral is defined by the following equation.

$$S(x) = \int_0^x \sin\left(\frac{\pi}{2}t^2\right)dt$$

### See Also

`dawson`, `erf`, `erfc`, `fCosI`

# gamma

## Purpose

Computes the gamma function.

## Usage

Computes the complete gamma function.

```
    y = gamma(x)
```

Computes the incomplete gamma function.

```
    y = gamma(x, a)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| x | Real Scalar | The input argument. |
| a | Real Scalar | The upper limit of the incomplete gamma function. |
| y | Real Scalar | The value of the gamma function. |

## Comments

The `gamma` function is defined as

$$\Gamma(x) = \int_0^\infty t^{x-1} e^{-t} dt$$

It is related to the factorial function by the identity

$$\Gamma(n+1) = n! \quad \text{for integer } n$$

The incomplete `gamma` function is defined as

$$\Gamma(x, a) = \frac{1}{\Gamma(x)} \int_0^a t^{x-1} e^{-t} dt$$

## Examples

### Computing the Bateman's G function and the derivative of the gamma function.

```
// Use the digamma function to compute the Bateman's G function
// and the derivative of the gamma function.

// Choose the evaluation point for the Bateman's G function.
x = random(-5, 5);

// Define the G function in terms of digamma().
G = {f:x:"digamma(.5*(x+1.0)) - digamma(.5*x)"};

// Compute the Bateman's G function at the evaluation point.
y = G(x);

// Compute the derivative of the gamma function at x.
dGamma = gamma(x)*digamma(x);
```

## See Also

`beta`, `digamma`, `fact`, `gammaC`

## gammaC

### Purpose

Computes the complementary incomplete gamma function.

### Usage

```
y = gammaC(x, a)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real Scalar | The input argument. |
| a | Real Scalar | The upper limit of the incomplete complementary gamma integral. |
| y | Real Scalar | The value of the complementary gamma function. |

### Comments

The complement of the incomplete `gamma` function is defined as

$$\Gamma_c(x, a) = \frac{1}{\Gamma(x)}\int_a^{\infty} t^{x-1} e^{-t} dt$$

It is related to the incomplete `gamma` function by the identity

$$\Gamma(x, a) + \Gamma_c(x, a) = 1$$

### See Also

`gamma`

## gauss

### Purpose

Computes the Gauss hypergeometric function.

### Usage

```
y = gauss(x, a, b, c)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `a` | Real Scalar | The third parameter of the Gauss hypergeometric function. |
| `b` | Real Scalar | The second parameter of the Gauss hypergeometric function. |
| `c` | Real Scalar | The first parameter of the Gauss hypergeometric function. |
| `y` | Real Scalar | The value of the Gauss hypergeometric function. |

### Comments

The Gauss hypergeometric function, F(x,a,b,c), is a solution of the differential equation

$$x(1-x)\frac{d^2w}{dx^2} + [c-(a+b+1)x]\frac{dw}{dx} - abw = 0$$

### See Also

`kummer`, `tricomi`

## gcd

### Purpose

Computes the greatest common divisor of two numbers or polynomials.

### Usage

Calculates the greatest common divisor of two integers.

```
y = gcd(a, b)
```

Calculates the greatest common divisor of a set of integers.

```
y = gcd(x)
```

Calculates the greatest common divisor of two polynomials.

```
y = gcd(p, q, tolr)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Integer Scalar | The first input argument. |
| `b` | Integer Scalar | The second input argument. |
| `x` | Integer Vector | A vector of integers. |
| `p` | Polynomial | The first polynomial argument. |
| `q` | Polynomial | The second polynomial argument. |
| *`tolr`* | Real Scalar | Relative tolerance. (Optional.) |
| `y` | Integer Scalar or Real or Complex Polynomial | The greatest common divisor of the input arguments. |

## Comments

If the inputs are relatively prime, the value of the result is one.

HiQ uses the Euclid algorithm to calculate the greatest common divisor of two polynomials. This algorithm computes divisors whose remainder is less than a specified tolerance value `tolr`. The result is a normalized polynomial. (The leading coefficient of the polynomial is equal to one.) The default is

$$2^{n^2 + 1}\varepsilon$$

where $n$ is the maximum degree of the two polynomials and $\varepsilon$ is the constant `<epsilon>`.

## See Also

`lcm`

## getFileName

### Purpose

Displays the file dialog box prompting for an existing filename.

### Usage

```
   file = getFileName(path, filter, iFilter, title)
```

Creates a temporary file.

```
   file = getFileName(<temp>, baseName)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| *`path`* | Text | The initial directory path to display. (Optional.) |
| *`filter`* | Text | A list of file types (suffixes) to display. (Optional.) |
| *`iFilter`* | Integer Scalar | An index (to filter) that is the default file type to display. (Optional. Default = `1`) |
| *`title`* | Text | The title of the dialog box. (Optional.) |
| *`baseName`* | Text | The base name to use for the temporary file. (Optional. Default = `HiQ`) |
| `file` | Text | The full path and name of the selected file. |

### Comments

The parameter filter is a list of filter name and filter type pairs separated by vertical bars (|) as follows.

```
Filter_Name_1|Filter_1|Filter_Name_2|Filter_2|...|Filter_Name_n|Filter_n|
```

The filter name appears in the **Files of Type** pull-down menu of the dialog box. Users can choose from among any of the file types you specify in your filter string. For example, the following `getFileName` function call prompts the user with the **Open** dialog box and allows file searches for two file types, including All Files (*.*), in the current directory:

```
getFileName("", "All Files (*.*)|*.*|Data Files (*.dat)|*.dat", 1, "Open");
```

## Examples

### Prompting for a file of a specific type (HiQ-Script).

This example show how to prompt the user for an Excel file, only displaying files with a `.xls` extension in the file dialog box.

```
//Prompt for a file name. Only files with a .xls extension
//are displayed in the file dialog box.
file = getFileName("c:\", "Excel files | *.xls");

//Import all of the data on the first sheet of the Excel
//notebook.
A = import(file,"%excel::");

//Import all of the data on the second sheet.
B = import(file,"%excel[Sheet2]::");

//Import the data in cells A3 to C9 on the third sheet.
C = import(file,"%excel[Sheet3]%range[A3:C9]::");
```

## See Also

`putFileName`

## getFilePos

### Purpose

Returns the current position of the file pointer.

### Usage

```
pos = getFilePos(fid)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | A valid file ID. |
| `pos` | Integer Scalar | The current position of the file pointer in bytes from the beginning of file. |

### Comments

You can use this function to ensure you are reading from or writing to the correct location in a structured file.

### See Also

`close`, `getFileSize`, `isEOF`, `open`

## getFileSize

### Purpose

Returns the size of a file.

### Usage

```
n = getFileSize(fid)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | A valid file ID returned from open. |
| `n` | Integer Scalar | The number of bytes in the file. |

### Comments

You can use this function to indicate the size of the data in the file and therefore the memory required to import the data.

### See Also

`close`, `getFilePos`, `isEOF`, `open`

# getNumber

## Purpose

Displays a dialog box prompting for a numeric object.

## Usage

```
y = getNumber(prompt, default)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| *prompt* | Text or Real Scalar | Prompt to be displayed in the dialog box. (Optional. Default = "Enter number:") |
| *default* | Real Scalar | The default value. (Optional. Default = 0) |
| y | Real Scalar | The value entered in the dialog box. |

## Comments

HiQ creates an integer, real, or scalar object depending on the number entered. For example, the number (1,1) creates the complex scalar $1 + 1i$. The number $1.0e - 6$ creates a real scalar. The number 64 creates an integer scalar. You must enter a valid number to continue execution of the script.

## See Also

getText

## getText

### Purpose

Displays a dialog box prompting for a text object.

### Usage

```
y = getText(prompt, default)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| *`prompt`* | Text | Prompt to be displayed in the dialog box. (Optional. Default = `"Enter string:"`) |
| *`default`* | Text | The default value. (Optional.) |
| `y` | Text | The value entered in the dialog box. |

### Comments

You can enter only one line of text. The created text object does not contain a carriage return or line feed character.

### See Also

`getNumber`

## givens

### Purpose

Computes the Givens rotation parameters of a two-element vector.

### Usage

Computes the Givens rotation parameters of a two-element vector.

```
[c, s, rho] = givens(v, elem1, elem2)
```

Decodes the Givens parameters from the single parameter.

```
[c, s] = givens(rho)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `v` | Real Vector | The input vector. |
| `elem1` | Integer Scalar | The first element of the vector to use. (Optional. Default = `1`) |
| `elem2` | Integer Scalar | The second element of the vector to use. (Optional. Default = `2`) |
| `rho` | Real Scalar | A single input parameter encoding the Givens parameters `c` and `s`. |
| `c` | Real Scalar | The first term of the Givens rotation. |
| `s` | Real Scalar | The second term of the Givens rotation. |
| `rho` | Real Scalar | Return parameters `c` and `s` encoded into a single parameter. |

### Comments

The Givens rotation **G** is a 2D, orthogonal transformation that rotates the input vector **x** counter-clockwise through an angle $\theta$ such that the second element of the vector $\mathbf{y} = \mathbf{G}^{\mathrm{T}}\mathbf{x}$ is zero.

$$\begin{bmatrix} y_1 \\ 0 \end{bmatrix} = \mathbf{G}^{\mathrm{T}} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \quad \text{where } \mathbf{G} = \begin{bmatrix} c & s \\ -s & c \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{bmatrix}$$

You can use the Givens rotations to selectively introduce zeros into a matrix and to perform coordinate system transformations. This function returns the parameters **c** and **s** of **G** without computing the value of the angle $\theta$ to prevent problems associated with inverse trigonometric calculations.

Because Givens is an orthogonal transformation, the parameters **c** and **s** are related by the identity

$$c^2 + s^2 = 1$$

and therefore can be encoded by a single value `rho`. You can use this value in a subsequent call to Givens to extract the values **c** and **s** as follows.

```
[c, s] = Givens(rho)
```

## See Also

`rotate`

# gradient

## Purpose

Computes the gradient of a function.

## Usage

`y = gradient(fct, x, `*`h, method`*`)`

## Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function | The input function. |
| `x` | Real Vector | The vector of values. |
| *`h`* | Real Scalar | The step size to use. (Optional.) |
| *`method`* | HiQ Constant | The finite difference method to use. (Optional. Default = `<central>`)<br>`<extended>`<br>`<forward>`<br>`<central>` |
| `y` | Real Vector | The gradient of the function. |

## Comments

Given a scalar-valued function *f* of several variables

$$y = f(x_1, \ldots, x_n)$$

the gradient vector **v** of the function *f* is defined by the following equation.

$$\mathbf{v} = \text{grad } f = \nabla f = \begin{bmatrix} \dfrac{\partial f}{\partial x_1} \\ \vdots \\ \dfrac{\partial f}{\partial x_n} \end{bmatrix}$$

If the step size is equal to zero, HiQ chooses an appropriate step size based on the precision of your computer.

The forward, central, and extended central finite difference formulas result in finite difference approximations of order one, two, and four respectively.

## See Also

`curl`, `derivative`, `div`, `laplacian`

## guder

### Purpose

Computes the gudermannian function.

### Usage

```
y = guder(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The gudermannian of the input. |

### See Also

`guderInv`

## guderInv

### Purpose

Computes the inverse of the gudermannian function.

### Usage

```
y = guderInv(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The inverse gudermannian of the input. |

### See Also

`guder`

## hessenbergD

### Purpose

Computes the Hessenberg decomposition of a matrix.

### Usage

```
[H, Q] = hessenbergD(A, nType)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real Matrix | The square *n*x*n* input matrix. |
| *`nType`* | HiQ Constant | The type of orthogonal transformation to use. (Optional. Default = `<house>`)<br>`<house>`<br>`<givens>` |
| `H` | Real Matrix | A square *n*x*n* Hessenberg matrix. |
| `Q` | Real Matrix | A square *n*x*n* orthogonal matrix. |

### Comments

The Hessenberg decomposition (or Hessenberg normal form) of a matrix **A** is defined as

$$\mathbf{A} = \mathbf{QHQ}^{\mathrm{T}}$$

where **Q** is orthogonal and **H** is a Hessenberg matrix. A Hessenberg matrix is defined as a matrix **H** with zeros under the main subdiagonal:

$$\mathbf{H} = \begin{bmatrix} H_{11} & H_{12} & \dots & H_{1n} \\ H_{21} & H_{22} & & \vdots \\ 0 & & \ddots & \\ \vdots & \ddots & & \\ 0 & \dots & 0 & H_{nn} \end{bmatrix}$$

This normal form is used in matrix analysis to reduce the required number of computations. For example, consider the linear system

$$(\mathbf{A} - \lambda\mathbf{I})\mathbf{x} = \mathbf{b}$$

for several values of $\lambda$ and **b**. The Hessenberg form $\mathbf{H}(\lambda) = \mathbf{H} - \lambda\mathbf{I}$ is invariant. This system is equivalent to

$$(\mathbf{H} - \lambda\mathbf{I})\mathbf{y} = \mathbf{Qb}$$

$$\mathbf{x} = \mathbf{Qy}$$

The solution to this new system requires only $O(n^2)$ operations because of the number of zeros in **H**.

This function introduces zeros using either Householder reflections or Givens rotations. Householder reflections are more efficient for introducing many zeros into the matrix and HiQ uses this method by default. Givens rotations might be more efficient for introducing zeros when the input matrix already has many zeros below the diagonal.

If **Q** is not requested, this function executes faster.

## See Also

`LUD`, `QRD`, `schurD`, `SVD`

## hessian

### Purpose

Computes the Hessian of a function.

### Usage

```
y = hessian(fct, x0, h, method)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function | The input function of *n* equations in *m* variables. |
| `x0` | Real Vector | The point at which to calculate the Hessian. Must have *m* elements. |
| *`h`* | Real Scalar | The step size to use. (Optional.) |
| *`method`* | HiQ Constant | The finite difference method to use. (Optional. Default = `<central>`)<br>`<forward>`<br>`<central>` |
| `y` | Real Matrix | The *m*x*n* Hessian matrix. |

### Comments

Given a scalar-valued function *f* of several variables

$$y = f(x_1, \ldots, x_n)$$

the Hessian matrix **A** of the function *f* is defined by the following equation.

$$\mathbf{A} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}, a_{ij} = \frac{\partial^2 f}{\partial x_i \partial x_j}$$

If the step size is equal to zero, HiQ chooses an appropriate step size based on the precision of your computer.

The forward and central finite difference formulas result in finite difference approximations of order one and two respectively.

## See Also

`derivative`, `jacobian`, `partial`

## histogram

### Purpose

Computes the histogram of a data set.

### Usage

```
y = histogram(x, bin)
y = histogram(x, nBin)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input values. |
| `bin` | Real Vector | The values defining the bin boundaries. |
| `nBin` | Integer Scalar | The number of bins to create. |
| `y` | Integer Vector | The number of input values whose value lies within each bin. |

### Comments

The histogram of an *n*-element data set **x** is the number of elements in the data set that lie within each interval (bin) of a set of *m* intervals. Each interval is defined by the range

$$(b_{i-1}, b_i] \qquad \text{where } i = 1, 2, \ldots, m;\ b_0 = -\infty$$

Given a set of *m* monotonically increasing values **b** that define *m* contiguous intervals, then the histogram **h** of a data set **x** is defined by the following equation.

$$h_i = \text{number of elements in the set } \{x_j : b_{i-1} < x_j < b_i\}$$

where $i = 1, 2, \ldots, m$
$j = 1, 2, \ldots, n$
$b_0 = -\infty$

### See Also

`quartile`, `range`

# householder

## Purpose

Computes the Householder reflection of a vector.

## Usage

```
[v, lambda] = householder(x)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input vector. |
| `v` | Real Vector | The Householder vector for the input. |
| `lambda` | Real Scalar | The Householder parameter –2/norm(`v`). |

## Comments

The Householder reflection is an orthogonal transformation **H** that reflects the input vector **x** into an output vector **y** such that all but the first element of **y** are zero. This transformation can be uniquely defined by the Householder vector **v**:

$$\begin{bmatrix} y_1 \\ \mathbf{0} \end{bmatrix} = \mathbf{Hx} \qquad \text{where } \mathbf{H} = \mathbf{I} - \frac{2\mathbf{v}\mathbf{v}^{\mathrm{T}}}{\|\mathbf{v}\|^2}$$

Geometrically, **H** is the orthogonal reflection with respect to the hyperplane **y** perpendicular to **v**:

$$\{\mathbf{y}:\langle\mathbf{y}|\mathbf{v}\rangle = 0\}$$

You can use the Householder reflection to efficiently introduce zeros in matrix columns or rows. An optional return value, *`lambda`*, is defined as

$$\lambda = -\frac{2}{\|\mathbf{v}\|^2}$$

The Householder vector and matrix exhibit the following properties:

$$\mathbf{v} = \mathbf{x} + \mathrm{sign}(x_1)\|\mathbf{x}\|_2\mathbf{e}_1$$

$\mathbf{v}$ is normalized with $\mathbf{v}_1 = 1$

$$\mathbf{Hx} = -\mathrm{sign}(x_1)\|\mathbf{x}\|_2\mathbf{e}_1$$

$$\mathbf{H}^{-1} = \mathbf{H}^{\mathrm{T}} = \mathbf{H}$$

where $\mathbf{x} = (x_1, x_2, \ldots, x_n)$

$\mathbf{e}_1 = (1, 0, \ldots, 0)$

HiQ generates an error for the input vector $\mathbf{x} = 0$.

## See Also

`givens`, `reflect`, `rotate`

## ident

### Purpose

Creates an identity matrix.

### Usage

```
A = ident(n)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `n` | Integer Scalar | The number of rows and columns to create. |
| `A` | Real Matrix | The resulting identity matrix. |

### Comments

The identity matrix is a matrix with ones along the main diagonal.

$$\begin{bmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \dots & 0 & 1 \end{bmatrix}$$

### See Also

`createMatrix`, `fill`

## import

### Purpose

Imports data from a file.

### Usage

```
data = import(source, format, row, column, progressFct)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `source` | File ID or Text | A valid file ID returned by the function open or a valid filename. |
| *`format`* | Text | Describes how to import the data. (Optional.) |
| *`row`* | Integer Scalar | Number of rows to create. (Optional. Default = <`toEndOfStream`>) |
| *`column`* | Integer Scalar | Number of columns to create. (Optional.) |
| *`progressFct`* | Function | A user function that monitors the progress of the import. (Optional.) |
| `data` | Object | An object containing the imported data. |

### Comments

HiQ uses the parameter *`format`* to convert data from a source object to a target object. For the `import` function, the source object is a file and the target object is a HiQ object. HiQ provides predefined constants for the most commonly used data format strings. If you do not provide the parameter *`format`*, HiQ imports the data as numeric text and creates a matrix object.

If provided, the parameters *`row`* and *`column`* determine the dimension of the resulting vector or matrix object. If you only provide the *`row`* parameter, HiQ repetitively imports data from the file using the format description *`row`* times. The resulting object has as many columns as numbers imported on a single pass of the format description. If you provide both parameters, HiQ imports enough data from the file to create an appropriately dimensioned matrix (or vector if column is one). If these parameters are not provided, HiQ imports the entire source file and creates a vector object if the source file is numeric binary data or a matrix object if the source file is numeric text data. Each row in the resulting matrix contains the values on each line of the source file. The matrix row elements are zero-padded to create a square matrix if necessary.

A format string is composed of three strings describing the external data source, the format of the data, and the internal target object. These strings are separated by colons (:) as follows.

```
"[ExternalDescr]:[FormatDescr]:[InternalDescr]"
```

Each string is composed of identifiers preceded by a percent sign (%). These strings and their identifiers are described in detail below for the `import` function.

## External Description

The external source description string describes how the data is stored in the file. HiQ supports both big endian and little endian byte ordering. The valid identifiers for the source description string are defined in the following table.

| Source Identifier | Description |
|---|---|
| `%littleendian`<br>`%intel` | Bytes are stored in the file with the least significant byte first. Intel CPU-based computers use little endian byte ordering. (Default.) |
| `%bigendian`<br>`%motorola` | Bytes are stored in the file with the most significant byte first. Motorola CPU-based computers use big endian byte ordering. |
| `%Excel`<br>`%Excel[`*`sheet`*`]` | Source file is an Excel file. In the second form the name of the sheet to be imported is specified. If omitted the first sheet in the file is imported. |
| `%range[`*`A1style`*`]`<br>`%range[`*`HiQStyle`*`]` | For Excel files, indicates the desired cell range. If omitted all cells with data are imported. The range can be the Excel A1 style (for example, `%range[A1:C3]`) or the HiQ-Script subscript range style (for example, `%range[1:3,1:3]`). The HiQ-Script range works exactly as in script except that if the upper range is omitted it is assumed to be *. In other words `%range[1,1]` is the same as `%range[1:*,1:*]`. |
| `%comment[`*`comments`*`]` | Specifies which characters in the file indicate comments. Everything from the comment to the end of the line is ignored on import. For example, `%comment[rem]` causes everything to the right of `rem` to be ignored. |

## Format Description

The format description string describes how HiQ interprets the numeric data in the file. For example, you can specify the numeric data as text or binary, the data as integer, real, or complex, or the width and precision of a text numeric field. The import wizard (**Notebook»Import Data...**) is a convenient place to learn how the format description string works. In expert mode, you can enter and modify a format string and immediately view the results in the Preview window. The valid identifiers for the format description string are defined in the following table.

| **Format Identifier** | **Description** |
|---|---|
| `%delimiters[`*`list`*`]` | Delimiter identifier specifying the characters that separate numeric values. (Optional.) |
| `%`*`count type`*`[`*`modifiers`*`]` | Numeric identifier describing the repeat count and format type for integer and real numeric values. (Optional.) |
| `%`*`count cType`*`[`*`type`*`[`*`modifiers`*`]]` | Numeric identifier describing the repeat count and format type for complex numeric values. (Optional.) |

A format description string can have multiple numeric format identifiers but only one delimiter format identifier. The components of a format identifier string are defined in the following table.

| **Parameter** | **Description** |
|---|---|
| *`list`* | A string of characters that delimit the numeric values in a file. If *`list`* is empty, HiQ interprets any non-numeric character as a delimiter. For special characters, use the following:<br>`\t` (tab)<br>`\]` (right square bracket)<br>`\[` (left square bracket)<br>`\\` (backslash) |
| *`count`* | Indicates the number of times to apply the format identifier. A value of zero repeats the format identifier until HiQ reaches an end-of-line character. A zero value is invalid with binary forms. (Optional. Default = `1`.) |

| Parameter | Description |
|---|---|
| *type* | Indicates whether the data is text numeric or binary numeric and integer or real. (Optional)<br>`fb` Binary Real.<br>`ib` Binary Integer.<br>`ub` Binary Unsigned integer. |
| *modifiers* | Indicates the numeric field width, number of digits to the right of the decimal point, and whether to discard the data. (Optional)<br>*wn* For text source: Specifies the width of the hexadecimal integer field in number of characters. (Optional.) On import this must be specified for every format if a fixed width import is used.<br>For binary source: Specifies the width of the number in number of bits (not bytes). (Optional.)<br>`d` Tells HiQ to discard the number in this position after importing. Note: If you are using this to read a rectangular block of data it would be easier to use the %range source descriptor in some cases. If you use this in combination with the %range descriptor the %range filtering takes place after the discard and the discarded data is not counted when applying the %range filter. |

Examples of valid format description strings include the following.

```
%delimiters[,]
%5fb[w8]
%co[fb[w16]]
%2cd[fb[w16]ib[w8]]
```

## Internal Description

The internal target description string describes the HiQ object to create with the data. The valid identifiers for the target description string are defined in the following table.

| Target Identifier | Description |
|---|---|
| `%scalar` | Create a scalar object. (Default.) If more than one value is found the data is automatically promoted to matrix. |
| `%vector` | Create a vector object. |
| `%matrix` | Create a matrix object. |
| `%poly` `%polynomial` | Create a polynomial object. |
| `%transpose` | Transpose the data while writing to the target. Reverses the meaning of row and column counts. |
| `%text` | Create a text object. |
| `%script` | Create a script object. |

HiQ imports data according to the format description string. If imported numeric data results in more than one number, HiQ promotes the target object to a matrix regardless of the value of the target identifier.

## Examples

### Importing data from Excel files (HiQ-Script).

This example shows how to import data from an Excel (`.xls`) file.

```
//Prompt for a file name. Only files with a .xls extension
//are displayed in the file dialog box.
file = getFileName("c:\", "Excel files | *.xls");

//Import all of the data on the first sheet of the
//Excel notebook.
A = import(file,"%excel::");

//Import all of the data on the second sheet.
B = import(file,"%excel[Sheet2]::");

//Import the data in cells A3 to C9 on the third sheet.
C = import(file,"%excel[Sheet3]%range[A3:C9]::");
```

## See Also

`export`, `read`, `toComplex`, `toInteger`, `toNumeric`, `toReal`, `toText`

## integEqn

### Purpose

Solves a system of integral equations.

### Usage

Solves a system of Volterra integral equations of the first kind.

```
[t, X, nIter] = integEqn(KFct, gFct, <Volterra1>, a, b, nSteps, x0,
xTolr, maxIter, iExtrap)
```

Solves a system of Volterra or Fredholm integral equations of the second kind.

```
[t, X, nIter] = integEqn(KFct, gFct, <Volterra2>, a, b, nSteps,
xTolr, maxIter, iExtrap)
[t, X, nIter] = integEqn(KFct, gFct, <Fredholm2>, a, b, nSteps,
xTolr, maxIter, iExtrap)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `KFct` | Function | The *n* kernel equations of the integral equations. |
| `gFct` | Function | The *n* equations on the right side of the equation. |
| `a` | Real Scalar | The left end-point of the solution interval. |
| `b` | Real Scalar | The right end-point of the solution interval. |
| `nSteps` | Integer Scalar | The number of steps in the solution interval. |
| `x0` | Real Vector | The initial guess of the first solution. |
| *`xTolr`* | Real Scalar | The tolerance to use for the solution. (Optional. Default = `.0001`) |
| *`maxIter`* | Integer Scalar | The maximum number of iterations to perform. (Optional. Default = `32`) |
| *`iExtrap`* | Integer Scalar | Indicates whether Richardson's extrapolation is used. (Optional. Default = `false`) |
| `t` | Real Vector | The vector of values of the independent variable at the solution points. |

| Name | Type | Description |
|---|---|---|
| `X` | Real Matrix | The matrix of solution values. |
| `nIter` | Integer Scalar | The actual number of iterations performed. |

## Examples

### 1. Solving a Fredholm integral equation of the second kind.

This script solves a Fredholm integral equation of the second kind. It also illustrates the increased accuracy when using Richardson's extrapolation.

```
//The exact solution of this Fredholm integral equation
//of the second kind is
//f(t) = sin(t)

a = 0.0;
b = 1.0;
nSteps = 8;
//Without Richardson's extrapolation
[t1,X1]=integEqn(KEqn, gEqn, <Fredholm>, a, b, nSteps);
//With Richardson's extrapolation
[t2,X2]=integEqn(KEqn, gEqn, <Fredholm>, a, b, nSteps,,,true);

//Calculate the error between the exact solution
//and the computed solution.
//The solution using Richardson's extrapolation is more accurate.
error1 = norm(eval(sin,t1)-X1[:,1]);
error2 = norm(eval(sin,t2)-X2[:,1]);

function KEqn(t, s, f)
   K[1] = -t*s*f[1]^2;
   return K;
end function;

function gEqn(t)
   g[1] = sin(t) + t*(3-2*sin(2)-cos(2))/8.0;
   return g;
end function;
```

## 2. Solving a Volterra integral equation of the first kind.

This script solves a Volterra integral equation of the first kind. It also illustrates the increased accuracy when using Richardson's extrapolation.

```
//The exact solution of this Volterra integral equation
//of the first kind is
//f1(t) = 1
//f2(2) = t

a = 0.0;
b = 1.0;
nSteps = 8;
x0 = {v:0.5, 0.5};
//Without Richardson's extrapolation
[t1,X1]=integEqn(KEqn, gEqn, <Volterra1>, a, b, nSteps, x0);
//With Richardson's extrapolation
[t2,X2]=integEqn(KEqn, gEqn, <Volterra1>, a, b, nSteps, x0,,, true);

//Calculate the error between the exact solution
//and the computed solution.
//The solution using Richardson's extrapolation is more accurate.
exact = {ones(X1.rows);t1};
exact = exact';
error1 = norm(exact-X1);
error2 = norm(exact-X2);

function KEqn(t, s, f)
   K[1] = exp(s-t)*f[1]^2+f[2];
   K[2] = (t-s)*f[2]^2/(1+f[1]^2);
   return K;
end function;

function gEqn(t)
   g[1] = 1 - exp(-t)+t^2/2.0;
   g[2] = t^4/24.0;
   return g;
end function;
```

### 3. Solving a Volterra integral equation of the second kind.

This script solves a Volterra integral equation of the second kind. It also illustrates the increased accuracy when using Richardson's extrapolation.

```
//The exact solution of this Volterra integral equation of the second
//kind is
//f(t) = exp(t)

a = -1.0;
b = 1.0;
nSteps = 8;
//Without Richardson's extrapolation
[t1,X1]=integEqn(KEqn, gEqn, <Volterra2>, a, b, nSteps);
//With Richardson's extrapolation
[t2,X2]=integEqn(KEqn, gEqn, <Volterra2>, a, b, nSteps,,, true);

//Calculate the error between the exact solution
//and the computed solution.
//The solution using Richardson's extrapolation is more accurate.
exact = eval(exp,t1);
error1 = norm(exact-X1[:,1]);
error2 = norm(exact-X2[:,1]);

function KEqn(t, s, f)
   K[1] = (t-s-1.5)*sqrt(t-s)*f[1];
   return K;
end function;

function gEqn(t)
   g[1] = exp(t)+((t+1)^(3/2))/<e>;
   return g;
end function;
```

## See Also

ODEBVP, ODEIVP

## integrate

### Purpose

Computes the integral of a function, polynomial, or data set.

### Usage

Integrates a data set over its entire interval.

```
z = integrate(x, y, idAlg)
```

Integrates a data set over a specified interval.

```
z = integrate(x, y, a, b, idAlg)
```

Integrates a function over a specified interval.

```
z = integrate(fct, a, b, ifAlg)
z = integrate(fct, a, b, <adSimpson>, nDiv, tolr)
z = integrate(fct, a, b, <gauss>, nOrder)
z = integrate(fct, a, b, <simpson>, nDiv)
z = integrate(fct, a, b, <trapezoid>, nDiv)
```

Integrates a weighted function over a specified or pre-defined interval.

```
z = integrate(fct, a, b, <chebSing1>, nDegree)
z = integrate(fct, a, b, <chebSing2>, nDegree)
z = integrate(fct, <hermite>, nDegree)
z = integrate(fct, <laguerre>, nDegree)
z = integrate(fct, <logSing>, nOrder)
```

Creates the polynomial object that represents the indefinite integral of a polynomial.

```
zPoly = integrate(yPoly)
```

Integrates a polynomial over a specified interval.

```
z = integrate(yPoly, a, b)
```

Computes the integral of a waveform.

```
w = integrate(v, h, vInit, vFinal)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | A vector containing the independent data. |
| `y` | Real Vector | A vector containing the dependent data. |

| Name | Type | Description |
|---|---|---|
| *idAlg* | HiQ Constant | The data integration algorithm to use. (Optional. Default = `<parabolic>`)<br>`<spline>`<br>`<parabolic>` |
| `a` | Real Scalar | The lower limit of the integral. |
| `b` | Real Scalar | The upper limit of the integral. |
| `fct` | Function | The integrand. |
| `ifAlg` | HiQ Constant | The function integration algorithm to use. (Optional. Default = `<adSimpson>`)<br>`<adSimpson>`<br>`<gauss>`<br>`<simpson>`<br>`<trapezoid>` |
| `nDiv` | Integer Scalar | The number of divisions to use over the interval. (Optional.) |
| `tolr` | Real Scalar | The solution tolerance. (Optional. Default = `<epsilon>`) |
| `nOrder` | Integer Scalar | The order of the Gauss integration method. (Optional. Default = `2`) |
| `nDegree` | Integer Scalar | The degree of the polynomial to use. (Optional.) |
| `yPoly` | Polynomial | The input polynomial. |
| `v` | Real Vector | An *n*-element vector representing a signal. |
| `h` | Real Scalar | The step size to use. |
| `vInit` | Real Scalar | The value represented by `v`[0]. |
| `vFinal` | Real Scalar | The value represented by `v`[n+1]. |
| `z` | Real Scalar | The value of the numeric integration. |
| `zPoly` | Polynomial | A polynomial object representing the indefinite integral of the input polynomial. |
| `w` | Real Vector | An *n*-element vector representing the integral of the input signal. |

## Comments

For data sets, HiQ returns the integral of the interpolated data set using natural cubic spline interpolation or quadratic polynomial interpolation.

For functions, HiQ uses the extended (composite) Simpson's method, adaptive Simpson's method, modified trapezoidal method, or Gauss's formula.

The integral of a function *f* with respect to a weighting function *w* is defined as

$$\int_a^b w(x)f(x)dx$$

HiQ uses Gauss's formula to compute the following weighted integrals.

| Integral | HiQ Constant | Comments |
|---|---|---|
| $\int_a^b \frac{f(x)}{\sqrt{(x-a)(b-x)}}dx$ | `<chebSing1>` | The roots of the Chebyshev polynomial of the first kind of degree `nDegree` are used in Gauss's formula. |
| $\int_a^b \sqrt{(x-a)(b-x)}f(x)dx$ | `<chebSing2>` | The roots of the Chebyshev polynomial of the second kind of degree `nDegree` are used in Gauss's formula. |

## See Also

`derivative`

# interp

## Purpose

Computes the interpolation of a data set.

## Usage

Generates the piecewise linear or piecewise polynomial interpolation.

```
[coefs, intervals] = interp(x, y, <linear>)
[coefs, intervals] = interp(x, y, <poly>)
```

Generates the Hermite or Lagrange polynomial interpolation.

```
p = interp(x, y, <hermite>)
p = interp(x, y, <lagrange>)
```

Generates the rational polynomial interpolation.

```
[pNum, pDen] = interp(x, y, <rational>)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The *n*-element vector of independent data points. |
| `y` | Real Vector | The *n*-element vector of dependent data points. |
| `pnum` | Polynomial | The numerator polynomial for the rational interpolation. |
| `pDen` | Polynomial | The denominator polynomial for the rational interpolation. |
| `coefs` | Matrix | The matrix of coefficients for each linear or polynomial interpolant. |
| `intervals` | Matrix | The domains for each linear or polynomial interpolant. |
| `p` | Polynomial | The Hermite or Lagrange polynomial interpolation. |

## Comments

This function creates an interpolating polynomial of degree $n - 1$ for an $n$-element data set using Newton's divided-differences formula and evaluates this polynomial at the given data set **x**. The Hermite and Lagrange interpolating polynomials might have difficulties with large data sets due to the high degree of the polynomial.

Lagrange interpolation requires the values in the **x** data set to be distinct. The Lagrange polynomial interpolant $p$ of data sets **x** and **y** is defined as

$$p(x) = \sum_{i=0}^{n} y_i L_i(x) \quad \text{where } L_i(x) = \prod_{\substack{j=0 \\ j \neq i}}^{n} \frac{x - x_j}{x_i - x_j}$$

Hermite interpolation allows repeated values in **x**. When a value is repeated, the corresponding value in the **y** data set determines the value of a derivative at that point. For example, the Hermite interpolation **v** of the **x** and **y** data sets

$$\mathbf{x} = \{1, 2, 3, 3, 3, 4, 5\}$$

$$\mathbf{y} = \{9, 7, 5, 1, 0.5, 7, 9\}$$

result in the following values evaluated at **x**.

$$v(\mathbf{x}) = \{9, 7, 5, 7, 9\}$$

with

$$\left.\frac{dv}{dx}\right|_{x=3} = 1$$

$$\left.\frac{d^2v}{dx^2}\right|_{x=3} = 0.5$$

Rational interpolation is useful when your data exhibits the characteristics of a singularity. A rational function is represented by the ratio of two polynomials.

$$r(x) = \frac{p(x)}{q(x)}$$

For rational interpolation of an *n*-element data set, HiQ uses polynomial degrees for *p* and *q* of $n/2$ and $n/2$ if *n* is even $(n+1)/2$ and $(n-1)/2$ if *n* is odd. The zeros of the denominator polynomial model the singularity in the data set. If your data set does not exhibit any singular behavior, Lagrange polynomial interpolation might be a better choice.

## See Also

`fit`, `spline`, `interpEval`, `spline`, `splineEval`

## interpEval

### Purpose

Evaluates an interpolation at the given points.

### Usage

Evaluates the rational polynomial interpolation.

```
y = interpEval(x, <rational>, pNum, pDen)
```

Evaluates the linear or polynomial interpolation.

```
y = interpEval(x, <linear>, coefs, intervals)
y = interpEval(x, <poly>, coefs, intervals)
```

Evaluates the Hermite or Lagrange polynomial interpolation.

```
y = interpEval(x, <hermite>, p)
y = interpEval(x, <lagrange>, p)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The vector of values to evaluate the interpolation. |
| `coefs` | Matrix | The coefficients of the interpolants defining the interpolation. |
| `intervals` | Matrix | The intervals for each interpolant defined in the interpolation. |
| `p` | Polynomial | The polynomial representing the interpolation. |
| `pNum` | Polynomial | The numerator for the rational polynomial interpolation. |
| `pDen` | Polynomial | The denominator for the rational polynomial interpolation. |
| `y` | Vector | The interpolation evaluated at the given points. |

## Comments

When evaluating piecewise polynomial interpolants, domain values outside the original domain of the interpolant model produce NaN results when applied to the model. To extend the interpolant, use the following usage of the built-in function `createPoly`.

```
firstPoly = createPoly(coefs[*,1], <ascending>);
```

```
lastPoly = createPoly(coefs[*,coefs.cols], <ascending>);
```

Use these polynomials to evaluate domain values below and above the original domain values. Remember that this is practical only for values that are still relatively close to the original domain. For an example of using this approach, see the comments for `splineEval`.

## See Also

`fit`, `fitEval`, `interpEval`, `spline`, `splineEval`

## inv

### Purpose

Computes the inverse of a matrix, polynomial, or permutation.

### Usage

Computes the inverse of a matrix.

```
    B = inv(A)
```

Computes the inverse of a polynomial.

```
    q = inv(p, maxDegree)
```

Computes the inverse of a permutation vector.

```
    s = inv(r)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `r` | Integer Vector | An *n*-element permutation vector. |
| `A` | Matrix | The square matrix to invert. |
| `p` | Polynomial | The polynomial to invert. |
| *`maxDegree`* | Integer Scalar | The maximum degree of the polynomial inverse. (Optional. Default = `128`) |
| `s` | Integer Vector | The inverse of the input permutation vector. |
| `B` | Matrix | The inverse of the input matrix. |
| `q` | Polynomial | The inverse of the input polynomial. |

### Comments

The input matrix **A** must be square and non-singular. If it is numerically deficient an error is generated. For matrices that are not square or are numerically singular, use `pinv`.

The `inv` function is equivalent to the following syntax for matrices:

```
B = A^-1;
```

The accuracy of the computed inverse is closely related to the condition number of the input matrix. Refer to the function `solve` for more information. Solving a linear system using the inverse of a matrix is usually impractical. The functions `LUD` and `solve` are quicker and more accurate. The computational requirements for calculating the inverse of a matrix are O($n^3$).

For polynomials, you can limit the maximum degree of the computed inverse with the optional parameter *`maxDegree`*.

## See Also

`compose`, `det`, `LUD`, `permu`, `pinv`

## iPart

### Purpose

Computes the integer part (whole part) of a number.

### Usage

```
y = iPart(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, or Matrix | The input argument. |
| `y` | Scalar, Vector, or Matrix | The integer part of the input argument. |

### Comments

The result retains the sign of the input. For example, the following script returns a value of –4 for `y`.

```
y = iPart(-4.82);
```

For vector and matrix objects, `iPart(x)` returns the integer part of the input on an element-by-element basis.

### See Also

`fPart`, `toInteger`

## isEOF

### Purpose

Checks whether the file pointer is at the end of a file.

### Usage

```
y = isEOF(fid)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | A valid file ID. |
| `y` | Integer Scalar | `true` (1): The file pointer is at the end of file.<br>`false` (0): The file pointer is not at the end of file. |

### Comments

You can use this function to stop reading a file when the end-of-file is reached.

```
while not isEOF(fid) do
   text = readLine(fid,1);
end while;
```

### See Also

`close`, `getFilePos`, `open`

## isMatrix

### Purpose

Queries the attributes of a matrix object.

### Usage

```
y = isMatrix(a, attrib, tolr)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Matrix | The input matrix. |
| `attrib` | HiQ Constant | The matrix attribute to check.<br>`<allZero>`<br>`<GT>`<br>`<GE>`<br>`<LT>`<br>`<LE>`<br>`<square>`<br>`<symmetric>`<br>`<lowerTri>`<br>`<upperTri>`<br>`<diagonal>`<br>`<posDef>`<br>`<negDef>`<br>`<rowDiagdom>`<br>`<colDiagDom>`<br>`<orthogonal>`<br>`<allReal>`<br>`<hermitian>`<br>`<unitary>` |
| *`tolr`* | Scalar | A tolerance parameter required by some attributes. (Optional. Default = `0.0`) |
| `y` | Integer Scalar | `true` (1) Matrix satisfies the attribute.<br>`false` (0) Matrix does not satisfy the attribute. |

## Comments

HiQ computes the properties of a matrix as defined in the following table.

| HiQ Constant | Properties |
|---|---|
| `<allZero>` | $\lvert a_{ij}\rvert < tolr$ |
| `<GT>` | $a_{ij} > tolr$ |
| `<GE>` | $a_{ij} \geq tolr$ |
| `<LT>` | $a_{ij} < tolr$ |
| `<LE>` | $a_{ij} \leq tolr$ |
| `<square>` | $i = j$ |
| `<diagonal>` | $\lvert a_{ij}\rvert \leq tolr \quad \text{if } i \neq j$ |
| `<symmetric>` | $\lvert a_{ij} - a_{ji}\rvert \leq tolr$ |
| `<lowerTri>` | $\lvert a_{ij}\rvert \leq tolr \quad \text{if } i < j$ |
| `<upperTri>` | $\lvert a_{ij}\rvert \leq tolr \quad \text{if } i > j$ |
| `<posDef>` | $\lvert a_{ij} - a_{ji}\rvert \leq tolr$ and $\lambda_i \geq tolr\lambda_{\max}$ |
| `<negDef>` | $\lvert a_{ij} - a_{ji}\rvert \leq tolr$ and $\lambda_i \leq -tolr\lambda_{\max}$ |
| `<rowDiagDom>` | $\lvert a_{ii}\rvert \geq (\sum a_{ij}) - \mathrm{trace}(\mathbf{A}) + tolr$ |
| `<colDiagDom>` | $\lvert a_{jj}\rvert \geq (\sum a_{ij}) - \mathrm{trace}(\mathbf{A}) + tolr$ |
| `<ortho>` | $\langle a_{i^*}, a_{j^*}\rangle \leq tolr$ |

| HiQ Constant | Properties |
|---|---|
| `<hermitian>` | $\lvert a_{ij} - a_{ji} \rvert \le tolr$ |
| `<unitary>` | $\langle a_{i^*}, a_{j^*} \rangle \le tolr$ |

This function evaluates the structure of the matrix, not the physical storage type. To determine the storage type of a matrix, use the storage attribute as follows.

```
storage = A.storage;
```

The valid matrix storage types are `<rect>`, `<band>`, `<upperTri>`, `<lowerTri>`, `<symmetric>`, and `<hermitian>`.

## See Also

`createMatrix`, `sparsity`

## jacobian

### Purpose

Computes the Jacobian of a function.

### Usage

```
y = jacobian(fct, x, h, method)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function | The input function. |
| `x` | Real Vector | The point at which to calculate the jacobian. |
| *`h`* | Real Scalar | The step size to use. (Optional.) |
| *`method`* | HiQ Constant | The finite difference method to use. (Optional. Default = `<central>`) `<central>` `<forward>` |
| `y` | Real Matrix | The Jacobian matrix of the function. |

### Comments

Given a vector-valued function of several variables

$$\begin{bmatrix} y_1 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} f_1(x_1, \ldots, x_n) \\ \vdots \\ f_n(x_1, \ldots, x_n) \end{bmatrix} = \mathbf{f}(\mathbf{x})$$

the Jacobian matrix **A** of the function *f* is defined as

$$\begin{bmatrix} \frac{\partial f_1}{\partial x_1} & \cdots & \frac{\partial f_1}{\partial x_n} \\ \vdots & \ddots & \\ \frac{\partial f_n}{\partial x_1} & & \frac{\partial f_n}{\partial x_n} \end{bmatrix}$$

If the step size is equal to zero, HiQ chooses an appropriate step size based on the precision of your computer.

The forward and central finite difference formulas result in finite difference approximations of order one, two, and four respectively.

## See Also

`derivative`, `hessian`, `partial`

## kelvinI

### Purpose

Computes the complex Kelvin function of the first kind.

### Usage

```
be = kelvinI(x, n)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `n` | Integer Scalar | The value of the Bessel order. |
| `be` | Complex Scalar | The value of the Kelvin function of the first kind. Complex pair (`ber`,`bei`). |

### Comments

The complex-valued Kelvin function of the first kind of order ν is a solution of the complex-valued differential equation

$$x^2\frac{d^2w}{dx^2} + x\frac{dw}{dx} - (ix^2 - v^2)w = 0$$

The real and imaginary parts of the Kelvin function of the first kind of order ν are solutions of the differential equation

$$x^4\frac{d^4w}{dx^4} + 2x^3\frac{d^3w}{dx^3} - (1 + 2v^2)\left(x^2\frac{d^2w}{dx^2} - x\frac{dw}{dx}\right) + (v^4 - 4v^2 + x^4)w = 0$$

HiQ supports the real domain $(-\infty, \infty)$.

### See Also

`besselJ`, `besselK`, `kelvinK`

## kelvinK

### Purpose

Computes the complex Kelvin function of the second kind.

### Usage

```
ke = kelvinK(x, n)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `n` | Integer Scalar | The value of the Bessel order. |
| `ke` | Complex Scalar | The value of the Kelvin function of the second kind. Complex pair (`ker`,`kei`). |

### Comments

The complex-valued Kelvin function of the second kind of order ν is a solution of the complex-valued differential equation

$$x^2\frac{d^2w}{dx^2} + x\frac{dw}{dx} - (ix^2 - v^2)w = 0$$

The real and imaginary parts of the Kelvin function of the first kind of order ν are solutions of the differential equation

$$x^4\frac{d^4w}{dx^4} + 2x^3\frac{d^3w}{dx^3} - (1 + 2v^2)\left(x^2\frac{d^2w}{dx^2} - x\frac{dw}{dx}\right) + (v^4 - 4v^2 + x^4)w = 0$$

HiQ supports the real domain $(-\infty, \infty)$.

### See Also

`besselJ`, `besselK`, `kelvinI`

## kummer

### Purpose

Computes the Kummer function (confluent hypergeometric function).

### Usage

```
y = kummer(x, a, b)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `a` | Real Scalar | The first parameter of the Kummer function. |
| `b` | Real Scalar | The second parameter of the Kummer function. |
| `y` | Real Scalar | The value of the Kummer function. |

### Comments

The Kummer function (confluent hypergeometric function), $M(x,a,b)$, is a solution of the differential equation

$$x\frac{d^2w}{dx^2} + (b - x)\frac{dw}{dx} - aw = 0$$

### See Also

`gauss`, `tricomi`

## kurtosis

### Purpose

Computes the kurtosis of a data sample.

### Usage

```
y = kurtosis(x, xMean)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input data set. |
| *`xMean`* | Real Scalar | The mean of the input data set. (Optional.) |
| `y` | Real Scalar | The kurtosis of the input data set. |

### Comments

The kurtosis of an *n*-element data set **x** is defined as

$$\frac{1}{\sigma^4}\,\frac{\sum_{i=1}^{n}(x_i-\bar{\mathbf{x}})^4}{n}$$

### See Also

`mean`, `moment`, `skew`

## laplacian

### Purpose

Computes the Laplacian of a function.

### Usage

```
y = laplacian(fct, x, h, method)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function | The input function. |
| `x` | Real Vector | The point at which to calculate the laplacian. |
| *`h`* | Real Scalar | The step size to use. (Optional.) |
| *`method`* | HiQ Constant | The finite difference method to use. (Optional. Default = `<central>`)<br>`<central>`<br>`<forward>` |
| `y` | Real Scalar | The Laplacian of the input function. |

### Comments

Given a scalar-valued function of several variables

$$y = f(x_1, \ldots, x_n)$$

the Laplacian of the function *f* is defined as

$$\nabla^2 f = \sum_{i=1}^{n} \frac{\partial^2 f}{\partial x_i^2}$$

If the step size is equal to zero, HiQ chooses an appropriate step size based on the precision of your computer.

The forward and central finite difference formulas result in finite difference approximations of order one, two, and four respectively.

### See Also

`derivative`, `gradient`

## lcm

### Purpose

Computes the least common multiple of a set of integers.

### Usage

Computes the least common multiple of two integers.

```
    y = lcm(a, b)
```

Computes the least common multiple of a set of integers.

```
    y = lcm(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Integer Scalar | The first input argument. |
| `b` | Integer Scalar | The second input argument. |
| `x` | Integer Vector | A set of integer arguments. |
| `y` | Integer Scalar | The least common multiple of the input. |

### Comments

The least common multiple of a set of integers is defined as the smallest integer that is a multiple of all integers in the set.

### See Also

`gcd`

## ln

### Purpose

Computes the natural logarithm of a number (logarithm to the base e).

### Usage

```
y = ln(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The natural logarithm of the input. |

### Comments

The natural logarithm is defined for the real domain (0, ∞).

### See Also

`exp`, `log`

## log

### Purpose

Computes the logarithm of a number to a given base.

### Usage

```
y = log(x, b)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real or Complex Scalar | The input argument. |
| b | Integer Scalar | The desired base of the logarithm. (Optional. Default = `10`) |
| y | Real or Complex Scalar | The logarithm of the input. |

### Comments

Because the base $b$ logarithm of a complex number is not single-valued, this function computes the result for the input parameter **x** in the principal branch of the complex plane. That is, the polar representation for any $x > 0$ is taken as

$$x = |x|e^{i\theta} \quad \text{where } -\pi < \theta < \pi$$

The logarithm is defined for the real domain $(0, \infty)$ and $b > 0$.

### See Also

`exp`, `ln`

## logMessage

### Purpose

Displays a message in the Log Window.

### Usage

`logMessage(text, `*`appendOption`*`)`

### Parameters

| Name | Type | Description |
|---|---|---|
| `text` | Text | The message to display. |
| *`appendOption`* | HiQ Constant | Specifies whether to append the text to the log contents or create a new line. (Optional. Default = `<newLine>`)<br>`<newLine>`<br>`<append>` |

### Comments

Unlike `message`, `logMessage` does not display a dialog box. All messages are displayed in the Log Window. This allows a script to continue executing while displaying messages.

### See Also

`clearLog`, `error`, `message`, `saveLog`, `warning`

## LUD

### Purpose

Computes the LU decomposition of a matrix.

### Usage

```
[L, U, pivot] = LUD(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Matrix | The square *n*x*n* input matrix. |
| `L` | Matrix | The lower triangular matrix. |
| `U` | Matrix | The upper triangular matrix |
| `pivot` | Integer Vector | A vector containing the row pivoting information. |

### Comments

The LU decomposition of a square $n \times n$ matrix **A** is the factorization

$$\mathbf{A} = \mathbf{LU}$$

where **L** is an $n \times n$ lower triangular matrix with ones along the main diagonal, and **U** is an $n \times n$ upper triangular matrix. This function uses row pivoting to ensure numerical stability with the output vector `pivot` containing the pivoting information. Thus the resulting LU decomposition is for the transformed matrix **PA** rather than **A**, where **P** is a permutation matrix. This permutation information is returned as a pivot vector in `pivot`. The following code shows how to generate the matrix **PA**:

```
[L, U, pivot] = LUD(A);

P = permu(pivot);

PA = permu(P, A);

LU = L*U;
```

By definition of the LU decomposition, the matrices **PA** and **LU** are identical.

The LU decomposition of a matrix is an essential step in solving a linear system. The output of this function should be used as the input to the function `solve` to solve a linear system as in the following script.

```
x = solve(L, U, b, pivot);
```

For a matrix with no structural properties, a modified Crout's algorithm with implicit scaling is used.

For symmetric (Hermitian), indefinite matrices, use the function `symD` to perform the tri-diagonal factorization $\mathbf{LTL}^T$.

For symmetric (Hermitian), positive definite matrices, use the function `choleskyD` to perform the Cholesky decomposition $\mathbf{LL}^T$. No row pivoting is required.

For an input matrix with band structure, the output matrix is band structure with bandwidths $m1(n1 + m1)$ where *m1* and *n1* are the lower and upper bandwidths of the input matrix, respectively.

## See Also

`choleskyD`, `hessenbergD`, `QRD`, `schurD`, `solve`, `SVD`, `symD`, `permu`

## max

### Purpose

Computes the maximum value of a data set.

### Usage

Finds the maximum value of two numbers.

```
y = max(a, b)
```

Finds the maximum value of a vector.

```
[y, i] = max(c)
```

Finds the maximum value of a matrix.

```
[y, i, j] = max(C)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Scalar | The first input argument. |
| `b` | Scalar | The second input argument. |
| `c` | Vector | The vector of input data. |
| `C` | Matrix | The matrix of input data. |
| `y` | Scalar | The maximum value of the input data. |
| `i` | Integer Scalar | The matrix row or vector element index of the maximum value. |
| `j` | Integer Scalar | The matrix column index of the maximum value. |

### Comments

If the maximum occurs in more than one element of a vector or matrix, HiQ returns the indices of the first maximum found. For matrices, HiQ searches on a row-by-row basis. NaNs affect the results. Use `replace()` to remove them if necessary.

### See Also

`min`

## mean

### Purpose

Computes the arithmetic mean (average) of a data sample.

### Usage

```
y = mean(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input data set. |
| `y` | Real Scalar | The mean value of the input data set. |

### Comments

The mean (average) of an *n*-element data set **x** is defined as

$$\frac{\sum_{i=1}^{n} x_i}{n}$$

### See Also

`median`, `stdDev`

## median

### Purpose

Computes the median of a data sample.

### Usage

```
y = median(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input data set. |
| `y` | Real Scalar | The median value of the input data set. |

### Comments

The median of an *n*-element data set **x** is defined as

$$\begin{cases} x_{\frac{n+1}{2}} & \text{if } n \text{ is odd} \\ \dfrac{x_{\frac{n}{2}} + x_{\frac{n}{2}+1}}{2} & \text{if } n \text{ is even} \end{cases}$$

### See Also

`histogram`, `mean`, `quartile`, `range`

## message

### Purpose

Displays a message dialog box.

### Usage

```
message(text)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `text` | Text | Message to display in the dialog box. |

### Comments

The message function displays a message dialog box containing the input text. The script continues execution if the user clicks on the OK button. Use the <Escape> key to stop execution of the script while the message dialog box is displayed. This is useful if you get into a situation where `message` is called inside a For Loop with many iterations.

### See Also

`error`, `warning`

# min

## Purpose

Computes the minimum value of a data set.

## Usage

Finds the minimum value of two numbers.

```
y = min(a, b)
```

Finds the minimum value of a vector.

```
[y, i] = min(c)
```

Finds the minimum value of a matrix.

```
[y, i, j] = min(C)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Integer or Real Scalar | The first input argument. |
| `b` | Integer or Real Scalar | The second input argument. |
| `v` | Integer or Real Vector | The vector of input data. |
| `C` | Integer or Real Matrix | The matrix of input data. |
| `y` | Scalar | The minimum value of the input arguments. |
| `i` | Integer Scalar | The matrix row or vector element of the minimum value. |
| `j` | Integer Scalar | The matrix column of the minimum value. |

## Comments

If the minimum occurs in more than one element of a vector or matrix, HiQ returns the indices of the first minimum found. For matrices, HiQ searches on a row-by-row basis. NaNs do affect the results. Use `replace()` to remove them if necessary.

## See Also

`max`

## moment

### Purpose

Computes the first moment of a data set.

### Usage

```
y = moment(x, order, xMean)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input data set. |
| *`order`* | Integer Scalar | The order of the moment to calculate. (Optional. Default = `1`) |
| *`xMean`* | Real Scalar | The mean of the input data set. (Optional.) |
| `y` | Real Scalar | The calculated moment of the input data set. |

### Comments

The first central moment, $\mu_1$, of an *n*-element data sample **x** is defined as

$$\frac{\sum_{i=1}^{n}(x_i - \bar{\mathbf{x}})}{n}$$

### See Also

`kurtosis`, `mean`, `skew`

## norm

### Purpose

Computes the norm of a vector or matrix.

### Usage

Computes the norm of a vector.

```
x = norm(a, vType)
```

Computes the norm of a matrix.

```
x = norm(A, mType)
```

Computes the weighted Euclidean norm of a vector.

```
x = norm(a, <Lw>, w)
```

Computes the p-norm of a vector.

```
x = norm(a, <Lp>, p)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Vector | The input vector. |
| *`vType`* | HiQ Constant | Type of vector norm to be calculated. (Optional. Default = `<L2>`)<br>`<L1>`<br>`<L2>`<br>`<Lp>`<br>`<Lw>`<br>`<Li>` |
| `w` | Vector | An *n*-element vector of weights. Use only when *`vType`* = `<Lw>`. |
| `p` | Scalar | p-norm parameter. Use only when *`vType`* = `<Lp>`. (Must be greater than 0, Default = `2`.) |
| `A` | Matrix | The input matrix. |

| Name | Type | Description |
|---|---|---|
| *mType* | HiQ Constant | Type of matrix norm to be calculated. (Optional. Default = `<L2>`)<br>`<L2>`<br>`<L2sq>`<br>`<frob>`<br>`<L1>`<br>`<Li>` |
| `x` | Real Scalar | The norm of the input. |

## Comments

A norm $\|\mathbf{a}\|$ of a vector **a** in a vector space is an important nonnegative real function that is the generalization of the concept of length. A norm satisfies three axioms:

$$\|\mathbf{a}\| \geq 0 \text{, for all } \mathbf{a} \text{ and } \|\mathbf{a}\| = 0 \text{ if and only if } \mathbf{a} = 0$$

$$\|c\mathbf{a}\| = |c|\|\mathbf{a}\| \text{ where } c \text{ is scalar}$$

$$\|\mathbf{a} + \mathbf{b}\| \leq \|\mathbf{a}\| + \|\mathbf{b}\|$$

This function implements the following *n*-dimensional vector space norms:

L1: $$\|\mathbf{a}\|_1 = \sum_i |a_i|$$

L2 (Euclidean): $$\|\mathbf{a}\|_2 = \left(\sum_i |a_i|^2\right)^{\frac{1}{2}}$$

L2$^2$: $$\|\mathbf{a}\|_2 = \sum_i |a_i|^2$$

Li: $$\|\mathbf{a}\|_\infty = \max_i |a_i|$$

Lp: $$\|\mathbf{a}\|_p = \left(\sum_i |a_i|^p\right)^{\frac{1}{p}}$$

Weighted L2: $$\|\mathbf{a}\|_2 = \left(\sum_i w_i |a_i|^2\right)^{\frac{1}{2}}$$

This concept also applies to matrices because a matrix can be considered a vector in an $m \times n$ vector space. This leads to the Frobenius norm:

$$\|\mathbf{A}\|_F = \left(\sum_{ij} |a_{ij}|^2\right)^{\frac{1}{2}}$$

Finally, the norm concept can be applied to linear matrix operators that map an *n*-dimensional vector space into an *m*-dimensional vector space. The norm $\|\mathbf{A}\|$ of a linear operator **A** is defined as:

$$\|\mathbf{A}\| \equiv \sup_{\|\mathbf{x}\| = 1} \|\mathbf{Ax}\|$$

where **x** is an *n*-dimensional vector and **Ax** is an *m*-dimensional vector. The vector norm used on the right-hand side of this equation dictates the resulting matrix norm. The function `norm` implements the following matrix operator norms:

L1: $$\|\mathbf{A}\|_1 = \max_j \left(\sum_i |a_{ij}|\right)$$

L2 (Euclidean): $$\|\mathbf{A}\|_2 = (\lambda_{\max}(\mathbf{A}^* \cdot \mathbf{A}))^{\frac{1}{2}}$$

Li: $$\|\mathbf{A}\|_\infty = \max_i \left(\sum_j |a_{ij}|\right)$$

## See Also

`cond`, `dist`

# ODEBVP

## Purpose

Solves a set of ordinary differential equations given boundary conditions.

## Usage

Solves a set of nonlinear differential equations given boundary conditions.

```
[tOut, X] = ODEBVP(nonlinFct, guessFct, BCFct, start, stop,
stepSize, IVPAlg, absTolr, relTolr, maxIter, BCType, maxShoot,
outStep, thresh)
[tOut, X] = ODEBVP(nonlinFct, guessFct, BCFct, tIn, IVPAlg,
absTolr, relTolr, maxIter, BCType, maxShoot, thresh)
```

Solves a set of linear differential equations given linear boundary conditions.

```
[tOut, X] = ODEBVP(linBVPFct, RHSFct, BStart, BStop, BRHS, start,
stop, stepSize, IVPAlg, absTolr, relTolr, shootAlg, maxShoot,
outStep, thresh)
[tOut, X] = ODEBVP(linBVPFct, RHSFct, BStart, BStop, BRHS, tIn,
IVPAlg, absTolr, relTolr, shootAlg, maxShoot, thresh)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `nonlinFct` | Function | The input function of *n* nonlinear differential equations. |
| `guessFct` | Function | The solution guess as a function of the independent variable. |
| `BCFct` | Function | The function of *n* boundary conditions. |
| `start` | Real Scalar | The starting value of the independent variable. |
| `stop` | Real Scalar | The ending value of the independent variable. |
| `stepSize` | Real Scalar | The step size to use for the solution matrix. |

| Name | Type | Description |
|---|---|---|
| `IVPAlg` | HiQ Constant | The initial value problem algorithm to use. (Optional. Default = <`RKF`>)<br>`<RKF>`<br>`<BDF>`<br>`<BDF1>`<br>`<ABM>`<br>`<cc>`<br>`<BS>` |
| *`absTolr`* | Real Scalar | The absolute tolerance to use for the solution matrix. (Optional. Default = `.0001`) |
| `relTolr` | Real Scalar | The relative tolerance to use for the solution matrix. (Optional. Default = `.0001`) |
| `maxIter` | Integer Scalar | The maximum number of iterations to perform. (Optional. Default = `128`) |
| `BCType` | HiQ Constant | Specifies the type of boundary conditions. (Optional. Default = <`nonlinear`>)<br>`<linear>`<br>`<nonlinear>` |
| `maxShoot` | Real Scalar | The maximum shooting interval to use. (Optional. Default = `0.0`) |
| `outStep` | HiQ Constant | Determines the spacing of the solution matrix. (Optional. Default = <`fixed`>)<br>`<variable>`<br>`<fixed>` |
| `thresh` | Real Scalar | Value added to solution before checking relative tolerance. (Optional. Default = `.25`) |
| `tIn` | Real Vector | A vector of independent values at which to compute the solution. |
| `linBVPFct` | Function | The input function of *n* linear differential equations. |
| `RHSFct` | Function | The forcing function of the linear differential equations. |
| `BStart` | Real Matrix | The linear boundary conditions at the starting point. |

| Name | Type | Description |
|---|---|---|
| `BStop` | Real Matrix | The linear boundary conditions at the stopping point. |
| `BRHS` | Real Vector | The right side of the linear boundary conditions. |
| *`shootAlg`* | HiQ Constant | The shooting algorithm to use. (Optional. Default = `<marching>`)<br>`<simple>`<br>`<marching>` |
| `tOut` | Real Vector | The independent vector of solution values. |
| `X` | Real Matrix | The matrix of solution values. |

## Comments

An equation that is a function of an independent variable *x* and a dependent variable *y* and its derivatives with respect to *x* is called a differential equation. The order of a differential equation is equal to the order of the highest derivative in the equation. For example,

$$\frac{dy}{dx} = 2xy^2$$

is a first-order differential equation, and

$$x^2\frac{d^2y}{dx^2} + x\frac{dy}{dx} + (x^2 - p^2)y = 0$$

is a second-order differential equation. Differential equations like those above that are a function of a single independent variable are called ordinary differential equations.

A system of *n* first-order differential equations can be represented by the following equation.

$$\frac{d\mathbf{y}(x)}{dx} = \begin{cases} \dfrac{dy_1(x)}{dx} = f_1(x, \mathbf{y}) \\ \dfrac{dy_2(x)}{dx} = f_2(x, \mathbf{y}) \\ \qquad\vdots \\ \dfrac{dy_n(x)}{dx} = f_n(x, \mathbf{y}) \end{cases}$$

A unique solution to this set of differential equations over an interval $x_0 \le x \le x_f$ requires a set of initial conditions or a set of boundary conditions on the dependent variable **y**. The boundary-value problem computes a solution given a set of boundary conditions

$$\mathbf{h}(\mathbf{y}(x_0), \mathbf{y}(x_f)) = 0$$

If the differential equations and boundary conditions are linear in **y**, the boundary value problem reduces to the following equations.

$$\frac{d\mathbf{y}(x)}{dx} = \mathbf{A}(x)\mathbf{y} + \mathbf{q}(x)$$

$$x_0 \le x \le x_f$$

$$\mathbf{B}_0\mathbf{y}(x_0) + \mathbf{B}_0\mathbf{y}(x_f) = \mathbf{b}$$

The function `ODEBVP` computes the solution **y**(*x*) to a set of first-order ordinary differential equations for a range of values of the dependent variable given the boundary conditions imposed on the independent variable **y**.

For the linear and non-linear boundary value problem, HiQ uses a multi-step shooting method that reduces the problem to an algebraic nonlinear system and iteratively solves an initial-value problem. The parameter `maxShoot` specifies the maximum shooting interval to use. A small shooting interval results in a better conditioned nonlinear system, but increases the dimension of the system. The following values are recommended for the shooting interval.

$$L, \frac{L}{2}, \frac{L}{4}, \ldots, \frac{L}{32} \qquad \text{where } L = x_f - x_0$$

For the non-linear boundary value problem, a value of `<linear>` for the parameter `BCType` allows HiQ to take advantage of boundary conditions that are linear in **y**. For the linear boundary value problem, a value of `<marching>` for the parameter `shootAlg` allows HiQ to reduce the dimension of the algebraic system using QR decomposition. This can reduce the amount of time required to compute the solution.

The following algorithms for solving the initial value problem are available in HiQ.

| Algorithm | Description |
|---|---|
| Runge-Kutta-Fehlberg | Fehlberg's version of the Runge-Kutta algorithm. Uses fourth- and fifth-order formulas to estimate the solution error and is a good general method for well-behaved differential equations. |

| Algorithm | Description |
|---|---|
| Adams-Bashforth-Moulton | Multistep method using an Adams-Bashforth predictor and an Adams-Moulton corrector. This method requires fewer function evaluations than the Runge-Kutta- Fehlberg method and therefore is useful when the evaluation of the differential equations is time-consuming. |
| Bulirsch-Stoer | Extrapolation method using the Aitken-Neville triangle rule. This method performs well for small absolute and relative error tolerances. |
| Backward differentiation formula | Multistep, variable order method using orders up to six. This method is designed for stiff sets of equations. It is also known as Gear's method. |
| Cyclic composite | Multistep, variable order method. This method is designed for stiff sets of equations. |

The columns of the $m \times n$ solution matrix, $\mathbf{X}$, contain the solutions of the $n$ differential equations at the values contained in the $m$-element vector `tOut`. If you specify `<variable>` for the parameter *`outStep`*, the solution matrix contains the solutions at values chosen by the selected algorithm. In this case, the parameter `stepSize` specifies the maximum step size used by the algorithm. If you provide a vector of values `tIn` for the independent variable, the solution is computed at each of these values and `tOut` is equal to `tIn`. If an algorithm encounters numerical problems, HiQ returns a partial vector of solutions.

The solution $\mathbf{y}_i$ at each value of the independent variable satisfies the following absolute tolerance $\varepsilon_a$ and relative tolerance $\varepsilon_r$ requirements.

$$\|\mathbf{y}_i - \mathbf{y}_{i-1}\|_2 < \varepsilon_a$$

$$\frac{\|\mathbf{y}_i - \mathbf{y}_{i-1}\|_2}{\|\mathbf{y}_i\|_2 + \delta} < \varepsilon_r$$

The denominator contains a small, non-zero value to prevent division by zero. The parameters *`absTolr`*, *`relTolr`*, and *`thresh`* correspond to $\varepsilon_a$, $\varepsilon_r$, and $\delta$ respectively.

## See Also

`ODEIVP`

## ODEIVP

### Purpose

Solves a set of ordinary differential equations given initial conditions.

### Usage

Solves a set of nonlinear differential equations.

`[tOut, X] = ODEIVP(fct, x0, start, stop, stepSize, IVPAlg, absTolr, relTolr, out`*`Step, callback`*`)`

`[tOut, X] = ODEIVP(fct, x0, tIn`*`, IVPAlg, absTolr, relTolr, callback`*`)`

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function | The function defining the set of *n* first order differential equations. |
| `x0` | Real Vector | The initial conditions. |
| `start` | Real Scalar | The starting value of the independent variable. |
| `stop` | Real Scalar | The stopping value of the independent variable. |
| `stepSize` | Real Scalar | The step size to use. |
| *`IVPAlg`* | HiQ Constant | The ODE solver method to use. (Optional. Default = <`RKF`>)<br><`RKF`>—Runge-Kutta-Fehlberg<br><`cc`> —cyclic composite<br><`ABM`>—Adams-Bashforth-Moulton<br><`BDF`>—backward differentiation formula<br><`BS`>—Bulirsch-Stoer |

| Name | Type | Description |
|---|---|---|
| *absTolr* | Real Scalar | The absolute tolerance to use for the solution matrix. (Optional. Default = `.0001`) |
| *relTolr* | Real Scalar | The relative tolerance to use for the solution matrix. (Optional. Default = `.0001`) |
| *outStep* | HiQ Constant | Determines the spacing of the solution matrix. (Optional. Default = `<fixed>`)<br>`<fixed>`<br>`<variable>` |
| *callback* | Function | A user function called after each iteration with the current value of the independent variable and solution. (Optional.) |
| `tIn` | Real Vector | A vector of values at which to compute the solution. |
| `tOut` | Real Vector | The vector of independent solution values. |
| `X` | Real Matrix | The *n*-column matrix whose columns contain the solution to the *n* differential equations. |

## Comments

An equation that is a function of an independent variable *x* and a dependent variable *y* and its derivatives with respect to *x* is called a differential equation. The order of a differential equation is equal to the order of the highest derivative in the equation. For example,

$$\frac{dy}{dx} = 2xy^2$$

is a first-order differential equation, and

$$x^2\frac{d^2y}{dx^2} + x\frac{dy}{dx} + (x^2 - p^2)y = 0$$

is a second-order differential equation. Differential equations like those above that are a function of a single independent variable are called ordinary differential equations.

A system of *n* first-order differential equations can be represented by the following equation.

$$\frac{d\mathbf{y}(x)}{dx} = \begin{cases} \dfrac{dy_1(x)}{dx} = f_1(x, \mathbf{y}) \\ \dfrac{dy_2(x)}{dx} = f_2(x, \mathbf{y}) \\ \vdots \\ \dfrac{dy_n(x)}{dx} = f_n(x, \mathbf{y}) \end{cases}$$

A unique solution to this set of differential equations over an interval

$$x_0 \le x \le x_f$$

requires a set of initial conditions or a set of boundary conditions on the dependent variable **y**. The initial-value problem computes a solution given a set of initial conditions

$$\mathbf{y}(x_0) = \mathbf{y}_0$$

The function `ODEIVP` computes the solution $\mathbf{y}(x)$ to a set of first-order ordinary differential equations for a range of values of the dependent variable given the initial conditions $\mathbf{y}_0$. The following algorithms for solving the initial value problem are available in HiQ.

| Algorithm | Description |
|---|---|
| Runge-Kutta-Fehlberg | Fehlberg's version of the Runge-Kutta algorithm. Uses fourth- and fifth-order formulas to estimate the solution error and is a good general method for well-behaved differential equations. |
| Adams-Bashforth-Moulton | Multistep method using an Adams-Bashforth predictor and an Adams-Moulton corrector. This method requires fewer function evaluations than the Runge-Kutta- Fehlberg method and therefore is useful when the evaluation of the differential equations is time-consuming. |
| Bulirsch-Stoer | Extrapolation method using the Aitken-Neville triangle rule. This method performs well for small absolute and relative error tolerances. |

| Algorithm | Description |
|---|---|
| Backward differentiation formula | Multistep, variable order method using orders up to six. This method is designed for stiff sets of equations. It is also known as Gear’s method. |
| Cyclic composite | Multistep, variable order method. This method is designed for stiff sets of equations. |

The columns of the $m \times n$ solution matrix, **X**, contain the solutions of the *n* differential equations at the values contained in the *m*-element vector `tOut`. If you specify `<variable>` for the parameter *`outStep`*, the solution matrix contains the solutions at values chosen by the selected algorithm. In this case, the parameter `stepSize` specifies the maximum step size used by the algorithm. If you provide a vector of values `tIn` for the independent variable, the solution is computed at each of these values and `tOut` is equal to `tIn`. If an algorithm encounters numerical problems, HiQ returns a partial vector of solutions.

The solution $\mathbf{y}_i$ at each value of the independent variable satisfies the following absolute tolerance $\varepsilon_a$ and relative tolerance $\varepsilon_r$ requirements.

$$\|\mathbf{y}_i - \mathbf{y}_{i-1}\|_2 < \varepsilon_a$$

$$\frac{\|\mathbf{y}_i - \mathbf{y}_{i-1}\|_2}{\|\mathbf{y}_i\|_2 + \delta} < \varepsilon_r$$

The denominator contains a small, non-zero value to prevent division by zero. The parameters `absTolr`, `relTolr`, and `thresh` correspond to $\varepsilon_a$, $\varepsilon_r$, and $\delta$ respectively.

## See Also

`ODEBVP`

## ones

### Purpose

Creates a vector or matrix with all elements set to one.

### Usage

```
A = ones(m)
```

Creates an m-element vector with all elements set to one.

```
A = ones(m, n)
```

Creates an mxn matrix with all elements set to one.

### Parameters

| Name | Type | Description |
|---|---|---|
| `m` | Integer Scalar | Number of rows. |
| `n` | Integer Scalar | Number of columns. |
| `A` | Integer Vector or Matrix | The vector or matrix with elements initialized to one. |

### Comments

All elements of the vector or matrix are set to one.

### See Also

`createMatrix`, `createVector`, `fill`

## open

### Purpose

Opens a file.

### Usage

```
fid = open(fileName, access)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fileName` | Text | The path and file name to open. |
| *`access`* | Text | The file access mode. (Optional.)<br>`"r"`<br>`"w"`<br>`"a"`<br>`"rb"`<br>`"wb"`<br>`"ab"`<br>`"r+"`<br>`"w+"`<br>`"a+"`<br>`"rb+"`<br>`"wb+"`<br>`"ab+"` |
| `fid` | Integer Scalar | A file handle for the open file. |

### Comments

If the parameter `access` is not specified, HiQ uses `"r+"` if the files exists and `"w+"` if the file does not exist.

| **Mode** | **Result** |
|---|---|
| `"r"` | Open an existing text file for reading. |
| `"w"` | Create a text file or open and truncate an existing text file for writing. |
| `"a"` | Create a text file or open an existing text file for writing. The file position indicator is positioned at the end of the file before each write. |
| `"rb"` | Open an existing binary file for reading. |
| `"wb"` | Create a binary file or open and truncate an existing binary file for writing. |

| Mode | Result |
|---|---|
| `"ab"` | Create a binary file or open an existing binary file for writing. The file position indicator is positioned at the end of the file before each write. |
| `"r+"` | Open an existing text file for reading and writing. |
| `"w+"` | Create a text file or open and truncate an existing text file for reading and writing. |
| `"a+"` | Create a text file or open an existing text file for reading and writing. The file position indicator is positioned at the end of the file before each write. |
| `"rb+"` | Open an existing binary file for reading and writing. |
| `"wb+"` | Create a binary file or open and truncate an existing binary file for reading and writing. |
| `"ab+"` | Create a binary file or open an existing binary file for reading and writing. The file position indicator is positioned at the end of the file before each write. |

Files are automatically closed when the script finishes execution.

## See Also

`close`

## optimize

### Purpose

Finds the minimum value of a linear or nonlinear equation.

### Usage

Computes the minimum value and minimizing vector of an unconstrained nonlinear function.

```
[fmin, xmin, nIter, kgTolr, kxTolr] = optimize(sFct, x0, uType,
gTolr, xTolr, maxIter, grdSFct, callback)
[fmin, xmin, nIter, kjTolr, kxTolr] = optimize(mFct, x0,
<marquardt>, jTolr, xTolr, maxIter, jacMFct, callback)
```

Computes the minimum value and minimizing vector of a nonlinear function with nonlinear constraints.

```
[fmin, xmin, nIter, kfTolr, kTolr] = optimize(sFct, x0, eqFct,
ineqFct, cType, tolr, maxIter, maxFctcalls, callback)
```

Computes the minimum value and minimizing vector of a linear system with linear constraints.

```
[fmin, xmin] = optimize(f, A, b, iLT, iGT, iEQ)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `sFct` | Function | The objective function to minimize. |
| `x0` | Real Vector | The initial guess for the minimizing vector. |
| *`uType`* | HiQ Constant | The unconstrained algorithm to use. (Optional. Default = `<conjGrad>`)<br>`<nelderMead>`<br>`<conjGrad>`<br>`<quasiNewton>` |
| *`gTolr`* | Real Scalar | The tolerance of the gradient of the input function to meet. (Optional. Default = `.0001`) |
| *`xTolr`* | Real Scalar | The tolerance of the solution vector to meet. (Optional. Default = `.0001`) |
| *`maxIter`* | Integer Scalar | The maximum number of iterations to perform. (Optional. Default = `32`) |

| Name | Type | Description |
|---|---|---|
| *`grdSFct`* | Function | A function representing the gradient of the input function `sFct`. (Optional.) |
| *`callback`* | Function | A function called at the end of each iteration. (Optional.) |
| `mFct` | Function | The objective function to minimize. |
| *`jTolr`* | Real Scalar | The tolerance of the jacobian of the input function to meet. (Optional. Default = `.0001`) |
| *`jacMFct`* | Function | A function representing the jacobian of the input function `mFct`. (Optional.) |
| `eqFct` | Function | A function containing the equality (=) constraints. |
| `ineqFct` | Function | A function containing the inequality (<>) constraints. |
| *`cType`* | HiQ Constant | The unconstrained optimization algorithm to use. (Optional. Default = `<conjGrad>`)<br>`<quasiNewton>`<br>`<conjGrad>` |
| *`tolr`* | Real Scalar | The tolerance on both the function value and solution value. (Optional. Default = `.0001`) |
| *`maxFctcalls`* | Integer Scalar | The maximum number of function calls to allow. (Optional. Default = `1024`) |
| `f` | Real Vector | The coefficients of the linear objective function. |
| `A` | Real Matrix | The coefficients of the less than and greater than inequality constraints and the equality constraints. |
| `b` | Real Vector | The right side constants of the constraint equations. |
| `iLT` | Integer Scalar | The number of less than (<) inequality constraints. |
| `iGT` | Integer Scalar | The number of greater than (>) inequality constraints. |

| Name | Type | Description |
|---|---|---|
| `iEQ` | Integer Scalar | The number of equality (=) constraints. |
| `fmin` | Real Scalar | The minimum value of the function. |
| `xmin` | Real Vector | The minimizing vector. |
| `nIter` | Integer Scalar | The number of iterations performed. |
| `kgTolr` | Integer Scalar | `true` (1) if the gradient tolerance parameter was met; `false` (0) if not. |
| `kxTolr` | Integer Scalar | `true` (1) if solution tolerance parameter was met; `false` (0) if not. |
| `kjTolr` | Integer Scalar | `true` (1) if the jacobian tolerance parameter was met; `false` (0) if not. |
| `kTolr` | Integer Scalar | `true` (1) if the tolerance parameter was met; `false` (0) if not. |

## Comments

Optimization is an extremely useful tool for solving a diverse set of problems including asset allocation, resource planning, parameter estimation, guidance and control, and approximation. The function `optimize` finds the minimum of an unconstrained nonlinear function or a constrained linear or nonlinear function.

The solution, $\mathbf{x}^*$, to the unconstrained optimization problem of a nonlinear single-valued function (objective function or performance index) of several variables

$$f(x_1, x_2, \ldots, x_n) = f(\mathbf{x})$$

is a local minimum of the function *f*.

The constrained optimization of the nonlinear function *f* adds the following constraints to the unconstrained optimization problem.

$$g(\mathbf{x}) = 0$$

$$h(\mathbf{x}) < 0$$

A necessary condition for the solution of the optimization problem is that the gradient of the function *f* at the solution $\mathbf{x}^*$ must be zero.

$$\nabla f(\mathbf{x}_i) = 0$$

A sufficient condition for the solution of the optimization problem is that the Hessian of the function *f* at the solution $\mathbf{x}^*$ must be positive definite.

$$\frac{\partial^2 f(\mathbf{x})}{\partial \mathbf{x}^2} > 0$$

HiQ uses the quasi-Newton method, conjugate gradient method, or Nelder-Mead method to find the solution to the unconstrained optimization problem defined above.

The quasi-Newton method derives from the necessary and sufficient conditions above to generate the following iterative update to the solution.

$$\mathbf{x}^{i+1} = \mathbf{x}^i - \lambda \mathbf{H}^{-1} \nabla \mathbf{x}^i \quad \text{where } \mathbf{H} = \frac{\partial^2 f(\mathbf{x})}{\partial \mathbf{x}^2}$$

The initial inverse of the Hessian matrix **H** is computed using the Cholesky decomposition and is updated using the Broyden-Fletcher-Goldfarb-Shano update method.

The conjugate gradient method is a direct iterative search using the gradient of *f* as the initial value of the conjugate gradient **p** used in the following equation.

$$\mathbf{x}^{i+1} = \mathbf{x}^i - \lambda \mathbf{p}^i \quad \text{where } \mathbf{p}^0 = \nabla f(\mathbf{x})$$

The conjugate gradient **p** is updated numerically using one of the following methods.

Polak–Ribiere (<conjGradPR>)

$$\mathbf{p}^{i+1} = -\nabla f(\mathbf{x}^{i+1}) + \frac{\nabla f(\mathbf{x}^{i+1})^{\mathrm{T}} (\nabla f(\mathbf{x}^{i+1}) - \nabla f(\mathbf{x}^i))}{\nabla f(\mathbf{x}^i)^{\mathrm{T}} \nabla f(\mathbf{x}^i)} \mathbf{p}^i$$

Beale–Sorenson (<conjGradBS>)

$$\mathbf{p}^{i+1} = -\nabla f(\mathbf{x}^{i+1}) + \frac{\nabla f(\mathbf{x}^{i+1})^{\mathrm{T}} (\nabla f(\mathbf{x}^{i+1}) - \nabla f(\mathbf{x}^i))}{\mathbf{p}^{i^{\mathrm{T}}} (\nabla f(\mathbf{x}^{i+1}) - \nabla f(\mathbf{x}^i))} \mathbf{p}^i$$

Polak–Ribiere (<conjGradPR>)

$$\mathbf{p}^{i+1} = -\nabla f(\mathbf{x}^{i+1}) + \frac{\nabla f(\mathbf{x}^{i+1})^{\mathrm{T}} \nabla f \mathbf{x}^{i+1}}{\nabla f(\mathbf{x}^i)^{\mathrm{T}} \nabla f(\mathbf{x}^i)} \mathbf{p}^i$$

HiQ uses the Polak-Ribiere update method as the default (`<conjGrad>`).

$$\|\nabla f(\mathbf{x}_i)\| < \varepsilon_f$$

$$\|\mathbf{x}_i - \mathbf{x}_{i-1}\| < \varepsilon_x$$

The Nelder-Mead method is a simplex search method that does not require the computation of the gradient of *f*.

Unconstrained optimization of a nonlinear multi-valued function of several variables

$$\mathbf{f}(\mathbf{x}) = \begin{matrix} f_1(x_1, x_2, \ldots, x_n) \\ \vdots \\ f_m(x_1, x_2, \ldots, x_n) \end{matrix}$$

is defined by the following equation.

$$x^* = \min_{\mathbf{x}} \sum_{i=1}^{m} (f_i(\mathbf{x}))^2$$

HiQ uses the Levenberg-Marquardt method to compute the solution to the unconstrained optimization of a nonlinear multi-valued function described above.

For the constrained optimization problem, the nonlinear constraints are adjoined to the objective function *f* to create the unconstrained optimization problem

$$\min_{\mathbf{x}} f(\mathbf{x}) + \lambda_g g(\mathbf{x}) + \lambda_h h(\mathbf{x})$$

where $\lambda_g$ and $\lambda_h$ are the Lagrange multipliers. HiQ computes the solution to this unconstrained optimization using the quasi-Newton method or the conjugate gradient method. The nonlinear constraints are enforced only after the iterative solution of the unconstrained optimization problem. Therefore, solutions of the unconstrained optimization problem may violate the constraints. To prevent problems with constraint violation, you must make sure the objective function is defined for values of **x** outside the constraints.

The constrained optimization problem of a linear function of *n* variables with *n* linear constraints is defined by the following equations.

minimize $\mathbf{c}^T\mathbf{x}$ subject to the constraints

$$\mathbf{A}_1\mathbf{x} < \mathbf{b}_1$$

$$\mathbf{A}_2\mathbf{x} < \mathbf{b}_2$$

$$\mathbf{A}_3\mathbf{x} = \mathbf{b}_3$$

The constraint matrices $\mathbf{A_1}$, $\mathbf{A_2}$, and $\mathbf{A_3}$, are dimensioned $p \times n$, $q \times n$, and $r \times n$, where $p + q + r = n$. The function `optimize` requires the constraint matrices and constraint vectors to be consolidated as follows.

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}_1 \\ \mathbf{A}_2 \\ \mathbf{A}_3 \end{bmatrix}$$

$$\mathbf{b} = \begin{bmatrix} \mathbf{b}_1 \\ \mathbf{b}_2 \\ \mathbf{b}_3 \end{bmatrix}$$

## Example

### Computing the shape of a rope hanging between two points.

```
// When a heavy rope or chain is hung between two points
// with equivalent horizon, the shape made by the rope or
// chain is known as a catenary. To construct this shape,
// only two basic elements are required: the length of the
// rope or chain and the distance between the hanging points.

// Provide a sample length and distance for a catenary.
L = 3;
h = 1;

// The formula used to compute the catenary is based on a
// single constant b related to L and h by bL = 2*sinh(bh/2).
// Solving for b is not direct, so optimization is used to
// compute it. Define the function to optimize.
bFct = {f:x:"x[1]*L - 2*sinh(.5*x[1]*h)"};

// Find b within a tolerance of 1e-4. Make an initial guess
// for b of 1.
b = optimize(bFct, {v: L - 2*sinh(.5*h)});
```

```
// Use the computed b constant to define the catenary
// function. We define the catenary so that the lowest
// point corresponds with x = 0.
function catenary(x)
   // Let the function know that b and h, which are defined outside
   // this function, will be used.
   project b, h;

   // By our definition, the catenary is only defined
   // between the hanging points, i.e., [-.5*h, .5*h]
   if (abs(x) > .5*h) then
      return <nan>;

   // Compute the catenary at point x.
   else
      return (cosh(b*x) - cosh(b*h))/b;
   end if;
end function;

// Generate a temporary set of evaluation points for the domain.
// Defining it as local frees it up after execution.
local domain = seq(-.5*h, .5*h, 100, <pts>);

// Graph the catenary over the provided domain.
catenaryGraph = createGraph(domain, catenary);

// Make the graph reflect the physical nature of the problem.
catenaryGraph.axis.y.range.inverted = true;
catenaryGraph.border.visible = <off>;
catenaryGraph.axes.majorgrid.visible = <off>;
catenaryGraph.plots.style = <point>;
catenaryGraph.plots.point.style = <emptycircle>;
catenaryGraph.plots.point.size = 6;
```

## See Also

`fit`, `solve`

## partial

### Purpose

Computes the partial derivative of a function.

### Usage

```
y = partial(fct, x, h, method, iFct)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function | The input function. A single equation as a function of multiple variables. |
| `x` | Real Vector | The point at which to calculate the derivative. |
| *`h`* | Real Scalar | The step size to use. (Optional.) |
| *`method`* | HiQ Constant | The finite difference method to use. (Optional. Default = `<central>`)<br>`<forward>`<br>`<extended>`<br>`<central>` |
| *`iFct`* | Integer Scalar | The input function variable of which to calculate the partial derivative. (Optional.) |
| `y` | Real Scalar or Vector | The partial derivatives of the input function. (Scalar value if `iFct` parameter is specified.) |

## Comments

Given a scalar-valued function of several variables

$$y = f(x_1, \ldots, x_n) = f(\mathbf{x})$$

the partial derivative of $f$ with respect to $\mathbf{x}$ is defined as

$$\frac{\partial f}{\partial \mathbf{x}} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \vdots \\ \frac{\partial f}{\partial x_n} \end{bmatrix}$$

If the step size is equal to zero, HiQ chooses an appropriate step size based on the precision of your computer.

The forward, central, and extended finite central difference formulas result in finite difference approximations of order one, two, and four respectively.

## See Also

`derivative`, `hessian`, `jacobian`

# PDF

## Purpose

Computes the probability density function.

## Usage

Computes the probability density of types requiring one parameter.

```
y = PDF(x, aType, a)
```

Computes the probability density of types requiring two parameters.

```
y = PDF(x, bType, a, b)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input value. |
| `aType` | HiQ Constant | The density type requiring a single parameter.<br>`<chiSq>`<br>`<student>`<br>`<geometric>`<br>`<poisson>` |
| `a` | Real Scalar | The first probability density parameter. |
| `bType` | HiQ Constant | The density type requiring two parameters.<br>`<beta>`<br>`<cauchy>`<br>`<exponential>`<br>`<f>`<br>`<gamma>`<br>`<normal>`<br>`<weibull>`<br>`<binomial>`<br>`<negBinomial>` |
| `b` | Real Scalar | The second probability density parameter. |
| `y` | Real Scalar | The value of the probability density function. |

## Comments

The probability densities are defined by the following equations.

| | |
|---|---|
| `PDF(x, <chiSq>, a)` | $\frac{1}{2^{\frac{a}{2}}\Gamma\left(\frac{a}{2}\right)}x^{\frac{a}{2}-1}e^{-\frac{x}{2}}$ |
| `PDF(x, <student>, a)` | $\frac{\Gamma\left(\frac{a+1}{2}\right)}{(a\pi)^{\frac{1}{2}}\Gamma\left(\frac{a}{2}\right)}\left(1+\frac{x^2}{a}\right)^{-\frac{a+1}{2}}$ |
| `PDF(k, <geometric>, a)` | $a(1-a)^x$ |
| `PDF(k, <poisson>, a)` | $\frac{e^{-a}a^x}{x!}$ |
| `PDF(x, <beta>, a, b)` | $\frac{1}{\beta(a, b)}x^{a-1}(1-x)^{b-1}$ |
| `PDF(x, <cauchy>, a, b)` | $\frac{1}{\pi b\left[1+\left(\frac{x-a}{b}\right)^2\right]}$ |
| `PDF(x, <exp>, a, b)` | $\frac{1}{b}e^{-\left(\frac{x-a}{b}\right)}$ |
| `PDF(x, <f>, a, b)` | $\frac{a^{\frac{a}{2}}b^{\frac{b}{2}}}{B(a, b)}\frac{x^{\frac{a}{2}-1}}{(b+ax)^{a+b}}$ |
| `PDF(x, <gamma>, a, b)` | $\frac{a^b}{\Gamma(b)}x^{b-1}e^{-ax}$ |
| `PDF(x, <normal>, a, b)` | $\frac{1}{\sqrt{2\pi}b}e^{\frac{(x-a)^2}{2b^2}}$ |

| | |
|---|---|
| `PDF(x, <weibull>, a, b)` | $abx^{a-1}e^{-bx^a}$ |
| `PDF(k, <binomial>, a, b)` | $\binom{a}{k}a^k(1-b)^{a-k}$ |
| `PDF(k, <negBinomial>, a, b)` | $\binom{a+k-1}{k}b^a(1-b)^k$ |

## See Also

`CDF`

## permu

### Purpose

Permutes a vector or matrix from the left (row permutation) and/or right (column permutation).

### Usage

Computes a permutation vector associated with a pivot vector.

```
p = permu(piv)
```

Computes the permutation of a vector.

```
B = permu(p, a)
```

Computes the row permutation of a matrix.

```
B = permu(p, A)
```

Computes the column permutation of a matrix.

```
B = permu(A, q)
```

Computes the row and column permutation of a matrix.

```
B = permu(p, A, q)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `piv` | Integer Vector | An *n*-element pivot vector. |
| `p` | Integer Vector | An *n*-element permutation vector. |
| `a` | Vector | An *n*-element input vector. |
| `A` | Matrix | A square *n*x*n* matrix. |
| `q` | Integer Vector | An *n*-element permutation vector. |
| `p` | Integer Vector | The *n*-element permutation vector associated with the pivot vector. |
| `B` | Matrix | The square *n*x*n* permuted matrix. |

### Comments

A permutation vector is a set of integers that define an ordering of a set of objects. In linear algebra, a permutation vector describes an ordering of elements in a vector or of rows or columns in a matrix. For example, the row permutation of a matrix results in the reordering of the rows in the matrix. A permutation of an $n \times n$ matrix **A** is defined as one of the following orthogonal transformations

| | |
|---|---|
| $\mathbf{B} = \mathbf{PA}$ | row permutation |
| $\mathbf{B} = \mathbf{AP}^{\mathrm{T}}$ | column permutation |
| $\mathbf{B} = \mathbf{PAQ}^{\mathrm{T}}$ | row and column permutation |
| $\mathbf{B} = \mathbf{PAP}^{\mathrm{T}}$ | symmetric row and column permutation |

where **P** and **Q** are $n \times n$ permutation matrices. A permutation matrix is a row (or column) permuted identity matrix defined by a permutation vector. For example, the permutation vector {5, 4, 3, 2, 1} describes the permutation matrix

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

## See Also

`compose`, `inv`

## pinv

### Purpose

Computes the pseudo-inverse of a matrix.

### Usage

```
B = pinv(A, tolr)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real Matrix | The *m*x*n* input matrix. |
| *`tolr`* | Real Scalar | The algorithm tolerance. (Optional. Default = `<epsilon>`) |
| `B` | Real Scalar | The pseudo-inverse of the input matrix. |

### Comments

An $m \times n$ matrix **A** can be thought of as a linear operator, mapping an *n*-dimensional input vector space **X** to an *m*-dimensional output vector space **Y**. If *m* is equal to *n* and **A** is full rank, every non-zero vector in the output space maps to one and only one non-zero vector in the input space. An operator, **B**, mapping the output space to the input space exists and is called the inverse of **A**. The matrices **A** and **B** satisfy the identity

$$\mathbf{AB} = \mathbf{I} = \mathbf{BA}$$

If *m* is not equal to *n* or if **A** is rank-deficient, an inverse operator does not exist. This is because there is no longer a one-to-one correspondence between vectors in **X** and **Y**. In this case, an operator, **B**, exists that satisfies the identities

$$\mathbf{ABA} = \mathbf{I}$$

$$\mathbf{BAB} = \mathbf{B}$$

The matrix **B** is called the pseudo-inverse of **A**. The matrix **A** and its pseudo-inverse **B** can be used to create an orthogonal projection onto the range space and the orthogonal complement of the null space of **A**. The nullspace of **A**, *N*(**A**)**,** is defined as

$$\{\mathbf{x}:\mathbf{Ax} = 0\}$$

and range space of **A**, *R*(**A**), is defined as

$$\{\mathbf{y}:\mathbf{y} = \mathbf{Ax}\}$$

The orthogonal projection onto the range space is **AB**. The orthogonal projection onto the orthogonal complement of the null space is **BA**.

## See Also

`inv`, `SVD`

## pow

### Purpose

Computes a scalar, matrix, or polynomial raised to a power.

### Usage

Computes a scalar or matrix raised to a power.

```
    y = pow(x, a)
```

Computes a polynomial raised to a power given a maximum degree.

```
    y = pow(p, a, maxDegree)
```

### Parameters

| **Name** | **Type** | **Description** |
|---|---|---|
| `x` | Scalar or Matrix | The input argument. |
| `a` | Scalar | The exponent. |
| `p` | Polynomial | The input polynomial. |
| `maxDegree` | Integer Scalar | The maximum degree of the output polynomial. (Optional. Default = `128`) |
| `y` | Scalar, Matrix, or Polynomial | The value of the argument raised to the exponent `a`. |

### Comments

The function `pow` is equivalent to the operators `^` and `**`.

### See Also

`cbrt`, `sqrt`

## prod

### Purpose

Computes the product of the elements in a vector or matrix.

### Usage

```
y = prod(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real or Complex Vector or Matrix | The input argument. |
| `y` | Real or Complex Scalar | The product of the elements in the input argument. |

### See Also

`sum`

## putFileName

### Purpose

Displays the file dialog box prompting for a new or existing filename.

### Usage

```
file = putFileName(path, name, filter, iFilter, title)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| *path* | Text | The initial directory path to display. (Optional.) |
| *name* | Text | The default file name to display. (Optional.) |
| *filter* | Text | A list of file types (suffixes) to display. (Optional.) |
| *iFilter* | Integer Scalar | An index (to filter) that is the default file type to display. (Optional. Default = `1`) |
| *title* | Text | The title of the dialog box. (Optional.) |
| `file` | Text | The full path and name of the selected file. |

### Comments

The parameter filter is a list of filter name and filter type pairs separated by vertical bars (|) as follows.

```
Filter_Name_1|Filter_1|Filter_Name_2|Filter_2|…|Filter_Name_n|Filter_n|
```

The filter name appears in the **Files of Type** pull-down menu of the dialog box. Users can choose from among any of the file types you specify in your filter string. For example, the following `putFileName` function call prompts the user with the **Open** dialog box and allows file searches for two file types, including All Files (*.*), in the current directory:

```
putFileName("", "All Files (*.*)|*.*|Data Files (*.dat)|*.dat", 1, "Open");
```

### See Also

`getFileName`

# QRD

## Purpose

Computes the QR decomposition of a matrix.

## Usage

`[R, Q, pivot, rank] = QRD(A, nType, tolr)`

## Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real Matrix | The input matrix. |
| *`nType`* | HiQ Constant | The type of orthogonal transformation to use. (Optional. Default = `<house>`)<br>`<mGS>`<br>`<house>`<br>`<givens>`<br>`<fastGivens>` |
| `tolr` | Real Scalar | The tolerance to use. (Optional. Default = `.0001`) |
| `R` | Real Matrix | An *n*x*n* upper triangular matrix. |
| `Q` | Real Matrix | An *n*x*n* orthogonal matrix. |
| `pivot` | Integer Vector | A vector containing the pivoting information. |
| `rank` | Integer Scalar | The rank of the input matrix. |

## Comments

The QR decomposition of an $m \times n$ matrix **A** is the factorization

$$\mathbf{A} = \mathbf{QR}$$

where **Q** is a square $m \times m$ orthonormal matrix, and **R** is an $m \times n$ upper triangular matrix.

The preferred algorithm to use in the QR decomposition depends on the structure of **A**. The Householder algorithm (default) constructs **Q** as a product of $n-2$ Householder reflections and is faster than Givens for non-sparse matrices. The Givens algorithm constructs **Q** as a product of Givens rotations and can be advantageous if the matrix **A** has many zeros. Numerical stability increases with both the Householder algorithm and the Givens algorithm by using column pivoting. If you provide the third output, `pivot`, this function performs column pivoting to ensure numerical stability and `pivot` contains the column pivoting information. Otherwise, no column pivoting occurs. If column pivoting is used, the output represents the QR decomposition for the permuted matrix, **AP**, where **P** is a permutation matrix associated with the pivoting vector. The following script shows how to construct **AP**.

```
P = permuPiv(piv);

AP = permu(A,P);
```

The rank of the input matrix **A** is returned as the fourth output parameter.

The fast Givens algorithm performs faster than the normal Givens algorithm because it does not require the square root function. This can be useful with sparse or narrow banded matrices. The modified Gram-Schmidt algorithm is faster than the Householder algorithm but not as accurate and requires $m \geq n$.

## See Also

`hessenbergD`, `LUD`, `schurD`, `SVD`

## quartile

### Purpose

Computes the value at the upper end of a quartile of a data set.

### Usage

```
y = quartile(x, n)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input data set. |
| *`n`* | Integer Scalar | The desired quartile of the data set. (Optional. Default = `1`) |
| `y` | Real Scalar | The value of the upper limit of the *n*-th quartile of the data set. |

### Comments

The quartiles of a data set are the values in the data set that divide the data set into four parts. The $i^{th}$ quartile of an *n*-element data set **x** is the value $x_i$ in the data set that lies at the upper range of the $i^{th}$ quarter.

The zeroth quartile returns the minimum of the data set and the fourth quartile returns the maximum of the data set.

### See Also

`histogram`, `median`, `range`

## random

### Purpose

Generates a random number.

### Usage

Generates a random number between zero and one.

```
y = random()
```

Generates a random number with uniform distribution within the specified range.

```
y = random(a, b, <uniform>)
```

Generates a random number with normal distribution.

```
y = random(xMean, xStddev, <normal>)
```

Generates a random number with exponential distribution.

```
y = random(k, <exp>)
```

Generates a random number with Bernoulli distribution.

```
y = random(p, <bernoulli>)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `a` | Real Scalar | The minimum value for the uniform distribution. |
| `b` | Real Scalar | The maximum value for the uniform distribution. |
| `xMean` | Real Scalar | The mean of the normal distribution. |
| `xStddev` | Real Scalar | The standard deviation of the normal distribution. |
| `k` | Real Scalar | The reciprocal of the average of the exponential distribution. |
| `p` | Real Scalar | The probability of ones occurring in the distribution. |
| `y` | Real Scalar | A real random number. |

## Comments

The usage `random()` generates a random number over the interval [0, 1] using the fast Knuth algorithm.

HiQ automatically seeds the random number generator before a script executes. You should manually seed the random number generator once with the `seed` function when you want to duplicate a random sequence.

| Usage | Probability Density |
|---|---|
| `random(a, b, <uniform>)` | $\frac{1}{b-a}, a < x < b$ <br> 0, otherwise |
| `random(a, b, <normal>)` | $\frac{1}{(2\pi b^2)^{0.5}} e^{-\left(\frac{(x-a)^2}{2b^2}\right)}$ |
| `random(k, <exp>)` | $\frac{1}{k} e^{-\frac{x}{k}}$ |
| `random(p, <bernoulli>)` | $\frac{1}{\sqrt{2\pi b}} e^{(x-a)^2/(2b^2)}$ |

## See Also

`createMatrix`, `createVector`, `seed`

## range

### Purpose

Computes the range of a data set.

### Usage

Computes the range of the entire data set.

```
y = range(x)
```

Computes the interquartile range of a data set.

```
y = range(x, <quartile>)
```

### Parameters

| **Name** | **Type** | **Description** |
|---|---|---|
| `x` | Real Vector | The input data set. |
| `y` | Real Scalar | The range of the data set. |

### Comments

The range of an *n*-element data set **x** is the difference between the maximum and minimum values in **x**.

The interquartile range of an *n*-element data set **x** is the range of values between the first and third quartiles of **x**.

### See Also

`histogram`, `median`, `quartile`

## rank

### Purpose

Computes the rank of a matrix.

### Usage

```
y = rank(A, tolr)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Matrix | The input matrix. |
| *`tolr`* | Real Scalar | The tolerance to use. (Optional. Default = `.01`) |
| `y` | Integer Scalar | The rank of the input matrix. |

### Comments

The rank of a matrix can be defined as the maximum number of linearly independent rows (or columns). To maximize accuracy, HiQ uses a robust SVD algorithm. The rank of the matrix is equal to the number of singular values greater than a specified tolerance. This tolerance is defined as

$$\min(m, n)\sigma_{\max} tolr$$

where $\sigma_{\max}$ is the maximum singular value of the input matrix and *tolr* is the specified tolerance.

Although the result of this function is generally reliable and agreeable with the function `cond`, it can be too conservative. Numerical rank also can be calculated using the function `QRD`.

### See Also

`det`, `inv`, `LUD`, `trace`

## read

### Purpose

Reads bytes from an open file.

### Usage

```
text = read(fid, nBytes)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | The file handle of an open file. |
| `nBytes` | Integer Scalar | The number of bytes to read. |
| `text` | Text | The resulting data. |

### Comments

The resulting text object contains the byte stream as stored in the file. If the file data represents numeric data, use the function `toNumeric` to convert the text object to a numeric object.

### See Also

`import`, `open`, `readLine`, `toNumeric`, `write`

## readLine

### Purpose

Reads lines from an open file.

### Usage

```
text = readLine(fid, nLines)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | The file handle. |
| `nLines` | Integer Scalar | The number of lines to read. |
| `text` | Text | Contains the lines read in. |

### Comments

Each line in the file must be terminated by a carriage return and linefeed characters. This function should be used for ASCII files only. If the text object represents numeric data, use the function `toNumeric` to convert the text object to a numeric object.

### See Also

`import`, `open`, `read`, `toNumeric`, `writeLine`

## reflect

### Purpose

Computes the Householder reflection of a vector or matrix.

### Usage

Computes the Householder reflection of a vector.

```
y = reflect(v, x, lambda)
```

Computes the Householder row reflection of a matrix.

```
Y = reflect(v, X, lambda)
```

Computes the Householder column reflection of a matrix.

```
Y = reflect(X, v, lambda)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `v` | Real Vector | The Householder reflection vector. |
| `x` | Real Vector | The input vector to reflect. |
| *`lambda`* | Real Scalar | The Householder parameter. (Optional.) |
| `X` | Real Matrix | The input matrix to reflect. |
| `y` | Real Vector | The reflected output vector. |
| `Y` | Real Matrix | The reflected output matrix. |

### Comments

Geometrically, the result is the orthogonal reflection with respect to the hyperplane **y** perpendicular to **v**:

$$\{\mathbf{y} : \langle \mathbf{y} | \mathbf{v} \rangle = 0\}$$

### See Also

`householder`, `rotate`

## remove

### Purpose

Removes elements of a vector or matrix.

### Usage

Removes elements of a vector.

```
y = remove(x, indices)
```

Removes rows and columns of a matrix.

```
Y = remove(X, rowIndices, colIndices)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Vector | The input vector. |
| `indices` | Integer Vector | The indices of the elements to remove. |
| `X` | Matrix | The input matrix. |
| *`rowIndices`* | Integer Vector | The vector of indices of the rows to remove. (Optional.) |
| *`colIndices`* | Integer Vector | The vector of indices of the columns to remove. (Optional.) |
| `y` | Vector | The resulting vector. |
| `Y` | Matrix | The resulting matrix. |

## Comments

When all items of the input object are removed, the resulting object is the same type as the input object and contains 0, <nan>, or (<nan,<nan>) if the input object was integer, real, or complex respectively.

This operation can either generate a new object or alter the current object in place as follows.

```
xNew = remove(x, indices);
x = remove(x, indices);
```

Altering the current object in place saves memory usage.

For matrices, removal of only rows or columns can be performed as follows.

```
Xcols = remove(X, rowIndices);

Xrows = remove(X,, colIndices);
```

## See Also

`find`, `replace`

## removePlot

### Purpose

Removes a plot from a graph.

### Usage

`removePlot(graph, *plot*)`

### Parameters

| Name | Type | Description |
|---|---|---|
| `graph` | 2D or 3D Graph | The graph containing the desired plot. |
| *`plot`* | Integer or 2D or 3D Plot | The plot to remove. If not specified, the function removes all plots. (Optional.) |

### Comments

For embedded plots, use the plot handle to remove the desired embedded plot. For plot objects, the plot is removed only from the specified graph. The plot object still exists in the notebook and in any other graphs.

### See Also

`addPlot`

## renameFile

### Purpose

Renames a file.

### Usage

```
renameFile(old, new)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `old` | Text | The original file name. |
| `new` | Text | The new file name. |

### Comments

Path name may be included to actually change the directory where the file is stored.

### See Also

`deleteFile`, `open`

## replace

### Purpose

Replaces the elements of a vector or matrix.

### Usage

Replaces a value in a vector or matrix.

```
[y, replacedIndices, nReplaced] = replace(x, oldValue, newValue)
```

Replaces a set of values in a vector or matrix.

```
[y, replacedIndices, nReplaced, valIndices] = replace(x,
oldValues, newValues, <elements>)
```

Replaces the occurrences of a subvector or submatrix in a vector or matrix.

```
[y, replacedIndices, nReplaced] = replace(x, oldxSub, newxSub)
```

Replaces the occurrences of a subvector in a vector.

```
[y, replacedIndices, nReplaced] = replace(x, oldXSub, newXSub,
direction)
```

Replaces the occurrences of values satisfying a predefined condition in a vector or matrix.

```
[y, replacedIndices, nReplaced] = replace(x, operator, base,
newValue)
```

Replaces the values in a vector or matrix based on a user-defined function.

```
[y, replacedIndices, nReplaced] = replace(x, replaceFct)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Vector or Matrix | The input vector or matrix. |
| `oldValue` | Scalar | The old value to replace. |
| `newValue` | Scalar | The new value to use. |
| `oldValues` | Vector or Matrix | The set of old values to replace. |
| `newValues` | Vector or Matrix | The set of new values. |

| Name | Type | Description |
|---|---|---|
| `oldxSub` | Vector or Matrix | The old subvector or submatrix to replace |
| `newxSub` | Vector or Matrix | The new subvector or submatrix. |
| `oldXSub` | Vector | The old subvector to replace |
| `newXSub` | Vector | The new subvector. |
| *`direction`* | HiQ Constant | The orientation of the vector to replace. (Optional. Default = `<row>`)<br>`<row>`<br>`<column>` |
| `operator` | HiQ Constant | A predefined operator with which to compare values.<br>`<GT>`<br>`<LT>`<br>`<GE>`<br>`<LE>`<br>`<NE>` |
| `base` | Scalar | A parameter used for the predefined condition. |
| `replaceFct` | Function | A user function that determines which values are replaced. |
| `y` | Vector or Matrix | The output vector or matrix containing the new values. |
| `replaced Indices` | Integer Vector or Matrix | The indices of the replaced elements. |
| `nReplaced` | Integer Scalar | The number of elements replaced. |
| `valIndices` | Integer Vector or Matrix | The indices into the input set of values corresponding to the actual values replaced. |

## Comments

The replacement in vectors is performed from first element to last. The replacement in matrices is performed row-wise, first column to last. If you are replacing a set of elements and the set of elements contains duplicate values, only the first value is used to determine the replacement value.

The object type and size of `replacedIndices` is directly related to the type of objects being replaced.

| Input Object | Old Object | Options | Indices |
|---|---|---|---|
| vector | scalar | | vector |
| vector | subvector | | *n*x2 matrix |
| vector | vector | <elements> | vector |
| matrix | scalar | | *n*x2 matrix |
| matrix | subvector | <row> or <column> | *n*x4 matrix |
| matrix | submatrix | | *n*x4 matrix |
| matrix | matrix | <elements> | *n*x2 matrix |

If replacing a subvector, each row of an *n*x2 matrix represents the range of the subvector replaced. Otherwise, each row of an *n*x2 matrix represents the row and column index of the scalar replaced. Each row of an *n*x4 matrix represents the row and column indices of the upper left (the first two elements of the row) and lower right (the last two elements of the row) corners of the occurrence of the replaced object in the matrix.

If the input parameter `oldvalues` is a vector, the return object `valIndices` is a vector of indices. If the input parameter `oldvalues` is a matrix, the return object `valIndices` is a matrix of row and column indices.

When no items are replaced, this function returns the original input object.

The user-defined replace function, `replaceFct`, for the usage above has the following definitions.

```
function replaceFct(x, i, j)
//If the object being replaced is a vector,
//do not use the third input parameter.
//x - scalar, the current element under inspection.
//i - integer scalar, the vector index (or matrix row)
//of the current element.
//j - integer scalar, the matrix column of the current element.

return newValue;
//newValue - scalar, the new value to use.
end function;
```

## See Also

`find`, `remove`, `subrange`

## root

### Purpose

Computes a single root of a function or polynomial.

### Usage

Computes the root of a real function between two end points.

```
[y, nIter] = root(fct, a, b, xTolr, maxIter)
```

Computes the root of a real function closest to a specified value.

```
y = root(fct, x0, <newton>, fTolr, xTolr, maxIter, callback,
derivFct)
```

Computes the root of a complex function closest to a specified value.

```
y = root(fct, x0, <muller>, fTolr, xTolr, maxIter)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function or Polynomial | The input function. |
| `x0` | Real or Complex Scalar | The initial guess. |
| *`fTolr`* | Real Scalar | The tolerance on the function value. (Optional. Default = `.0001`) |
| *`xTolr`* | Real Scalar | The tolerance on the solution value. (Optional. Default = `.0001`) |
| *`maxIter`* | Integer Scalar | The maximum number of iterations to perform. (Optional. Default = `64`) |
| *`callback`* | Function | A user function called at the end of each iteration. (Optional.) |
| *`derivFct`* | Function | A user function representing the derivative of the input function. (Optional.) |
| `a` | Real Scalar | The left end point. |
| `b` | Real Scalar | The right end point. |

| Name | Type | Description |
|---|---|---|
| `y` | Real or Complex Scalar | The calculated root. |
| `nIter` | Integer Scalar | The number of iterations performed. |

## Comments

If you provide a complex guess, `x0`, HiQ computes a complex root if it exists. If you provide a real guess, HiQ computes a real root if it exists.

The real function must be continuous on the interval. The complex function must be analytic.

## See Also

`optimize`, `roots`, `solve`

## roots

### Purpose

Computes the roots of a function or polynomial.

### Usage

Computes the roots of a complex analytic function within a circle of a specified radius.

```
y = roots(fct, radius, nTrap)
```

Computes the roots of a polynomial.

```
y = roots(p)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fct` | Function or Polynomial | The input function or polynomial. |
| `radius` | Real Scalar | The radius within which to calculate the roots. |
| `nTrap` | Integer Scalar | The number of points to use in the trapezoidal rule. (Optional. Default = `8`) |
| `p` | Polynomial | The input polynomial. |
| `y` | Complex Vector | The calculated roots. |

### Comments

A polynomial *p* of degree *n* has *n* complex roots.

This function computes the roots of a complex analytic function within a radius from the origin of the complex plane.

### Examples

#### Sorting the roots of a polynomial according to magnitude.

```
// Order the roots returned from the polynomial root solver in
// descending order according to the root magnitudes.

// Create an example polynomial used to generate the roots.
poly = {poly: "x^5 + x^3 - 2x - 5"};
```

```
// Compute the roots of the polynomial.
proots = roots(poly);

// Generate the sorting index based on the root magnitudes.
// Designate the object rootsAbs as local so it will be freed
// after execution is complete.
local rootsAbs;
[rootsAbs,index] = sort(abs(proots));

// Sort the original set of roots based on the sort index.
proots = sort(proots, index);

// Now make sure that the complex root pairs are ordered by
// ..., a - bi, a + bi, ...
i = 1;
while i < rootsAbs.size do
   // Check the ordering of a root pair.
   if abs(rootsAbs[i] - rootsAbs[i+1]) < <epsilon> then
      local proot = proots[i];

      // If the order is incorrect, swap them.
      // Otherwise, jump to the next potential pair.
      if (sign(proot.i) > 0) then
         proots[i] = conj(proots[i]);
         proots[i+1] = conj(proots[i+1]);
      else
         i = i + 2;
      end if;
   // Look for the next pair starting with the next root.
   else
      i = i + 1;
   end if;
end while;
```

## See Also

optimize, root, solve

## rotate

### Purpose

Computes the rotation of a vector or matrix through an angle.

### Usage

Computes the rotation of a vector.

```
y = rotate(c, s, x, row1, row2)
```

Computes the row rotation of a matrix.

```
Y = rotate(c, s, X, row1, row2)
```

Computes the column rotation of a matrix.

```
Y = rotate(X, c, s, col1, col2)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `c` | Real Scalar | The first rotation parameter. |
| `s` | Real Scalar | The second rotation parameter. |
| `x` | Real Vector | The *n*-element vector to rotate. |
| `row1` | Integer Scalar | The first row to rotate about. |
| `row2` | Integer Scalar | The second row to rotate about. |
| `X` | Real Matrix | The *mxn* matrix to rotate. |
| `col1` | Integer Scalar | The first column to rotate about. |
| `col2` | Integer Scalar | The second column to rotate about. |
| `y` | Real Vector | The rotation of the input vector. |
| `Y` | Real Matrix | The rotation of the input matrix. |

### Comments

The result is the orthogonal transformation

$$\mathbf{y} = \mathbf{G}^{\mathrm{T}} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \quad \text{where } \mathbf{G} = \begin{bmatrix} c & s \\ -s & c \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{bmatrix}$$

You can use this function with the `givens` function to selectively introduce zero elements in a matrix. This function is also useful for performing coordinate transformations.

## See Also

`givens`, `reflect`

## round

### Purpose

Rounds a number to the nearest whole number.

### Usage

```
y = round(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar, Vector, or Matrix | The input argument. |
| `y` | Real Scalar, Vector, or Matrix | The rounded value of the input argument. |

### Comments

For numbers having a fractional part of .5, this function rounds towards positive infinity. For numbers having a fractional part of –.5, this function rounds towards negative infinity.

For vectors and matrices, `round(x)` rounds the input on an element-by-element basis.

### See Also

`ceil`, `floor`

## saveLog

### Purpose

Saves the contents of the Log Window to file.

### Usage

```
saveLog(fileName)
```

### Parameters

| **Name** | **Type** | **Description** |
|---|---|---|
| `fileName` | Text | The file to which you want to save the Log Window. |

### Comments

The function is useful for documenting the execution results of a script when used in conjunction with `logMessage`.

### See Also

`clearLog`, `logMessage`

## schurD

### Purpose

Computes the Schur decomposition of a matrix.

### Usage

```
[H, Q] = schurD(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real Matrix | The input matrix. |
| `H` | Real Matrix | The *n*x*n* block triangular Schur real normal form. |
| `Q` | Real Matrix | An *n*x*n* orthogonal matrix. |

### Comments

The real Schur decomposition of a square $n \times n$ matrix **A** is defined as

$$\mathbf{A} = \mathbf{QHQ}^{\mathrm{T}}$$

where **Q** is an $n \times n$ orthogonal matrix, and **H** is a block upper triangular with $1 \times 1$ and $2 \times 2$ blocks on main diagonal:

$$\mathbf{H} = \begin{bmatrix} \mathbf{H}_{11} & \mathbf{H}_{12} & \dots & \mathbf{H}_{1m} \\ 0 & \mathbf{H}_{22} & & \mathbf{H}_{2m} \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \dots & \mathbf{H}_{mm} \end{bmatrix}$$

where $\mathbf{H}_{ii}$ are square blocks of dimension 1 or 2. The structure of the block triangular matrix **H** is called the real Schur normal form. The Schur decomposition is similar to the Jordan decomposition of a square $n \times n$ complex matrix defined as

$$\mathbf{A} = \mathbf{XJX}^{-1}$$

where **X** is an $n \times n$ nonsingular matrix, and **J** is an $n \times n$ bi-diagonal matrix with the eigenvalues on the main diagonal and ones and zeros on the super diagonal. The Schur decomposition trades the bi-diagonal structure of **J** for a block upper triangular structure in **H** in return for a better behaved, orthogonal matrix **Q**. This lends the numerical calculation of the Schur decomposition to stable numerical methods.

If all eigenvalues of **A** are real, **H** is upper triangular. Complex conjugate pairs of eigenvalues are responsible for the appearance of $2 \times 2$ blocks on main diagonal.

The algorithm for computing the decomposition is based on a QR algorithm with Hessenberg reduction and implicit double-shift Francis steps and is numerically stable for well-balanced matrices. This method is iterative and might generate a convergence error in some cases.

This function executes significantly faster when you request only the matrix **H** as in the following script.

```
H = schurD(A);
```

## See Also

`hessenbergD`, `LUD`, `QRD`, `SVD`

## sec

### Purpose

Computes the secant.

### Usage

```
y = sec(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input angle in radians. |
| `y` | Real or Complex Scalar | The secant of the input values. |

### Comments

The secant is defined for the real domain $(-\infty, \infty)$, $x \neq \pm k\pi - \frac{\pi}{2}$, $k = 0, 1, 2, \ldots$

### See Also

`arcsec`, `csc`, `sech`

## sech

### Purpose

Computes the hyperbolic secant.

### Usage

```
y = sech(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The hyperbolic secant of the input value. |

### Comments

The hyperbolic secant is defined for the real domain $(-\infty, \infty)$.

### See Also

`arcsech`, `csch`, `sec`

## seed

### Purpose

Seeds the random number generator.

### Usage

`seed(`*`i`*`)`

### Parameters

| Name | Type | Description |
|---|---|---|
| *i* | Integer Scalar | The seed value. (Optional.) |

### Comments

The usage `seed()` uses the current value of the system clock to seed the random number generator. HiQ automatically seeds the random number generator before a script executes, so normally you do not need to use this function. You should use this function when you want to duplicate a random sequence each time you run a script or when you want to start a new random sequence within the same script.

### See Also

`createMatrix`, `createVector`, `random`

## seq

### Purpose

Creates a sequence of scalars or vectors.

### Usage

Creates an *m*-element vector initialized with a sequence of whole numbers starting at one.

```
a = seq(m)
```

Creates a vector initialized with elements from start to stop with a specified step size.

```
a = seq(start, stop, stepSize, <size>)
a = seq(start, stop, stepSize)
```

Creates a vector initialized with elements from start to stop containing a specific number of elements.

```
a = seq(start, stop, nSteps, <points>)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `m` | Integer Scalar | The number of elements to create. |
| `start` | Real Scalar | The starting value. |
| `stop` | Real Scalar | The stopping value. |
| `stepSize` | Real Scalar | The step size to use. |
| `nSteps` | Integer Scalar | The number of steps between the start and stop values. |
| `x` | Vector | The starting vector. |
| `y` | Vector | The ending vector |

### Comments

To create a sequence starting at *a*, ending at *b*, with a given number of elements *n*, use `seq` as in the following script.

```
y = seq(a, b, n, <points>);
```

## Examples

### 1. Creating a vector of data with equally spaced points (HiQ-Script).

This example shows how to create a vector of data ranging from –<pi> to <pi> in steps of 0.1.

```
//Create a vector of x data.
x = seq(-<pi>,<pi>,.1);

//Create a vector of y data.
y = cos(x);

//Create a new graph with a new plot of the vector y.
myGraph = createGraph(x,y);
```

### 2. Creating a vector of data with a specified number of points (HiQ-Script).

This example shows how to create a five-element vector of data ranging from 1 to 5.

```
//Solving a symmetric, positive definite linear system.

//Create a 5x5 Moler matrix. The Moler matrix is
//symmetric and positive definite.
A = createMatrix(5,5,<moler>);

//Create the vector b from 1 to 5.
b = seq(5);

//Compute the decomposition (LL') of the
//symmetric, positive definite matrix A.
L = choleskyD(A);

//Solve the system Ax = b using the symmetric, positive
//definite decomposition matrix L.
x = solve(L,b,<choleskyD>);
```

## See Also

`createMatrix`, `createVector`, `fill`, `ones`

## setFilePos

### Purpose

Sets the position of a file pointer.

### Usage

```
setFilePos(fid, pos, mode)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | A valid file ID. |
| `pos` | Integer Scalar | The new position of the file pointer (in bytes from the beginning of file). |
| `mode` | HiQ Constant | The position in the file from which to move. (Optional. Default = `<seekFromCurrent>`)<br>`<seekFromEnd>`<br>`<seekFromStart>`<br>`<seekFromCurrent>` |

### Comments

You can use this function to ensure you are reading from or writing to the correct location in a structured file.

### See Also

`getFilePos`, `getFileSize`, `isEOF`

## sign

### Purpose

Computes the sign of a number.

### Usage

```
y = sign(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, or Matrix | The input argument. |
| `y` | Scalar, Vector, or Matrix | `1` if the sign of the input is positive, `-1` if the sign of the input is negative, and `0` if the input is 0. |

### Comments

This function returns the following results.

| Input | Result |
|---|---|
| x > 0 | 1 |
| x < 0 | –1 |
| x = 0 | 0 |
| x = <nan> | <nan> |

For complex numbers, `sign(x)` returns a complex number representing the sign of the real and imaginary components. For vectors and matrices, `sign(x)` returns the sign of the input on an element-by-element basis.

### See Also

`abs`, `arg`

## sin

### Purpose

Computes the sine.

### Usage

```
y = sin(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input angle in radians. |
| `y` | Real or Complex Scalar | The sine of the input value. |

### Comments

The sine is defined for the real domain $(-\infty, \infty)$.

### See Also

`arcsin`, `cos`, `sinh`

## sinh

### Purpose

Computes the hyperbolic sine.

### Usage

```
y = sinh(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The hyperbolic sine of the input. |

### Comments

The hyperbolic sine is defined for the real domain $(-\infty, \infty)$.

### Examples

#### 1. Creating a 2D graph with a function plot (HiQ-Script).

This example demonstrates how to quickly graph a function.

```
//Create a vector of x data with 100 points.
x = seq(-<pi>,<pi>,2*<pi>/100);

//Create a new graph with a new plot of the function sinh.
//Any function parameter (like sinh) must be a
//single-input, single-output function.
myGraph = createGraph(x,sinh);
```

#### 2. Computing the shape of a rope hanging between two points.

```
// When a heavy rope or chain is hung between two points
// with equivalent horizon, the shape made by the rope or
// chain is known as a catenary. To construct this shape,
// only two basic elements are required: the length of the
// rope or chain and the distance between the hanging points.
// Provide a sample length and distance for a catenary.
L = 3;
h = 1;

// The formula used to compute the catenary is based on a
// single constant b related to L and h by bL = 2*sinh(bh/2).
// Solving for b is not direct, so optimization is used to
// compute it. Define the function to optimize.
bFct = {f:x:"x[1]*L - 2*sinh(.5*x[1]*h)"};

// Find b within a tolerance of 1e-4. Make an initial guess
// for b of 1.
b = optimize(bFct, {v: L - 2*sinh(.5*h)});

// Use the computed b constant to define the catenary
// function. We define the catenary so that the lowest
// point corresponds with x = 0.
function catenary(x)
   // Let the function know that b and h, which are defined outside
   // this function, will be used.
   project b, h;

   // By our definition, the catenary is defined
   // only between the hanging points, i.e., [-.5*h, .5*h]
   if (abs(x) > .5*h) then
      return <nan>;

   // Compute the catenary at point x.
   else
      return (cosh(b*x) - cosh(b*h))/b;
   end if;
end function;

// Generate a temporary set of evaluation points for the domain.
// Defining it as local frees it up after execution.
local domain = seq(-.5*h, .5*h, 100, <pts>);
// Graph the catenary over the provided domain.
catenaryGraph = createGraph(domain, catenary);
```

```
// Make the graph reflect the physical nature of the problem.
catenaryGraph.axis.y.range.inverted = true;
catenaryGraph.border.visible = <off>;
catenaryGraph.axes.majorgrid.visible = <off>;
catenaryGraph.plots.style = <point>;
catenaryGraph.plots.point.style = <emptycircle>;
catenaryGraph.plots.point.size = 6;
```

## See Also

`arcsinh`, `cosh`, `sin`

# sinhI

## Purpose

Computes the hyperbolic sine integral function.

## Usage

```
y = sinhI(x)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The value of the hyperbolic sine integral. |

## Comments

The hyperbolic sine integral is defined by the following equation.

$$\mathrm{sinhI}(x) = \int_0^x \frac{\sinh(t)}{t}\,dt$$

## See Also

`coshI`, `expI`, `sinI`

## sinI

### Purpose

Computes the sine integral function.

### Usage

```
y = sinI(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The value of the sine integral. |

### Comments

The sine integral is defined by the following equation.

$$\sin\mathrm{I}(x) = \int_0^x \frac{\sin(t)}{t}\,dt$$

### See Also

`cosI`, `expI`, `sinhI`

## skew

### Purpose

Computes the skew of a data sample.

### Usage

```
y = skew(x, xMean)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input data set. |
| *`xMean`* | Real Scalar | The mean of the input data set. (Optional.) |
| `y` | Real Scalar | The skew of the input data set. |

### Comments

The skew an *n*-element data sample **x** is defined by the following equation.

$$\mu_3 = \frac{1}{\sigma^3} \frac{\sum_{i=1}^{n} (x_i - \bar{\mathbf{x}})^3}{n}$$

where $\bar{\mathbf{x}}$ is the mean and $\sigma$ is the standard deviation.

### See Also

`kurtosis`, `mean`, `moment`

# solve

## Purpose

Solves a linear or nonlinear system of equations.

## Usage

Solves a linear system of equations.

```
[y, residual, rnk] = solve(A, b, aType)
```

Solves a linear system of equations in LU (LU factorization) form.

```
y = solve(L, U, b, piv)
```

Solves a linear system of equations in LL' (Cholesky factorization) form.

```
y = solve(L, b, <choleskyD>)
```

Solves a linear system of equations in LTL' (symmetric indefinite factorization) form.

```
y = solve(L, T, b, piv, <symD>)
```

Solves a Vandermonde or Toeplitz linear system of equations.

```
y = solve(v, b, vType)
```

Solves a nonlinear system of equations.

```
[y, nIter, kfTolr, kxTolr] = solve(fct, x0, iAlg, fTolr, xTolr,
maxIter, Jiter, callback)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| A | Matrix | The *mxn* linear system matrix. |
| b | Vector | The *n*-element right side of the linear system. |
| aType | HiQ Constant | Restricts the solver algorithm. (Optional.)<br>`<leastSq>`<br>`<linearSys>` |
| L | Matrix | The lower triangular system matrix or decomposition matrix. |
| U | Matrix | The upper triangular system matrix or decomposition matrix. |
| piv | Integer Vector | The pivot vector returned from the function LUD. |

| Name | Type | Description |
|---|---|---|
| `T` | Matrix | The tri-diagonal decomposition matrix in the symmetric indefinite factorization LTL'. |
| `v` | Real Vector | The vector defining the Toeplitz or Vandermonde system. |
| `vType` | HiQ Constant | Specifies the type of special linear system.<br>`<vandermonde>`<br>`<toeplitz>` |
| `fct` | Function | A function containing the set of *m* nonlinear equations in *n* variables to solve. |
| `x0` | Real Vector | An *n*-element vector containing the initial guess. |
| `iAlg` | HiQ Constant | The algorithm to use. (Optional. Default = `<quasiNewton>`)<br>`<quasiNewton>`<br>`<newton>` |
| `fTolr` | Real Scalar | The function tolerance. (Optional. Default = `.0001`) |
| `xTolr` | Real Scalar | The solution tolerance. (Optional. Default = `.0001`) |
| `maxIter` | Integer Scalar | The maximum number of iterations to allow. (Optional. Default = `128`) |
| `JIter` | Integer Scalar | Specifies how often to recalculate the Jacobian matrix (in iterations). (Optional. Default = `1`) |
| `callback` | Function | A function called at the end of each iteration. (Optional.) |
| `y` | Vector | The solution to the set of linear or nonlinear equations. |
| `residual` | Real Scalar | The residual of the least-squares solution. |
| `rnk` | Integer Scalar | The rank of the input matrix. |
| `nIter` | Integer Scalar | The number of iterations performed. |

| Name | Type | Description |
|---|---|---|
| `kfTolr` | Integer Scalar | `true` (1) if the function tolerance was met; `false` (0) if not. |
| `kxTolr` | Integer Scalar | `true` (1) if the solution tolerance was met; `false` (0) if not. |

## Comments

A set of $n$ linear equations can be represented in matrix form as

$$\mathbf{A}\mathbf{x} = \mathbf{b}$$

where **A** is the $n \times m$ system matrix, **b** is an $n$-dimensional vector, and **x** is an $m$-dimensional vector of unknowns.

The usage `solve(A, b)` solves for **x** using LU decomposition if **A** is square and full rank or a least-squares algorithm if **A** is not square or is rank deficient. For a square, full-rank **A**, HiQ computes the LU decomposition of the system matrix **A**, then performs forward and backward substitution. The single function call

```
x = solve(A, b);
```

is equivalent to the following two function calls.

```
[L, U, pivot]=LUD(A);
x = solve(L, U, b, pivot);
```

See the comments for the function `LUD` for more information.

For a non-square or rank-deficient **A**, HiQ solves the least-squares problem defined by the optimization

$$\min_{\mathbf{x}} \|\mathbf{A}\mathbf{x} - \mathbf{b}\|_2$$

where $\|\mathbf{A}\mathbf{x} - \mathbf{b}\|_2$ is the objective function and $\|\cdot\|_2$ represents the L2 norm. If the number of equations is greater than the number of unknowns ($m > n$), the set of equations is said to be over-determined and in general an exact solution **x** does not exist. The least-squares solution **xls** for over-determined systems is the vector **x** that minimizes the objective function above. If the number of equations is less than the number of unknowns ($m < n$), the set of equations is said to be under-determined and an infinite number of solutions exist for the objective function above. In the under-determined system, the least-squares solution **xls** is the solution vector **x** having the minimum L2 norm.

$$\min_{\mathbf{x}} \|\mathbf{Ax} - \mathbf{b}\|_2 \qquad \text{over-determined system}$$

$$\min_{\|\mathbf{x}\|_2} \left\{ \mathbf{x} : \min_{\mathbf{x}} \|\mathbf{Ax} - \mathbf{b}\|_2 \right\} \qquad \text{under-determined system}$$

The residual is defined as the value of the objective function at the solution **xls**.

HiQ provides Householder- and Givens-based QR decomposition algorithms for full-rank and rank-deficient matrices and a singular value decomposition algorithm. The rank-deficient algorithms also solve full-rank systems but do not execute as fast as the full-rank algorithms. For an over-determined system, the full-rank QR algorithm is defined by the following equations.

$$\mathbf{A} = \mathbf{QR} = \begin{bmatrix} \mathbf{R}_1 \\ \mathbf{0} \end{bmatrix}$$

$$\mathbf{Q}^{\mathrm{T}}\mathbf{A} = \begin{bmatrix} \mathbf{R}_1 \\ \mathbf{0} \end{bmatrix}$$

$$\mathbf{Q}^{\mathrm{T}}\mathbf{b} = \begin{bmatrix} \mathbf{b}_1 \\ \mathbf{b}_2 \end{bmatrix}$$

$$\|\mathbf{Ax} - \mathbf{b}\|_2 = \|\mathbf{Q}^{\mathrm{T}}\mathbf{Ax} - \mathbf{Q}^{\mathrm{T}}\mathbf{b}\|_2 = \left\| \begin{bmatrix} \mathbf{R}_1 \\ \mathbf{0} \end{bmatrix} \mathbf{x} - \begin{bmatrix} \mathbf{b}_1 \\ \mathbf{b}_2 \end{bmatrix} \right\|_2 = \|\mathbf{R}_1\mathbf{x}_1 - \mathbf{b}_1\|_2 + \|\mathbf{b}_2\|_2$$

**Q** is an $m \times m$ orthogonal matrix, **R** is an $m \times n$ upper-triangular matrix, and $\mathbf{R}_1$ is an $n \times n$ upper-triangular matrix. Because **A** is full rank, $\mathbf{R}_1$ is full rank and $\mathbf{x}_1$ is the solution to the upper triangular system $\mathbf{R}_1\mathbf{x}_1 = \mathbf{b}_1$. The solution and residual to the over-determined, full-rank, least-squares problem is

$$\mathbf{x}_{ls} = \begin{bmatrix} \mathbf{x}_1 \\ \mathbf{0} \end{bmatrix}$$

$$\rho_{ls} = \|\mathbf{b}_2\|_2$$

The Householder algorithm constructs **Q** as a product of $n - 2$ Householder reflections. The Givens algorithm constructs **Q** as a product of Givens rotations and can be advantageous if the matrix **A** has many zeros.

The SVD algorithm is equivalent to solving the linear system using the pseudo inverse. It is slower than the QR algorithms but is very accurate and well behaved for ill-conditioned matrices.

A set of *n* nonlinear equations can be represented by the following equation.

$$\mathbf{f}(\mathbf{x}) = \begin{matrix} f_1(x_1, x_2, \ldots, x_n) \\ f_2(x_1, x_2, \ldots, x_n) \\ \vdots \\ f_n(x_1, x_2, \ldots, x_n) \end{matrix}$$

The solution to the above set of equations is defined as the vector $\mathbf{x}^*$ that satisfies the following equation.

$$\mathbf{f}(\mathbf{x}^*) = 0$$

HiQ uses the Newton or quasi-Newton algorithms to solve for $\mathbf{x}^*$. All three algorithms are iterative and return a valid solution based on the following criteria.

$$\|\mathbf{f}(\mathbf{x}^k)\|_2 < \varepsilon_f$$

$$\frac{\|\mathbf{x}^k - \mathbf{x}^{k-1}\|_2}{\|\mathbf{x}^k\|_2} < \varepsilon_x$$

The notation $\mathbf{x}^k$ indicates the $k^{th}$ iteration of the algorithm.

The Newton algorithm calculates an iterative solution using the inverse of the Jacobian of the equations. If the Jacobian is singular, HiQ displays an error message. The parameter `JIter` allows the Newton algorithm to re-use the Jacobian from previous iterations, updating the Jacobian every `JIter` iteration. This is useful for reducing the time required to solve many equations, or equations that take a long time to evaluate.

The quasi-Newton algorithm calculates the inverse of the Jacobian on the first iteration, then updates the inverse Jacobian using Broyden's method and the Sherman-Morrison matrix inversion formula. If the Jacobian is singular, HiQ displays an error message. The parameter `JIter` allows the quasi-Newton algorithm to re-use the Jacobian from previous iterations, updating the Jacobian every `JIter` iterations. This is useful for reducing the time required to solve many equations, or equations that take a long time to evaluate.

## Examples

### 1. Solving a symmetric, positive definite linear system.

This example shows how to solve a linear system, taking advantage of the symmetric, positive definite properties of the system matrix.

```
//Solving a symmetric, positive definite linear system.

//Create a 5x5 Moler matrix. The Moler matrix is
//symmetric and positive definite.
A = createMatrix(5,5,<moler>);

//Create the vector b from 1 to 5.
b = seq(5);

//Compute the decomposition (LL') of the
//symmetric, positive definite matrix A.
L = choleskyD(A);

//Solve the system Ax = b using the symmetric, positive
//definite decomposition matrix L.
x = solve(L,b,<choleskyD>);
```

### 2. Solving a symmetric, indefinite linear system.

This example shows how to solve a linear system, taking advantage of the symmetric, indefinite properties of the system matrix.

```
//Solving a symmetric, indefinite linear system.

//Create a 5x5 ding-dong matrix. The ding-dong matrix is
//symmetric and indefinite.
A = createMatrix(5,5,<dingdong>);

//Create the right-hand-side vector b from 1 to 5.
b = seq(5);

//Compute the symmetric decomposition (LTL') of the
//symmetric, indefinite matrix A.
[L,T,piv] = symD(A);

//Solve the system Ax = b using the symmetric, indefinite
//decomposition matrices L and T.
x = solve(L,T,b,piv,<symD>);
```

## See Also

`LUD`, `root`, `roots`

## sort

### Purpose

Sorts a data set.

### Usage

Sorts a data set.

```
[y, index] = sort(x, dir, alg, ties)
```

Sorts a data set using a set of indices.

```
y = sort(x, index)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Integer or Real Vector | The input data set. |
| `index` | Integer Vector | The indices by which to sort the input data set. |
| *`dir`* | HiQ Constant | The direction to sort. (Optional. Default = `<ascending>`)<br>`<ascending>`<br>`<descending>` |
| *`alg`* | HiQ Constant | The sorting algorithm to use. (Optional. Default = `<quickSort>`)<br>`<quickSort>`<br>`<heapSort>`<br>`<shellSort>`<br>`<insertionSort>`<br>`<bucketSort>` |
| *`ties`* | HiQ Constant | Specifies whether to keep duplicate data points. (Optional. Default = `<noTies>`)<br>`<noTies>`<br>`<keepTies>` |
| `index` | Integer Vector | The indices by which to sort the input data set. |

| Name | Type | Description |
|---|---|---|
| `y` | Integer or Real Vector | The sorted data set. |
| `index` | Integer Vector | The indices mapping the sorted data set to the unsorted data set. |

## Comments

When sorting using an index vector input, the index vector does not need to be the same size as the unsorted input vector. The sorted output vector will have the same number of elements as the index vector. Also, indices may appear more than once. For example, for a 10-element unsorted input vector, the following script creates a vector **y** containing the elements {6,7,4,9,9,7}.

```
x = {v:10, 9, 8, 7, 6, 5, 4, 3, 2, 1};

index = {v:5, 4, 7, 2, 2, 4};

y = sort(x, index);
```

## Examples

### 1. Sorting a set of complex elements based on magnitude.

```
// Sort a set of complex elements based on magnitude
// given a vector x of complex elements.

// Compute the magnitude of each complex element.
// Because xMag is not needed for the end result, defining
// it as local will remove it after execution.
local xMag = abs(x);

// Generate the sort index for the magnitudes.
[,index] = sort(xMag);

// Use the sort index from the magnitudes to reorder
// the original set of complex elements.
xSorted = sort(x, index);
```

### 2. Sorting a set of complex elements based on phase.

```
// Sort a set of complex elements based on phase
// given a vector x of complex elements.
// Compute the phase of each complex element.
// Because xPhase is not needed for the end result, defining
// it as local will remove it after execution.
local xPhase = arg(x);

// Generate the sort index based on the phase.
[,index] = sort(xPhase);

// Use the sort index from the phase to reorder
// the original set of complex elements.
xSorted = sort(x, index);
```

### 3. Sorting the roots of a polynomial according to magnitude.

```
// Order the roots returned from the polynomial root solver in
// descending order according to the root magnitudes.

// Create an example polynomial used to generate the roots.
poly = {poly: "x^5 + x^3 - 2x - 5"};

// Compute the roots of the polynomial.
proots = roots(poly);

// Generate the sorting index based on the root magnitudes.
// Designate the object rootsAbs as local so it will be freed
// after execution is complete.
local rootsAbs;
[rootsAbs,index] = sort(abs(proots));

// Sort the original set of roots based on the sort index.
proots = sort(proots, index);
```

```
// Now make sure that the complex root pairs are ordered by
// ..., a - bi, a + bi, ...
i = 1;
while i < rootsAbs.size do
   // Check the ordering of a root pair.
   if abs(rootsAbs[i] - rootsAbs[i+1]) < <epsilon> then
      local proot = proots[i];

      // If the order is incorrect, swap them.
      // Otherwise, jump to the next potential pair.
      if (sign(proot.i) > 0) then
         proots[i] = conj(proots[i]);
         proots[i+1] = conj(proots[i+1]);
      else
         i = i + 2;
      end if;
   // Look for the next pair starting with the next root.
   else
      i = i + 1;
   end if;
end while;
```

## See Also

`find`, `remove`, `replace`

## sparsity

### Purpose

Computes the percentage of zero-valued elements in a vector or matrix.

### Usage

```
[s, ss] = sparsity(A, tolr)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Vector or Matrix | The input vector or matrix. |
| *`tolr`* | Real Scalar | The tolerance to use for determining zero elements. (Optional.) |
| `s` | Real Scalar | The structural sparsity of the input. |
| `ss` | Real Scalar | The physical storage sparsity of the input. |

### Comments

The sparsity of an object is defined as the fraction of an object's elements whose value is zero or whose absolute value is less than a specified tolerance. The function `sparsity` calculates the dominance of zero elements or elements with a value less than a tolerance in a vector or matrix.

HiQ stores matrices with certain structural properties more efficiently in memory. The second return parameter, `ss`, contains the sparsity of the matrix as stored in memory. For more information matrix structural properties, see the function `convert`.

To limit round-off errors in real and complex objects, choose a tolerance equal to a multiple of the precision of your computer.

### See Also

`cond`, `isMatrix`, `vanish`

## spline

### Purpose

Computes the spline interpolation of a data set.

### Usage

Computes the natural cubic spline interpolation of a data set.

```
   [coefs, intervals] = spline(x, y, <natcubic>)
```

Computes the cubic spline interpolation of a data set.

```
   [coefs, intervals] = spline(x, y, <cubic>, knotlderiv, knotNderiv)
```

Computes the b spline interpolation of a data set.

```
   [coefs, intervals] = spline(x, y, <b>, knots, order)
```

Computes the polynomial spline interpolation of a data set.

```
   [coefs, intervals] = spline(x, y, <poly>, degree)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The *n*-element x data set used to create the spline. |
| `y` | Real Vector | The *n*-element y data set used to create the spline. |
| *`knotlderiv`* | Real Scalar | The first derivative at the start of the data. (Optional. Default = `0.0`) |
| *`knotNderiv`* | Real Scalar | The first derivative at the end of the data. (Optional. Default = `0.0`) |
| *`knots`* | Real Vector | The knots to use. (Optional.) |
| *`order`* | Integer Scalar | The order of the b spline. (Optional. Default = `3`) |
| `degree` | Integer Scalar | The degree of the polynomial spline. |
| `coefs` | Matrix | The coefficients of the polynomials defining the spline. |
| `intervals` | Matrix | The domains for each polynomial defining the spline. |

## Comments

Unlike data fitting, spline and polynomial interpolation require the interpolant to pass through the data set used to compute the interpolation. Spline interpolation uses several lower degree piecewise-continuous polynomials for interpolation of a data set, avoiding problems associated with higher degree single polynomial interpolation.

The cubic and natural cubic splines use cubic polynomials and differ only in the required end-point conditions of the interpolation. A cubic spline interpolant *s* of an *n*-element data set **x** requires the first derivative of the interpolant at the end points to be fixed.

$$\frac{ds}{dx_1} = a$$

$$\frac{ds}{dx_n} = b$$

A natural cubic spline interpolant *s* of an *n*-element data set **x** requires the second derivative of the interpolant at the end points to be zero.

$$\frac{d^2s}{dx_1^2} = 0$$

$$\frac{d^2s}{dx_n^2} = 0$$

The b-spline interpolant of an *n*-element data set **x** uses a cubic or higher degree polynomial and requires both end-point conditions of the cubic spline and the natural cubic spline with $a = 0$ and $b = 0$.

If the parameter `knots` is not provided, HiQ generates a knot vector by averaging the elements of the input vector in groups of `order+1`. The first and last knots are equal to the first and last elements of the input vector.

## See Also

`fit`, `interp`, `splineEval`

## splineEval

### Purpose

Evaluates a spline at the given points.

### Usage

```
y = splineEval(x, splineType, coefs, intervals)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The points to evaluate at the spline. |
| `splineType` | HiQ Constant | The type of spline to evaluate.<br>`<cubic>`<br>`<natcubic>`<br>`<b>` |
| `coefs` | Real Matrix | The matrix of coefficients defining the spline components. |
| `intervals` | Real Matrix | The matrix of intervals defining the domain for each spline component. |
| `y` | Real Vector | The value of the spline at the input. |

### Comments

The coefficient matrix stores each polynomial component in a column. For the i-th polynomial component, the k-th degree coefficient is located in row i and column k+1 of the object `coefs`. This means that the degree of the spline is `coef.rows-1` and the number of spline components is `coef.columns`.

For this model to be valid, the object `intervals` must have two rows and `coef.columns` columns. Each interval must be continuous and not overlapping. In other words, the value of `intervals[2,i]`, the end of the `i` interval over which the `i` polynomial is defined, must be identical to the vale of `intervals[1, i+1]`, the start of the `i`+1 interval over which the `i`+1 polynomial is defined.

This function returns `<NaN>` if an input element is outside the intervals defined.

### See Also

`fit`, `fitEval`, `interp`, `interpEval`, `spline`

## sqrt

### Purpose

Computes the square root of a number.

### Usage

```
y = sqrt(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The square root of the input argument. |

### Comments

The real domain of this function is $x \geq 0$. When you want to calculate a complex root, use the complex form of *x*. For example, the square root of –1 is represented by the square root of the complex number (–1, 0).

### See Also

`cbrt`, `pow`

## stdDev

### Purpose

Computes the standard deviation of a data sample.

### Usage

```
y = stdDev(x, xMean)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input data set. |
| *`xMean`* | Real Scalar | The mean of the input data set (Optional.) |
| `y` | Real Scalar | The standard deviation of the input data set. |

### Comments

The standard deviation, $\sigma$, of an $n$-element data set $\mathbf{x}$ is the square root of the variance and is defined as

$$\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{\mathbf{x}})^2}$$

### See Also

`avgDev`, `mean`

## stirling

### Purpose

Computes the Stirling approximation to the gamma function.

### Usage

```
y = stirling(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `y` | Real Scalar | The value of the stirling function. |

### Comments

The Stirling approximation to the `gamma` function is defined as

$$\Gamma(x) \approx e^{-x} x^{x-\frac{1}{2}} (2\pi)^{\frac{1}{2}} \left[1 + \frac{1}{12x} + \frac{1}{288x^2} - \frac{139}{51840x^3} - \frac{571}{2488320x^4} + \dots\right]$$

### See Also

`digamma`, `gamma`

## struve

### Purpose

Computes the struve function.

### Usage

```
y = struve(x, v)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `v` | Real Scalar | The index parameter. |
| `y` | Real Scalar | The value of the struve function. |

### Comments

The Struve function of order ν, $H_\nu(x)$, is a solution of the differential equation

$$x^2\frac{d^2w}{dx^2} + x\frac{dw}{dx} + (x^2 - v^2)w = \frac{4(0.5x)^{v+1}}{\sqrt{\pi}\Gamma(v+1)}$$

### See Also

`weber`

## subrange

### Purpose

Returns a subrange from a vector or matrix.

### Usage

Returns the subrange of a vector given a vector of indices.

```
y = subrange(x, indices)
```

Returns a subrange of a vector given a set of index ranges.

```
y = subrange(x, indexRanges)
```

Returns the subrange of a matrix given vectors of row and column indices.

```
y = subrange(X, rowIndices, colIndices)
```

Returns the input vector with new values in place of the original elements identified by indices.

```
y = subrange(x, indices, values)
```

Returns the input matrix with new values in place of the original elements identified by the row and column indices.

```
y = subrange(X, rowIndices, colIndices, Values)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Vector | The input vector. |
| `indices` | Integer Vector | The vector of indices. |
| `indexRanges` | Integer Matrix | Two-column matrix where each row specifies a range of indices. |
| `X` | Matrix | The input matrix. |
| `rowIndices` | Integer Scalar or Integer Vector | The row index or vector of row indices. |
| `colIndices` | Integer Scalar or Integer Vector | The column index or vector of column indices. |
| `values` | Scalar or Vector | The scalar value to use to fill the range of the input vector or the vector value to use to replace the input vector subrange. |

| Name | Type | Description |
|---|---|---|
| `Values` | Scalar, Vector, or Matrix | The scalar value to use to fill the range of the input matrix or the vector or matrix value to use to replace the input matrix subrange. |
| `y` | Vector | The resulting vector. |
| `Y` | Matrix | The resulting matrix. |

## Comments

The indices must be valid for the input object. When using this function to assign vector or matrix values to a subrange of a vector or matrix, the input vector (`values`) or matrix (`Values`) must be compatibly dimensioned with the given subrange.

The parameter indexRanges is a two-column matrix where each row specifies a starting and ending index for the range of indices to include. For example, the following script generates a vector equivalent to {v:1, 2, 4, 5, 7, 8, 9}.

```
x = seq(10);
indexRanges = {1,2;4,5;7,9};
y = subrange(x, indexRanges);
```

Repeating an index will cause that element or range to be repeated in the output.
This operation can either generate a new object or alter the current object as follows.

```
y = subrange(x, indices);
x = subrange(x, indices);
```

Also, retrieval based on only rows or columns is possible.

```
Xcols = subrange(X, rowIndices, <all>);
Xrows = subrange(X, <all>, colIndices);
```

## See Also

`find`, `remove`, `replace`

## sum

### Purpose

Computes the sum of the elements in a vector or matrix.

### Usage

```
y = sum(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Vector or Matrix | The input argument. |
| `y` | Scalar | The sum of the elements in the input argument. |

### See Also

`prod`

# SV

## Purpose

Computes the singular values of a matrix.

## Usage

```
s = SV(A)
```

## Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real Matrix | The input matrix. |
| `s` | Real Vector | The singular values of the input matrix in descending order. |

## Comments

The singular values of an $m \times n$ matrix **A** are the diagonal elements in the matrix $\mathbf{\Sigma}$ in the factorization

$$\mathbf{A} = \mathbf{U\Sigma V}^{\mathrm{T}}$$

where **U** is an $m \times m$ orthonormal matrix whose columns contain the $m$ left singular vectors, $\mathbf{\Sigma}$ is an $m \times n$ matrix

$$\mathbf{\Sigma} = \begin{bmatrix} \mathbf{S} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix}$$

**S** is a square $k \times k$ matrix ($k = \min(m, n)$) matrix with the $k$ singular values along the main diagonal in descending order,

$$S = \begin{bmatrix} \sigma_1 & 0 & \ldots & 0 \\ 0 & \sigma_2 & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \ldots & \sigma_k \end{bmatrix} \quad \text{if}_1 \geq \ldots \geq \sigma_p > 0 = \sigma_{p+1} = \ldots =$$

and **V** is an $n \times n$ orthonormal matrix whose columns contain the $n$ right singular vectors. The singular values are the positive square roots of the eigenvalues of $\mathbf{A}^{\mathrm{T}}\mathbf{A}$ if $m < n$ or $\mathbf{AA}^{\mathrm{T}}$ if $m > n$, and $p$ is equal to the rank of **A**.

## See Also

`eigen`, `pinv`, `SVD`

## SVD

### Purpose

Computes the singular value decomposition of a matrix.

### Usage

```
[U, S, V] = SVD(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Real Matrix | The input matrix. |
| `U` | Real Matrix | A matrix containing the left singular vectors. |
| `S` | Real Matrix | A matrix whose main diagonal contains the singular values. |
| `V` | Real Matrix | A matrix containing the right singular vectors. |

### Comments

The singular value decomposition of an $m \times n$ matrix **A** is the factorization

$$\mathbf{A} = \mathbf{U}\boldsymbol{\Sigma}\mathbf{V}^{\mathbf{T}}$$

where **U** is an $m \times m$ orthonormal matrix whose columns contain the *m* left singular vectors, $\boldsymbol{\Sigma}$ is an $m \times n$ matrix

$$\boldsymbol{\Sigma} = \begin{bmatrix} \mathbf{S} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix}$$

**S** is a square $k \times k$ matrix ($k = \mathrm{min}(m, n)$) matrix with the $k$ singular values along the main diagonal in descending order,

$$\mathbf{S} = \begin{bmatrix} \sigma_1 & 0 & \ldots & 0 \\ 0 & \sigma_2 & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \ldots & \sigma_k \end{bmatrix} \quad \text{if } \sigma_1 \geq \ldots \geq \sigma_p > 0 = \sigma_{p+1} = \ldots = \sigma_k$$

and **V** is an $n \times n$ orthonormal matrix whose columns contain the $n$ right singular vectors. The singular values are the positive square roots of the eigenvalues of $\mathbf{A}^T\mathbf{A}$ if $m < n$ or $\mathbf{A}\mathbf{A}^T$ if $m > n$, and $p$ is equal to the rank of **A**.

Singular value decomposition is extremely useful in numerical analysis and used by the function `rank` to calculate the rank of a matrix and the function `pinv` to calculate the pseudo inverse of a matrix. Applications of singular value analysis include solving the least squares problem, optimization, data fitting, and linear systems analysis.

## See Also

`hessenbergD`, `pinv`, `QRD`, `schurD`, `solve`, `SVD`

## symD

### Purpose

Computes the symmetric indefinite decomposition (LTL') of a matrix.

### Usage

```
[L, T] = symD(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Matrix | The square, *n*x*n* input matrix. |
| `L` | Matrix | The *n*x*n* lower triangular matrix in the decomposition LTL'. |
| `T` | Matrix | The *n*x*n* tri-diagonal matrix in the decomposition LTL'. |

### Comments

The $\mathrm{LTL}^\mathrm{T}$ decomposition of a square $n \times n$, symmetric, indefinite matrix **A** is the factorization

$$\mathbf{A} = \mathbf{LTL}^\mathrm{T}$$

where **L** is an $n \times n$ lower triangular matrix with ones along the main diagonal, and **T** is an $n \times n$ tri-diagonal symmetric matrix. This function uses row and column pivoting to ensure numerical stability and maintain symmetry. Thus the resulting $\mathrm{LTL}^\mathrm{T}$ decomposition is for the transformed matrix $\mathbf{PAP}^\mathrm{T}$ rather than **A**, where **P** is a permutation matrix. This permutation information is returned as a pivot vector in `pivot`. The following code shows how to generate the matrix $\mathbf{PAP}^\mathrm{T}$:

```
[L, T, pivot] = symD(A);
p = permuPiv(pivot);
PAP = permu(p, A, p);
LTL = L*T*L’;
```

By definition of the $\mathrm{LTL}^\mathrm{T}$ decomposition, the matrices **PAP** and **LTL** are identical.

## Examples

### Solving a symmetric, indefinite linear system.

This example shows how to solve a linear system, taking advantage of the symmetric, indefinite properties of the system matrix.

```
//Solving a symmetric, indefinite linear system.

//Create a 5x5 ding-dong matrix. The ding-dong matrix is
//symmetric and indefinite.
A = createMatrix(5,5,<dingdong>);

//Create the right-hand-side vector b from 1 to 5.
b = seq(5);

//Compute the symmetric decomposition (LTL') of the
//symmetric, indefinite matrix A.
[L,T,piv] = symD(A);

//Solve the system Ax = b using the symmetric, indefinite
//decomposition matrices L and T.
x = solve(L,T,b,piv,<symD>);
```

## See Also

`choleskyD`, `LUD`, `solve`

## tan

### Purpose

Computes the tangent.

### Usage

```
y = tan(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input angle in radians. |
| `y` | Real or Complex Scalar | The tangent of the input. |

### Comments

The tangent is defined for the real domain $(-\infty, \infty)$, $x \neq \pm k\pi - \frac{\pi}{2}$ where $k = 0, 1, 2, 3, \ldots$

### See Also

`arctan`, `cot`, `tanh`

## tanh

### Purpose

Computes the hyperbolic tangent.

### Usage

```
y = tanh(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real or Complex Scalar | The input argument. |
| `y` | Real or Complex Scalar | The hyperbolic tangent of the input. |

### Comments

The hyperbolic tangent is defined for the real domain $(-\infty, \infty)$.

### See Also

`arctanh`, `coth`, `tan`

# time

## Purpose

Returns the current time.

## Usage

`[now, hour, minute, second, millisecond] = time(`*`timeZone`*`)`

## Parameters

| Name | Type | Description |
|---|---|---|
| *`timeZone`* | HiQ Constant | Specifies either local or coordinated universal time. (Optional. Default = `<local>`)<br>`<local>`<br>`<utc>` |
| `now` | Text | The current time. |
| `hour` | Integer Scalar | The current hour. |
| `minute` | Integer Scalar | The current minute. |
| `second` | Integer Scalar | The current second. |
| `millisecond` | Integer Scalar | The current millisecond. |

## Comments

This function creates a text object containing the current hour, minute, and second using a twelve hour clock. For example, the following script returns text similar to `1:30:38 PM`.

```
now = time();
```

## See Also

`date`, `timer`, `wait`

## timer

### Purpose

Returns the time elapsed since the current session of HiQ began.

### Usage

```
elapsed = timer()
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `elapsed` | Real Scalar | The time elapsed since HiQ was launched. |

### Comments

The returned value represents real time, not CPU time. Timer resolution is approximately 0.84 microseconds.

### See Also

`date`, `time`, `wait`

## toComplex

### Purpose

Converts any numeric type to complex.

### Usage

```
z = toComplex(x, y)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, Matrix, or Polynomial | The object to use for the real portion of the result. |
| *`y`* | Scalar, Vector, Matrix, or Polynomial | The object to use for the imaginary portion of the result. (Optional.) |
| `z` | Complex Scalar, Vector, Matrix, or Polynomial | The complex result. |

### Comments

For integer and real inputs, the imaginary portion of the return object is set equal to zero.

### See Also

`fPart`, `iPart`, `toInteger`, `toReal`

## toInteger

### Purpose

Creates an integer numeric object.

### Usage

```
y = toInteger(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, or Matrix | The input argument. |
| `y` | Integer Scalar, Vector, or Matrix | The input cast to an integer object. |

### See Also

`fPart`, `iPart`, `toComplex`, `toReal`

## toMatrix

### Purpose

Converts any numeric object to a matrix object.

### Usage

```
y = toMatrix(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, Matrix, or Polynomial | The object to convert. |
| `y` | Matrix | The matrix result. |

### Comments

If the input is a vector then the matrix result contains the input vector in the first column. If the input is a polynomial, then the matrix result contains the coefficients of the polynomial in the first column.

### See Also

`toComplex`, `toInteger`, `toNumeric`, `toReal`, `toScalar`, `toText`, `toVector`

## toNumeric

### Purpose

Creates a numeric object from a text object.

### Usage

```
y = toNumeric(text, format, m, n)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `text` | Text | The input text object. |
| `format` | Text | The format to use to convert the string. |
| *`m`* | Integer Scalar | The number of rows to create. (Optional. Default = `<toEndOfStream>`) |
| *`n`* | Integer Scalar | The number of columns to create. (Optional.) |
| `y` | Scalar, Vector, or Matrix | The resulting numeric object. |

### Comments

HiQ uses the parameter `format` to convert data from a source object to a target object. For the `toNumeric` function, the source object is a text object and the target object is a numeric object. HiQ provides predefined constants for the most commonly used data format strings. If you do not provide the parameter *`format`*, HiQ imports the data as numeric text and creates a matrix object.

If provided, the parameters `m` and `n` determine the dimension of the resulting vector or matrix object. If you only provide the `m` parameter, HiQ repetitively imports data from the file using the format description `m` times. The resulting object has as many columns as numbers imported on a single pass of the format description. If you provide both parameters, HiQ imports enough data from the file to create an appropriately dimensioned matrix (or vector if column is one). If these parameters are not provided, HiQ imports the entire source file and creates a vector object if the source file is numeric binary data or a matrix object if the source file is numeric text data. Each row in the resulting matrix contains the values on each line of the source file. The matrix row elements are zero-padded to create a square matrix if necessary.

A format string is composed of three strings describing the external data source, the format of the data, and the internal target object. These strings are separated by colons (:) as follows.

```
"[ExternalDescr]:[FormatDescr]:[InternalDescr]"
```

Each string is composed of identifiers preceded by a percent sign (%). These strings and their identifiers are described in detail below for the `import` function.

## External Description

The source description string describes how the data is stored in the file. HiQ supports both big endian and little endian byte ordering. The valid identifiers for the source description string are defined in the following table.

| Source Identifier | Description |
|---|---|
| `%littleendian`<br>`%intel` | Bytes are stored in the file with the least significant byte first. Intel CPU-based computers use little endian byte ordering. (Default.) |
| `%bigendian`<br>`%motorola` | Bytes are stored in the file with the most significant byte first. Motorola CPU-based computers use big endian byte ordering. |
| `%Excel`<br>`%Excel[`*`sheet`*`]` | Source file is an Excel file. In the second form the name of the sheet to be imported is specified. If omitted the first sheet in the file is imported. |
| `%range[`*`A1style`*`]`<br>`%range[`*`HiQStyle`*`]` | For Excel files, indicates the desired cell range. If omitted all cells with data are imported. The range can be the Excel A1 style (for example, `%range[A1:C3]`) or the HiQ-Script subscript range style (for example, `%range[1:3,1:3]`). The HiQ-Script range works exactly as in script except that if the upper range is omitted it is assumed to be `*`. In other words `%range[1,1]` is the same as `%range[1:*,1:*]`. |
| `%comment[`*`comments`*`]` | Specifies which characters in the file indicate comments. Everything from the comment to the end of the line is ignored on import. For example, `%comment[rem]` causes everything to the right of `rem` to be ignored. |

## Format Description

The format description string describes how HiQ interprets the numeric data in the file. For example, you can specify the numeric data as text or binary, the data as integer, real, or complex, or the width and precision of a text numeric field. The valid identifiers for the format description string are defined in the following table.

| Format Identifier | Description |
|---|---|
| `%delimiters[`*`list`*`]` | Delimiter identifier specifying the characters that separate numeric values. (Optional.) |
| `%`*`count type`*`[`*`modifiers`*`]` | Numeric identifier describing the repeat count and format type for integer and real numeric values. (Optional.) |
| `%`*`count cType`*`[`*`type`*`[`*`modifiers`*`]]` | Numeric identifier describing the repeat count and format type for complex numeric values. (Optional.) |

A format description string can have multiple numeric format identifiers but only one delimiter format identifier. The components of a format identifier string are defined in the following table.

| Parameter | Description |
|---|---|
| *`list`* | A string of characters that delimit the numeric values in a file. If *`list`* is empty, HiQ interprets any non-numeric character as a delimiter. For special characters use the following.<br><br>`\t` (tab)<br>`\]` (right square bracket)<br>`\[` (left square bracket)<br>`\\` (backslash) |
| *`count`* | Indicates the number of times to apply the format identifier. A value of zero repeats the format identifier until HiQ reaches an end-of-line character. A zero value is invalid with binary forms. (Optional. Default = `1`.) |

| Parameter | Description |
|---|---|
| *type* | Indicates whether the data is text numeric or binary numeric and integer or real. (Optional)<br>`fb` Binary Real.<br>`ib` Binary Integer.<br>`ub` Binary Unsigned integer. |
| *modifiers* | Indicates the numeric field width, number of digits to the right of the decimal point, and whether to discard the data. (Optional)<br>`w`*n* For text source: Specifies the width of the hexadecimal integer field in number of characters. (Optional.) On import this must be specified for every format if a fixed width import is used.<br>For binary source: Specifies the width of the number in number of bits (not bytes). (Optional.)<br>`d` Tells HiQ to discard the number in this position after importing. Note: If you are using this to read a rectangular block of data it would be easier to use the %range source descriptor in some cases. If you use this in combination with the %range descriptor the %range filtering takes place after the discard and the discarded data is not counted when applying the %range filter. |

Examples of valid format description strings include the following.

```
%delimiters[,]
%5fb[w8]
%co[fb[w16]]
%2cd[fb[w16]ib[w8]]
```

## Internal Description

The internal target description string describes the HiQ object to create with the data. The valid identifiers for the target description string are defined in the following table.

| Target Identifier | Description |
|---|---|
| `%scalar` | Create a scalar object. (Default.) If more than one value is found, the data is automatically promoted to matrix. |
| `%vector` | Create a vector object. |
| `%matrix` | Create a matrix object. |
| `%poly`<br>`%polynomial` | Create a polynomial object. |
| `%text` | Create a text object. |
| `%script` | Create a script object. |
| `%transpose` | Transpose the data while writing to the target. Reverses the meaning of row and column counts. |

HiQ imports data according to the format description string. If imported numeric data results in more than one number, HiQ promotes the target object to a matrix regardless of the value of the target identifier.

## See Also

`getNumber`, `toText`

## toReal

### Purpose

Converts any numeric type to real.

### Usage

```
y = toReal(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, Matrix, or Polynomial | The object to convert. |
| `y` | Real Scalar, Vector, Matrix, or Polynomial | The real result. |

### Comments

For complex inputs, the imaginary portion is disregarded.

### See Also

`fPart`, `iPart`, `toComplex`, `toInteger`, `toMatrix`, `toNumeric`, `toScalar`, `toText`, `toVector`

## toScalar

### Purpose

Converts any numeric object to a scalar object.

### Usage

```
y = toScalar(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, Matrix, or Polynomial | The object to convert. |
| `y` | Scalar | The scalar result. |

### Comments

If the input is a vector, matrix, or polynomial, then the scalar result is the first element in the vector, matrix, or polynomial object.

### See Also

`toComplex`, `toInteger`, `toNumeric`, `toReal`, `toText`

## toText

### Purpose

Creates a text object from a numeric object.

### Usage

```
text = toText(x, format)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, or Matrix | The input values. |
| *`format`* | Text | The format used to create the text object. (Optional.) |
| `text` | Text | The output text object. |

### Comments

HiQ uses the parameter `format` to convert data from a source object to a target object. For the `toText` function, the source object is a numeric object and the target object is a text object. HiQ provides predefined constants for the most commonly used data format strings. If you do not provide the parameter `format`, HiQ converts the data as numeric text.

A format string is composed of three strings describing the external (target) data, the format of the data, and the internal (source) object. These strings are separated by colons (:) as follows.

```
"[ExternalDescr]:[FormatDescr]:[InternalDescr]"
```

Each string is composed of identifiers preceded by a percent sign (%). These strings and their identifiers are described in detail below for the `export` function.

#### External Description

The source description string describes how the data is stored in the file. HiQ supports both big endian and little endian byte ordering. The valid identifiers for the source description string are defined in the following table.

| Source Identifier | Description |
|---|---|
| `%littleendian`<br>`%intel` | Bytes are stored in the file with the least significant byte first. Intel CPU-based computers use little endian byte ordering. (Default.) |
| `%bigendian`<br>`%motorola` | Bytes are stored in the file with the most significant byte first. Motorola CPU-based computers use big endian byte ordering. |
| `%Excel`<br>`%Excel[`*`sheet`*`]` | Source file is an Excel file. In the second form the name of the sheet to be imported is specified. If omitted the first sheet in the file is imported. |
| `%range[`*`A1style`*`]`<br>`%range[`*`HiQStyle`*`]` | For Excel files, indicates the desired cell range. If omitted all cells with data are imported. The range can be the Excel A1 style (for example, `%range[A1:C3]`) or the HiQ-Script subscript range style (for example, `%range[1:3,1:3]`). The HiQ-Script range works exactly as in script except that if the upper range is omitted it is assumed to be `*`. In other words `%range[1,1]` is the same as `%range[1:*,1:*]`. |

## Format Description

The format description string describes how HiQ writes the numeric data to the file. For example, you can specify the numeric data as text or binary, the data as integer, real, or complex, or the width and precision of a text numeric field. The valid identifiers for the format description string are defined in the following table.

| Format Identifier | Description |
|---|---|
| `%delimiters[`*`list`*`]` | Delimiter identifier specifying the characters that separate numeric values. (Optional.) |
| `%`*`count type`*`[`*`modifiers`*`]` | Numeric identifier describing the repeat count and format type for integer and real numeric values. (Optional.) |
| `%`*`count cType`*`[`*`type`*`[`*`modifiers`*`]]` | Numeric identifier describing the repeat count and format type for complex numeric values. (Optional.) |

A format description string can have multiple numeric format identifiers but only one delimiter format identifier. The components of a format identifier string are defined in the following table.

| Parameter | Description |
|---|---|
| *`list`* | A string of characters that delimit the numeric values in a file. If *`list`* is empty, HiQ uses the tab character. For special characters use the following.<br>`\t` (tab)<br>`\]` (right square bracket)<br>`\[` (left square bracket)<br>`\\` (backslash) |
| *`count`* | Indicates the number of times to apply the format identifier. A value of zero repeats the format identifier for the entire row of a matrix. A zero value is invalid with binary forms. (Optional. Default = `1`.) |
| *`type`* | Indicates whether the data is text numeric or binary numeric and integer or real. (Optional. Default = `g`)<br>`f` Text Decimal real. For example, `123.456`.<br>`e` Text Scientific real. For example, `1.23456e02`.<br>`g` Text General real. For example, `1.23456e02`.<br>`ee` Text Engineering real. For example, `0.123456e03`.<br>`ge` Text General engineering real. For example, `0.123456e03`.<br>`i` Text Decimal integer. For example, `123`.<br>`d` Text Decimal integer. For example, `123`.<br>`x` Text Hexadecimal integer. For example, `D4A2`.<br>`pr` Text Polynomial with ascending coefficients.<br>`pf` Text Polynomial with descending coefficients.<br>`pv`*`x`* Text Polynomial with *x* as the dependent variable.<br>`fb` Binary Real.<br>`ib` Binary Integer.<br>`ub` Binary Unsigned integer. |

| Parameter | Description |
|---|---|
| *modifiers* | Indicates the numeric field width, number of digits to the right of the decimal point, and whether to discard the data. (Optional) |
|  | `w`*n* For text destination: Specifies the width of the numeric field in number of characters. For binary destination: Specifies the width of the number in number of bits. |
|  | `p`*n* Specifies the number of digits of precision to the right of the decimal point. (Default = `p6`.) |
|  | `p*` Tells HiQ to automatically determine the precision. |
|  | `e`*n* Specifies the number of digits in the exponent. Valid values of *n* are 1, 2 and 3. (Optional.) |
|  | `d` Writes a 0 formatted to the specified options for text formats. For binary formats if the write would extend the length of the file then a 0 is written according to the specified options. In binary mode if you are writing over an already written portion of the file it will simply seek past the position leaving it untouched. This allows you to do binary writes that interleave data. |
|  | `jr` Specifies to right justify the formatted number within the specified width. (Default.) |
|  | `jl` Specifies to left justify the formatted number within the specified width. |
|  | `wc` Turns width control on. This automatically adjusts the precision to fit within the width specified by `w`*n*. If the formatted number does not fit, then the width is increased appropriately. |
|  | `wc-` Turns width control off. (Default.) |
|  | `wc#` For width control, this fills the entire width with # signs if the formatted number does not fit. |
|  | `wc...` For width control, replaces each of the last three characters with a dot if the formatted number does not fit. |
|  | `wce` For width control, replaces the last character with the ellipses character if the formatted number does not fit. |

| Parameter | Description |
|---|---|
| | `zp` Zero pad the width of this format.<br>`zp+` Zero pad the width of this format.<br>`zp-` Do not zero pad the width of this format. (Default.)<br>`tz` Removes trailing zeros. (Default.)<br>`tz+` Removes trailing zeros.<br>`tz-` Do not remove trailing zeros.<br>`~` If the formatted string results in 0 and the original number is not identically 0, then output ~0.<br>`~-` Do not format 0 strings with ~0. (Default.) |
| *`cType`* | Indicates the data is a complex number and specifies the complex format. The optional modifier for *`cType`*, *`type`*[*`modifiers`*], describes the format of each of the two components of the complex number. If you provide only one modifier *`type`*[*`modifiers`*], that modifier is used for both components. The valid values for *`cType`* are defined in the following table.<br>`co` Ordered pair `(`*`real`*, *`imaginary`*`)`. (Default.)<br>`ci` Sum, i format *`real`* + *`imaginary`* `i`.<br>`cj` Sum, j format *`real`* + *`imaginary`* `j`.<br>`cd` Polar, degrees, *`magnitude`* @ *`degrees`* `°`.<br>`cr` Polar, radians, *`magnitude`* @ *`radians`* `r`.<br>`cg` Polar, grads, *`magnitude`* @ *`grads`* `g`.<br>Each complex type can modified by inserting the characters inside the outer modifier brackets.<br>`s` Turns space control on. This will strip extra spaces in the formatting of the complex number.<br>`s-` Turns space control off. (Default.)<br>`jr` Specifies to right justify the formatted number within the specified width. (Default for real part.)<br>`jl` Specifies to left justify the formatted number within the specified width. (Default for imaginary part.) |

Examples of valid format description strings include the following.

```
%delimiters[,]%5f%5i
%5f[w8p3]
%co[f[w6p2]]
%2cd[f[w6p2]i[w2]]
```

### Internal Description

The internal description string describes the HiQ object to export. The valid identifiers for the internal description string are defined in the following table.

| **Target Identifier** | **Description** |
|---|---|
| `%transpose` | Transposes the data while writing to the target. Reverses the meaning of row and column counts. |

## See Also

`getText`, `toNumeric`

## toVector

### Purpose

Converts any numeric object to a vector object.

### Usage

```
y = toVector(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Scalar, Vector, Matrix, or Polynomial | The object to convert. |
| `y` | Vector | The vector result. |

### Comments

If the input is a matrix, the vector result is the rows of the matrix appended together. If the input is a polynomial, the vector result is the coefficients of the polynomial.

### See Also

`toComplex`, `toInteger`, `toNumeric`, `toReal`, `toScalar`, `toText`

## trace

### Purpose

Computes the trace of a matrix.

### Usage

```
y = trace(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Matrix | A square *n*x*n* input matrix. |
| `y` | Scalar | The trace of the input matrix. |

### Comments

The trace of a square $n \times n$ matrix **A** is defined as the sum of the elements along the main diagonal:

$$\text{trace}(\mathbf{A}) = \sum_{i=1}^{n} \mathbf{A}_{ii}$$

### See Also

`det`, `rank`

## trans

### Purpose

Computes the transpose of a matrix.

### Usage

```
y = trans(A)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `A` | Vector or Matrix | The input vector or matrix. |
| `y` | Matrix | The transpose of the input (1x*m* matrix for vector input, *n*x*m* matrix for matrix input.) |

### Comments

For real matrices, this function is equivalent to the notation `A'`. For complex matrices, this function is equivalent to `conj(A')`.

For linear algebra operations, HiQ treats vectors as single-column matrices.

### See Also

`conj`

## tricomi

### Purpose

Computes the Tricomi function (associated confluent hypergeometric function).

### Usage

```
y = tricomi(x, a, b)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `a` | Real Scalar | The first parameter of the Tricomi function. |
| `b` | Real Scalar | The second parameter of the Tricomi function. |
| `y` | Real Scalar | The value of the Tricomi function. |

### Comments

The Tricomi function (associated confluent hypergeometric function), U(x,a,b), is a solution of the differential equation

$$x\frac{d^2w}{dx^2} + (b - x)\frac{dw}{dx} - aw = 0$$

### See Also

`gauss`, `kummer`

## updateViews

### Purpose

Updates the Notebook views of all objects or the Notebook views of a specified object.

### Usage

`updateViews(`*`object`*`)`

### Parameters

| Name | Type | Description |
|---|---|---|
| *`object`* | Object | The object to update. (Optional.) |

### Comments

Only the views of the currently active notebook are updated. If you call `updateViews` without an input, HiQ updates all views on the notebook. To update a view whenever the underlying object changes, enable the Immediate Update property of the view in the Object property page of the view.

## vanish

### Purpose

Sets vector or matrix elements with values below a threshold value to zero.

### Usage

```
Y = vanish(X, tolr)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `X` | Vector or Matrix | The input data. |
| *`tolr`* | Real Scalar | The tolerance to use to determine zero values. (Optional.) |
| `Y` | Vector or Matrix | The output data. |

### Comments

Because floating point arithmetic is not exact due to round-off errors, numeric object elements can take on very small non-zero values. This function sets an element value to zero if the initial value was less than a specified tolerance:

$$x = \begin{cases} x & \text{if } |x| > tol \\ 0 & \text{if } |x| \le tol \end{cases}$$

To limit round-off errors, choose a tolerance equal to a multiple of the precision of your computer.

### See Also

`cond`, `isMatrix`, `sparsity`

## var

### Purpose

Computes the variance of a data sample.

### Usage

```
y = var(x, xMean)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Vector | The input data set. |
| *`xMean`* | Real Scalar | The mean of the input data set. (Optional.) |
| `y` | Real Scalar | The variance of the input data set. |

### Comments

The variance of an *n*-element data set **x** is defined by as

$$\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{\mathbf{x}})^2$$

### See Also

`cor`, `cov`, `mean`

## wait

### Purpose

Pauses script execution for a specified number of seconds.

### Usage

```
wait(sec)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `sec` | Real Scalar | The number of seconds to wait. |

### Comments

The input time represents real time, not CPU time. Only the script containing the `wait` function pauses execution. All other scripts continue running.

### See Also

`date`, `time`, `timer`

## warning

### Purpose

Displays a warning dialog box.

### Usage

```
action = warning(text)
```

### Parameters

| **Name** | **Type** | **Description** |
|---|---|---|
| `text` | Text | Warning message to display. |
| `action` | Integer Scalar | `0` if the **OK** button is selected. `1` if the **Cancel** button is selected. |

### Comments

The `warning` function displays a warning dialog box containing the input text. The script continues execution if the user clicks on the **OK** button but terminates if the user clicks on the **Cancel** button.

### See Also

`error`, `message`

## weber

### Purpose

Computes the Weber function (D-parabolic cylinder function).

### Usage

```
y = weber(x, r)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `x` | Real Scalar | The input argument. |
| `r` | Real Scalar | The order of the Weber function. |
| `y` | Real Scalar | The value of the Weber function. |

### Comments

The Weber function (D-parabolic cylinder function), $D_v(x)$, is a solution of the differential equation

$$\frac{d^2w}{dx^2} - \left(\frac{x^2}{4} - v - \frac{1}{2}\right)w = 0$$

### See Also

`struve`

## write

### Purpose

Writes bytes to an open file.

### Usage

```
nBytes = write(fid, text)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | A valid file handle returned from open. |
| `text` | Text | The string of data to write. |
| `nBytes` | Integer Scalar | The number of bytes written to the file. |

### Comments

To write numeric data to a file, use the function `toText` to convert the numeric object to a text object first.

### See Also

`open`, `read`, `writeLine`

## writeLine

### Purpose

Writes lines to an open file.

### Usage

```
writeLine(fid, text)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| `fid` | Integer Scalar | A valid file handle returned from open. |
| `text` | Text | The lines of data to write. |

### Comments

The carriage return and line feed characters are automatically appended to the string written to file. To write numeric data to a file, use the function `toText` to convert the numeric object to a text object first.

### See Also

`open`, `readLine`, `write`

## zeta

### Purpose

Computes the zeta function.

### Usage

```
y = zeta(x)
```

### Parameters

| Name | Type | Description |
|---|---|---|
| x | Real Scalar | The input argument. |
| y | Real Scalar | The value of the zeta function. |

### Comments

The Riemann zeta function, $\zeta(x)$, is defined as

$$\sum_{i=1}^{\infty} i^{-x}$$

### See Also

beta, gamma

# A

# HiQ Functions Listed by Category

This appendix lists all HiQ built-in functions by category: Analysis, File I/O, Graphics, and Utilities. The analysis functions are divided into subcategories: approximation, basic math, derivatives, differential equations, integral equations, integration, linear algebra, nonlinear systems, optimization, polynomials, special functions, statistics, structures, trigonometric, and utility functions.

## Analysis

**Table A-1.** Analysis Functions

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Approximation** | `fit` | Computes the parameters of a function that best fit a data set. |
| | `fitEval` | Evaluates a fit at the given points. |
| | `interp` | Computes the interpolation of a data set. |
| | `interpEval` | Evaluates an interpolation at the given points. |
| | `spline` | Computes the spline interpolation of a data set. |
| | `splineEval` | Evaluates a spline at the given points. |
| **Basic Math** | `abs` | Computes the absolute value or complex magnitude of a number. |
| | `arg` | Computes the argument (principle value or phase angle) of a complex number. |
| | `cbrt` | Computes the cube root of a number. |
| | `ceil` | Rounds a number towards positive infinity. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Basic Math** (*continued*) | `conj` | Computes the complex conjugate of a number. |
| | `floor` | Rounds a number toward negative infinity. |
| | `gcd` | Computes the greatest common divisor of two numbers or polynomials. |
| | `lcm` | Computes the least common multiple of a set of integers. |
| | `pow` | Computes a scalar, matrix, or polynomial raised to a power. |
| | `prod` | Computes the product of the elements in a vector or matrix. |
| | `round` | Rounds a number to the nearest whole number. |
| | `sign` | Computes the sign of a number. |
| | `sqrt` | Computes the square root of a number. |
| | `sum` | Computes the sum of the elements in a vector or matrix. |
| **Derivatives** | `curl` | Computes the curl of a three-dimensional vector. |
| | `derivative` | Computes the derivative of a function or polynomial. |
| | `div` | Computes the divergence of a three-dimensional vector field. |
| | `gradient` | Computes the gradient of a function. |
| | `hessian` | Computes the Hessian of a function. |
| | `jacobian` | Computes the Jacobian of a function. |
| | `laplacian` | Computes the Laplacian of a function. |
| | `partial` | Computes the partial derivative of a function. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Differential Equations** | `ODEBVP` | Solves a set of ordinary differential equations given boundary conditions. |
| | `ODEIVP` | Solves a set of ordinary differential equations given initial conditions. |
| **Integral Functions** | `integEqn` | Solves a system of integral equations. |
| **Integration** | `integrate` | Computes the integral of a function, polynomial, or data set. |
| **Linear Algebra** | `bandwidth` | Computes the lower and upper bandwidths of a matrix. |
| | `basis` | Creates the Kronecker or Heaviside basis vector. |
| | `choleskyD` | Computes the Cholesky decomposition of a symmetric, positive definite matrix. |
| | `compose` | Computes the composition of two polynomials or permutations. |
| | `cond` | Computes the condition number of a matrix. |
| | `convert` | Converts a numeric object to another object type or converts the structure of a matrix object. |
| | `cross` | Computes the cross product of two three-element vectors. |
| | `det` | Computes the determinant of a matrix. |
| | `diag` | Creates a diagonal matrix or extracts diagonal elements from a matrix. |
| | `dim` | Returns the dimensions of a vector or matrix. |
| | `dist` | Computes the distance between two vectors or matrices. |
| | `dot` | Computes the dot product of two vectors. |
| | `eigen` | Computes the eigenvalues and eigenvectors of a matrix. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Linear Algebra** (*continued*) | `eigenDom` | Computes the dominant eigenvalue and eigenvector of a matrix. |
| | `eigenSel` | Computes the eigenvalue closest to a specified value and its corresponding eigenvector. |
| | `fill` | Creates a vector or matrix initialized with a value. |
| | `givens` | Computes the Givens rotation parameters of a two-element vector. |
| | `hessenbergD` | Computes the Hessenberg decomposition of a matrix. |
| | `householder` | Computes the Householder reflection of a vector. |
| | `inv` | Computes the inverse of a matrix, polynomial, or permutation. |
| | `LUD` | Computes the LU decomposition of a matrix. |
| | `norm` | Computes the norm of a vector or matrix. |
| | `ones` | Creates a vector or matrix with all elements set to one. |
| | `permu` | Permutes a vector or matrix from the left (row permutation) and/or right (column permutation). |
| | `pinv` | Computes the pseudo-inverse of a matrix. |
| | `QRD` | Computes the QR decomposition of a matrix. |
| | `rank` | Computes the rank of a matrix. |
| | `reflect` | Computes the Householder reflection of a vector or matrix. |
| | `rotate` | Computes the rotation of a vector or matrix through an angle. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Linear Algebra** (*continued*) | `schurD` | Computes the Schur decomposition of a matrix. |
| | `seq` | Creates a sequence of scalars or vectors. |
| | `solve` | Solves a linear or nonlinear system of equations. |
| | `sparsity` | Computes the percentage of zero valued elements in a vector or matrix. |
| | `SV` | Computes the singular values of a matrix. |
| | `SVD` | Computes the singular value decomposition of a matrix. |
| | `symD` | Computes the symmetric indefinite decomposition (LTL') of a matrix. |
| | `trace` | Computes the trace of a matrix. |
| | `trans` | Computes the transpose of a matrix. |
| | `vanish` | Sets vector or matrix elements with values below a threshold value to zero. |
| **Nonlinear Systems** | `root` | Computes a single root of a function or polynomial. |
| | `roots` | Computes the roots of a function or polynomial. |
| | `solve` | Solves a linear or nonlinear system of equations. |
| **Optimization** | `optimize` | Finds the minimum value of a linear or nonlinear equation. |
| **Polynomials** | `compose` | Computes the composition of two polynomials or permutations. |
| | `createPoly` | Creates a polynomial. |
| | `degree` | Computes the effective degree of a polynomial |
| | `divide` | Computes the ratio of two polynomials. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Polynomials** (*continued*) | `eval` | Evaluates a polynomial or single-valued function at the given input value. |
| | `evalPoly` | Evaluates a polynomial. |
| | `inv` | Computes the inverse of a matrix, polynomial, or permutation. |
| **Special Functions** | `airy` | Computes the Airy functions Ai and Bi. |
| | `besselI` | Computes the modified Bessel function of the first kind. |
| | `besselJ` | Computes the Bessel function of the first kind. |
| | `besselJs` | Computes the spherical Bessel function of the first kind. |
| | `besselK` | Computes the modified Bessel function of the second kind. |
| | `besselY` | Computes the Bessel function of the second kind. |
| | `besselYs` | Computes the spherical Bessel function of the second kind. |
| | `beta` | Computes the beta function. |
| | `coshI` | Computes the hyperbolic cosine integral function. |
| | `cosI` | Computes the cosine integral function. |
| | `dawson` | Computes the Dawson integral. |
| | `digamma` | Computes the digamma (psi) function. |
| | `diln` | Computes the dilogarithm function (Spence's Integral). |
| | `elliptic1` | Computes the elliptic integral of the first kind. |
| | `elliptic2` | Computes the elliptic integral of the second kind. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Special Functions** (*continued*) | `ellipticJ` | Computes the Jacobi elliptic functions. |
| | `exp` | Computes the exponential function. |
| | `expI` | Computes the exponential integral function. |
| | `fact` | Computes the factorial of a number. |
| | `fCosI` | Computes the Fresnel cosine integral function. |
| | `fSinI` | Computes the Fresnel sine integral function. |
| | `gamma` | Computes the gamma function. |
| | `gammaC` | Computes the complementary incomplete gamma function. |
| | `gauss` | Computes the Gauss hypergeometric function. |
| | `guder` | Computes the gudermannian function. |
| | `guderInv` | Computes the inverse of the gudermannian function. |
| | `kelvinI` | Computes the complex Kelvin function of the first kind. |
| | `kelvinK` | Computes the complex Kelvin function of the second kind. |
| | `kummer` | Computes the Kummer function (confluent hypergeometric function). |
| | `ln` | Computes the natural logarithm of a number (logarithm to the base e). |
| | `log` | Computes the logarithm of a number to a given base. |
| | `sinhI` | Computes the hyperbolic sine integral function. |
| | `sinI` | Computes the sine integral function. |
| | `stirling` | Computes the Stirling approximation to the gamma function. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Special Functions** (*continued*) | `struve` | Computes the struve function. |
| | `tricomi` | Computes the Tricomi function (associated confluent hypergeometric function). |
| | `weber` | Computes the Weber function (D-parabolic cylinder function). |
| | `zeta` | Computes the zeta function. |
| **Statistics** | `avgDev` | Computes the average deviation of a data sample. |
| | `CDF` | Computes the cumulative distribution function. |
| | `cor` | Computes the correlation of two data samples. |
| | `cov` | Computes the covariance of two data samples. |
| | `erf` | Computes the error function. |
| | `erfc` | Computes the complementary error function. |
| | `histogram` | Computes the histogram of a data set. |
| | `kurtosis` | Computes the kurtosis of a data sample. |
| | `mean` | Computes the arithmetic mean (average) of a data sample. |
| | `median` | Computes the median of a data sample. |
| | `moment` | Computes the first moment of a data set. |
| | `PDF` | Computes the probability density function. |
| | `quartile` | Computes the value at the upper end of a quartile of a data set. |
| | `random` | Generates a random number. |
| | `range` | Computes the range of a data set. |
| | `seed` | Seeds the random number generator. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Statistics** (*continued*) | `skew` | Computes the skew of a data sample. |
| | `stdDev` | Computes the standard deviation of a data sample. |
| | `var` | Computes the variance of a data sample. |
| **Structures** | `createMatrix` | Creates a variety of special matrices. |
| | `createVector` | Creates a variety of special vectors. |
| | `fill` | Creates a vector or matrix initialized with a value. |
| | `ident` | Creates an identity matrix. |
| | `ones` | Creates a vector or matrix with all elements set to one. |
| | `seq` | Creates a sequence of scalars or vectors. |
| **Trigonometric** | `arccos` | Computes the inverse cosine. |
| | `arccosh` | Computes the inverse hyperbolic cosine. |
| | `arccot` | Computes the inverse cotangent. |
| | `arccoth` | Computes the inverse hyperbolic cotangent. |
| | `arccsc` | Computes the inverse cosecant. |
| | `arccsch` | Computes the inverse hyperbolic cosecant. |
| | `arcsec` | Computes the inverse secant. |
| | `arcsech` | Computes the inverse hyperbolic secant. |
| | `arcsin` | Computes the inverse sine. |
| | `arcsinh` | Computes the inverse hyperbolic sine. |
| | `arctan` | Computes the inverse tangent. |
| | `arctanh` | Computes the inverse hyperbolic tangent. |
| | `cos` | Computes the cosine. |
| | `cosh` | Computes the hyperbolic cosine. |
| | `cot` | Computes the cotangent. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Trigonometric** (*continued*) | `coth` | Computes the hyperbolic cotangent. |
| | `csc` | Computes the cosecant. |
| | `csch` | Computes the hyperbolic cosecant. |
| | `sec` | Computes the secant. |
| | `sech` | Computes the hyperbolic secant. |
| | `sin` | Computes the sine. |
| | `sinh` | Computes the hyperbolic sine. |
| | `tan` | Computes the tangent. |
| | `tanh` | Computes the hyperbolic tangent. |
| **Utility** | `compose` | Computes the composition of two polynomials or permutations. |
| | `find` | Finds the occurrences of an element in a vector or matrix. |
| | `fPart` | Computes the fractional part of a number. |
| | `iPart` | Computes the integer part (whole part) of a number. |
| | `isMatrix` | Queries the attributes of a matrix object. |
| | `max` | Computes the maximum value of a data set. |
| | `min` | Computes the minimum value of a data set. |
| | `random` | Generates a random number. |
| | `remove` | Removes elements of a vector or matrix. |
| | `replace` | Replaces the elements of a vector or matrix. |
| | `seed` | Seeds the random number generator. |
| | `sort` | Sorts a data set. |
| | `subrange` | Returns a subrange from a vector or matrix. |
| | `toComplex` | Converts any numeric type to complex. |
| | `toInteger` | Creates an integer numeric object. |

**Table A-1.** Analysis Functions (Continued)

| Analysis Category | Function Name | Purpose |
|---|---|---|
| **Utility** (*continued*) | `toMatrix` | Converts any numeric object to a matrix object. |
| | `toNumeric` | Creates a numeric object from a text object. |
| | `toReal` | Converts any numeric type to real. |
| | `toScalar` | Converts any numeric object to a scalar object. |
| | `toText` | Creates a text object from a numeric object. |
| | `toVector` | Converts any numeric object to a vector object. |

## File I/O

**Table A-2.** File I/O Functions

| Function Name | Purpose |
|---|---|
| `close` | Closes an open file. |
| `export` | Exports data to a file. |
| `flush` | Flushes the contents of the file buffer to disk. |
| `getFilePos` | Returns the current position of the file pointer. |
| `getFileSize` | Returns the size of a file. |
| `import` | Imports data from a file. |
| `isEOF` | Checks whether the file pointer is at the end of a file. |
| `open` | Opens a file. |
| `read` | Reads bytes from an open file. |
| `readLine` | Reads lines from an open file. |
| `renameFile` | Renames a file. |
| `setFilePos` | Sets the position of a file pointer. |

**Table A-2.** File I/O Functions (Continued)

| Function Name | Purpose |
|---|---|
| `write` | Writes bytes to an open file. |
| `writeLine` | Writes lines to an open file. |

## Graphics

**Table A-3.** Graphics Functions

| Function Name | Purpose |
|---|---|
| `addPlot` | Adds a plot to a graph. |
| `changePlotData` | Changes the data associated with a plot object without changing the attributes of the plot object. |
| `createGraph` | Creates a new 2D or 3D graph. |
| `createPlot` | Creates a new 2D or 3D plot object. |
| `removePlot` | Removes a plot from a graph. |

## Utility

**Table A-4.** Utility Functions

| Function Name | Purpose |
|---|---|
| `clearLog` | Clears the Log Window. |
| `createInterface` | Creates an ActiveX object. |
| `createView` | Creates a view of an object in a separate window. |
| `date` | Returns the current date. |
| `deleteFile` | Deletes a file from hard disk. |
| `error` | Displays an error dialog box and terminates a HiQ-Script. |

**Table A-4.** Utility Functions (Continued)

| Function Name | Purpose |
|---|---|
| `getFileName` | Displays the file dialog box prompting for an existing filename. |
| `getNumber` | Displays a dialog box prompting for a numeric object. |
| `getText` | Displays a dialog box prompting for a text object. |
| `logMessage` | Displays a message in the Log Window. |
| `message` | Displays a message dialog box. |
| `putFileName` | Displays the file dialog box prompting for a new or existing filename. |
| `saveLog` | Saves the contents of the Log Window to a file. |
| `time` | Returns the current time. |
| `timer` | Returns the time elapsed since the current session of HiQ began. |
| `updateViews` | Updates the Notebook views of all objects or the Notebook views of a specified object. |
| `wait` | Pauses script execution for a specified number of seconds. |
| `warning` | Displays a warning dialog box. |

# B

# HiQ Constants

This appendix lists and describes the HiQ property constants, HiQ-Script language constants, and built-in function constants.

## Property Constants

**Table B-1.** Object Type Constants

| Constant | Description |
|---|---|
| `<ActiveXControl>` | ActiveX control |
| `<ActiveXInterface>` | Dispatch interface to an ActiveX automation server |
| `<ActiveXObject>` | ActiveX object |
| `<BIF>` | Built-in function |
| `<color>` | HiQ color |
| `<complex>` | Complex scalar |
| `<complexMatrix>` | Complex matrix |
| `<complexPoly>` | Complex polynomial |
| `<complexVector>` | Complex vector |
| `<constant>` | HiQ constant |
| `<font>` | HiQ font |
| `<graph2D>` | 2D Graph |
| `<graph3D>` | 3D Graph |
| `<integer>` | Integer scalar |
| `<integerMatrix>` | Integer matrix |
| `<integerVector>` | Integer vector |

**Table B-1.** Object Type Constants (Continued)

| Constant | Description |
|---|---|
| `<matrix>` | Any matrix |
| `<plot2D>` | 2D Plot |
| `<plot3D>` | 3D Plot |
| `<real>` | Real scalar |
| `<realMatrix>` | Real matrix |
| `<realPoly>` | Real polynomial |
| `<realVector>` | Real vector |
| `<scalar>` | Any scalar |
| `<script>` | Script |
| `<text>` | Text |
| `<untyped>` | Not yet typed |
| `<userFct>` | User function |
| `<vector>` | Any vector |

**Table B-2.** Border Style Constants

| Constant | Description |
|---|---|
| `<determinant>` | Determinant |
| `<embossed>` | Embossed |
| `<grooved>` | Grooved |
| `<line>` | Simple line |
| `<none>` | No border |
| `<raised>` | 3D raised |
| `<recessed>` | 3D recessed |
| `<thickline>` | Simple thick line |

**Table B-3.** Plot Style Constants

| Constant | Description |
|---|---|
| `<contour>` | Contour lines (3D only) |
| `<hiddenLine>` | Hidden line surface (3D only) |
| `<horizontalBar>` | Horizontal bar drawn from zero (2D only) |
| `<line>` | Line without any point markers |
| `<linePoint>` | Line with point markers |
| `<point>` | Points without a line connecting them |
| `<surface>` | Surface (3D only) |
| `<surfaceContour>` | Surface with contour lines (3D only) |
| `<surfaceLine>` | Surface with element edges shown (3D only) |
| `<surfaceNormal>` | Surface with a normal line shown (3D only) |
| `<verticalBar>` | Vertical bar drawn from zero (2D only) |

**Table B-4.** Fill Style Constants

| Constant | Description |
|---|---|
| `<flat>` | Surface polygons filled using flat shading |
| `<smooth>` | Surface polygons filled using Gouraud shading |

**Table B-5.** Line Style Constants

| Constant | Description |
|---|---|
| `<dashLine>` | Segmented line with longer segments |
| `<dotDashLine>` | Segmented line with alternating short and long segments |
| `<dotLine>` | Segmented line with very short segments |
| `<solidLine>` | Solid line |

**Table B-6.** Point Style Constants

| Constant | Description |
|---|---|
| `<asterisk>` | Asterisk (*) |
| `<boldX>` | Bold x |
| `<diamond>` | Diamond |
| `<emptyCircle>` | Empty circle |
| `<emptySquare>` | Empty square |
| `<solidCircle>` | Filled circle |
| `<solidCube>` | Solid cube |
| `<solidSphere>` | Solid sphere |
| `<solidSquare>` | Filled square |
| `<wireframeCube>` | Wireframe cube |
| `<wireframeSphere>` | Wireframe sphere |

**Table B-7.** Coordinate System Constants

| Constant | Description |
|---|---|
| `<cartesian>` | Cartesian |
| `<polar>` | Polar (2D only) |
| `<cylindrical>` | Cylindrical (3D only) |
| `<spherical>` | Spherical (3D only) |

**Table B-8.** Axis Scaling Constants

| Constant | Description |
|---|---|
| `<auto>` | Automatic axis ranging |
| `<linear>` | Linear |
| `<log>` | Logarithmic |
| `<manual>` | Manual axis ranging |

**Table B-9.** Contour Constants

| Constant | Description |
|---|---|
| `<magnitude>` | Generate contours with magnitude data |
| `<x>` | Generate contours with X data |
| `<y>` | Generate contours with Y data |
| `<z>` | Generate contours with Z data |

**Table B-10.** Projection Style Constants

| Constant | Description |
|---|---|
| `<orthographic>` | Orthographic projection |
| `<perspective>` | Perspective projection |

**Table B-11.** View Mode Constants

| Constant | Description |
|---|---|
| `<viewUserDefined>` | View angle is specified by the `.viewLongitude` and `.viewLatitude` attributes |
| `<viewXYPlane>` | View angle looks toward the XY plane in the negative Z direction |
| `<viewXZPlane>` | View angle looks toward the XZ plane in the positive Y direction |
| `<viewYZPlane>` | View angle looks toward the YZ plane in the negative X direction |

**Table B-12.** Lighting Attenuation Constants

| Constant | Description |
|---|---|
| `<linear>` | Intensity decreases as a linear function of distance |
| `<none>` | No attenuation |
| `<quadratic>` | Intensity decreases as a quadratic function of distance |

**Table B-13.** Color Map Constants

| Constant | Description |
|---|---|
| `<grayscale>` | Color map is a grayscale |
| `<none>` | No color map |
| `<shaded>` | Color map based on varying shades of fill color |
| `<spectrum>` | Color map is a color spectrum |

**Table B-14.** Line Interpolation Constants

| Constant | Description |
|---|---|
| `<cubicspline>` | Cubic spline interpolation between points |
| `<linear>` | Linear interpolation between points |

**Table B-15.** Numeric Formatting Constants

| Constant | Description |
|---|---|
| `<binary>` | Binary formatting for integer objects |
| `<binaryB>` | Binary formatting with appended `b` for integer objects |
| `<caret>` | Polynomial exponent style ^ |
| `<decimal>` | Decimal formatting |
| `<decimal>` | Decimal notation |
| `<degrees>` | Polar representation in degrees for complex objects |
| `<engineering>` | Engineering notation |
| `<fortran>` | Polynomial exponent style ** |
| `<gradians>` | Polar representation in gradians for complex objects |
| `<hexadecimal0x>` | Hexadecimal formatting with prepended `0x` for integer objects |
| `<hexadecimal>` | Hexadecimal formatting for integer objects |
| `<hexadecimalDollar>` | Hexadecimal formatting with prepended `$` for integer objects |
| `<hexadecimalH>` | Hexadecimal formatting with appended `h` for integer objects |
| `<left>` | Left justification of the number in the cell |

**Table B-15.** Numeric Formatting Constants (Continued)

| Constant | Description |
|---|---|
| `<octal0>` | Octal formatting with prepended `0` for integer objects |
| `<octal>` | Octal formatting for integer objects |
| `<octalo>` | Octal formatting with appended `o` for integer objects |
| `<pair>` | Cartesian representation for complex objects using ordered pairs |
| `<radians>` | Polar representation in radians for complex objects |
| `<raised>` | Polynomial exponent style superscript |
| `<right>` | Right justification of the number in the cell |
| `<scientific>` | Scientific notation |
| `<sumI>` | Cartesian representation for complex objects using `i` |
| `<sumJ>` | Cartesian representation for complex objects using `j` |

## Language Constants

**Table B-16.** Numeric Constants

| Numeric Constants | Value |
|---|---|
| `<catalan>` | 0.9159655941772190 |
| `<e>` | *e* (2.71828182845904523536) |
| `<epsilon>` | Machine epsilon |
| `<euler>` | γ (.5772156649015328768) |
| `<i>` | sqrt(–1) |

**Table B-16.** Numeric Constants (Continued)

| Numeric Constants | Value |
|---|---|
| `<INF>` | Positive infinity |
| `<maxInt>` | Largest positive integer |
| `<maxLn>` | `ln(<MaxReal>)` |
| `<maxReal>` | Largest positive normalized real number |
| `<minInt>` | Smallest negative integer |
| `<minLn>` | `ln(<MinReal>)` |
| `<minReal>` | Smallest positive normalized real number |
| `<NAN>` | Not a number |
| `<NINF>` | Negative infinity –<INF> |
| `<pi>` | π (3.14159265358979323846) |
| `<PINF>` | Positive infinity |

**Table B-17.** Text Constants

| Text Constants | Value |
|---|---|
| `CR` | Carriage return character |
| `CRLF` | Carriage return and linefeed characters |
| `LF` | Linefeed character |
| `tab` | Tab character |

**Table B-18.** Color Constants

| Color Constants | Value |
|---|---|
| `<Black>` | {color: 0, 0, 0} |
| `<Blue>` | {color: 0, 0, 128} |
| `<Brown>` | {color: 128, 64, 0} |
| `<Cyan>` | {color: 0, 128, 128} |
| `<Gray>`<br>`<Grey>` | {color: 128, 128, 128} |
| `<Green>` | {color: 0, 128, 0} |
| `<LtBlue>` | {color: 0, 0, 255} |
| `<LtCyan>` | {color: 0, 255, 255} |
| `<LtGray>`<br>`<LtGrey>` | {color: 192, 192, 192} |
| `<LtGreen>` | {color: 0, 255, 0} |
| `<LtMagenta>` | {color: 255, 0, 255} |
| `<LtRed>` | {color: 255, 0, 0} |
| `<Magenta>` | {color: 128, 0, 128} |
| `<Orange>` | {color: 255, 128, 0} |
| `<Pink>` | {color: 255, 128, 255} |
| `<Red>` | {color: 192, 0, 0} |
| `<White>` | {color: 255, 255, 255} |
| `<Yellow>` | {color: 255, 255, 0} |

## Function Constants

**Table B-19.** Function Constants

| Function | Constant |
|---|---|
| basis | <heaviside> |
| | <kronecker> |
| CDF | <beta> |
| | <binomial> |
| | <cauchy> |
| | <chiSq> |
| | <exponential> |
| | <f> |
| | <gamma> |
| | <geometric> |
| | <negBinomial> |
| | <normal> |
| | <poisson> |
| | <student> |
| | <weibull> |
| cond | <frob> |
| | <L1> |
| | <L2> |
| | <L2sq> |
| | <Li> |
| convert | <band> |
| | <hermitian> |
| | <lowerTri> |
| | <rect> |
| | <symmetric> |
| | <upperTri> |

**Table B-19.** Function Constants (Continued)

| Function | Constant |
|---|---|
| createGraph | <graph2D> |
| | <graph3D> |
| createMatrix | <band> |
| | <bordered> |
| | <dingdong> |
| | <fill> |
| | <frank> |
| | <gram> |
| | <hankel> |
| | <hilbert> |
| | <ident> |
| | <kahanL> |
| | <kahanU> |
| | <lowerTri> |
| | <moler> |
| | <random> |
| | <rect> |
| | <seq> |
| | <symmetric> |
| | <toeplitz> |
| | <upperTri> |
| | <vandermonde> |
| | <wilkMinus> |
| | <wilkPlus> |

**Table B-19.** Function Constants (Continued)

| Function | Constant |
|---|---|
| `createPoly` | `<aLaguerre>`<br>`<ascending>`<br>`<chebyshev1>`<br>`<chebyshev2>`<br>`<descending>`<br>`<fill>`<br>`<gegenbauer>`<br>`<hermite>`<br>`<laguerre>`<br>`<legendre>` |
| `createVector` | `<heaviside>`<br>`<kronecker>`<br>`<random>`<br>`<seq>` |
| `createView` | `false`<br>`true` |
| `curl` | `<central>`<br>`<extended>`<br>`<forward>` |
| `date` | `<long>`<br>`<short>` |
| `derivative` | `<central>`<br>`<extended>`<br>`<forward>` |

**Table B-19.** Function Constants (Continued)

| Function | Constant |
|---|---|
| `dist` | `<frob>`<br>`<L1>`<br>`<L2>`<br>`<L2sq>`<br>`<Li>`<br>`<Lp>`<br>`<Lw>` |
| `div` | `<central>`<br>`<extended>`<br>`<forward>` |
| `eigen` | `<hermitian>`<br>`<symmetric>` |
| `eigenDom` | `<hermitian>`<br>`<symmetric>` |
| `evalPoly` | `<aLaguerre>`<br>`<chebyshev1>`<br>`<chebyshev2>`<br>`<hermite>`<br>`<jacobi>`<br>`<laguerre>`<br>`<legendre>` |
| `find` | `<column>`<br>`<GE>`<br>`<GT>`<br>`<LE>`<br>`<LT>`<br>`<NE>`<br>`<row>` |

**Table B-19.** Function Constants (Continued)

| Function | Constant |
|---|---|
| `fit` | `<conjGrad>`<br>`<gauss>`<br>`<givensDefRank>`<br>`<givensFullRank>`<br>`<houseDefRank>`<br>`<houseFullRank>`<br>`<line>`<br>`<marquardt>`<br>`<poly>`<br>`<quasiNewton>`<br>`<SVD>` |
| `fitEval` | `<exp>`<br>`<gauss>`<br>`<line>` |
| `gradient` | `<central>`<br>`<extended>`<br>`<forward>` |
| `hessenbergD` | `<givens>`<br>`<house>` |
| `hessian` | `<central>`<br>`<forward>` |
| `integEqn` | `<Fredholm2>`<br>`<Volterra1>`<br>`<Volterra2>` |

**Table B-19.** Function Constants (Continued)

| Function | Constant |
|---|---|
| `integrate` | `<adSimpson>`<br>`<gauss>`<br>`<hermite>`<br>`<laguerre>`<br>`<logSing>`<br>`<parabolic>`<br>`<simpson>`<br>`<spline>`<br>`<trapezoid>` |
| `interp` | `<poly>` |
| `isMatrix` | `<allReal>`<br>`<allZero>`<br>`<colDiagDom>`<br>`<diagonal>`<br>`<GE>`<br>`<GT>`<br>`<hermitian>`<br>`<LE>`<br>`<lowerTri>`<br>`<LT>`<br>`<negDef>`<br>`<orthogonal>`<br>`<posDef>`<br>`<rowDiagdom>`<br>`<square>`<br>`<symmetric>`<br>`<unitary>`<br>`<upperTri>` |

**Table B-19.** Function Constants (Continued)

| Function | Constant |
|---|---|
| `jacobian` | `<central>`<br>`<forward>` |
| `laplacian` | `<central>`<br>`<forward>` |
| `logMessage` | `<append>`<br>`<newLine>` |
| `norm` | `<frob>`<br>`<L1>`<br>`<L2>`<br>`<L2sq>`<br>`<Li>`<br>`<Lp>`<br>`<Lw>` |
| `ODEBVP` | `<ABM>`<br>`<BDF>`<br>`<BDF1>`<br>`<BS>`<br>`<cc>`<br>`<fixed>`<br>`<linear>`<br>`<marching>`<br>`<nonlinear>`<br>`<RKF>`<br>`<simple>`<br>`<variable>` |

**Table B-19.** Function Constants (Continued)

| Function | Constant |
|---|---|
| ODEIVP | `<ABM>`<br>`<BDF>`<br>`<BS>`<br>`<cc>`<br>`<fixed>`<br>`<RKF>`<br>`<variable>` |
| optimize | `<conjGrad>`<br>`<marquardt>`<br>`<nelderMead>`<br>`<quasiNewton>`<br>`<quasiNewton>` |
| partial | `<central>`<br>`<extended>`<br>`<forward>` |
| PDF | `<beta>`<br>`<binomial>`<br>`<cauchy>`<br>`<chiSq>`<br>`<exponential>`<br>`<f>`<br>`<gamma>`<br>`<geometric>`<br>`<negBinomial>`<br>`<normal>`<br>`<poisson>`<br>`<student>`<br>`<weibull>` |

**Table B-19.** Function Constants (Continued)

| Function | Constant |
|---|---|
| QRD | <fastGivens><br><givens><br><house><br><mGS> |
| range | <quartile> |
| random | <normal><br><uniform> |
| replace | <column><br><GE><br><GT><br><LE><br><LT><br><NE><br><row> |
| root | <muller><br><newton> |
| setFilePos | <seekFromCurrent><br><seekFromEnd><br><seekFromStart> |
| solve | <choleskyD><br><leastSq><br><linearSys><br><newton><br><quasiNewton><br><symD><br><toeplitz><br><vandermonde> |

**Table B-19.** Function Constants (Continued)

| Function | Constant |
|---|---|
| `sort` | `<ascending>`<br>`<bucketSort>`<br>`<descending>`<br>`<heapSort>`<br>`<insertionSort>`<br>`<keepTies>`<br>`<noTies>`<br>`<quickSort>`<br>`<shellSort>` |
| `spline` | `<b>`<br>`<cubic>`<br>`<natcubic>` |
| `splineEval` | `<b>`<br>`<cubic>`<br>`<natcubic>` |
| `time` | `<local>`<br>`<utc>` |

# Customer Communication

For your convenience, this appendix contains forms to help you gather the information necessary to help us solve your technical problems and a form you can use to comment on the product documentation. When you contact us, we need the information on the Technical Support Form and the configuration form, if your manual contains one, about your system configuration to answer your questions as quickly as possible.

National Instruments has technical assistance through electronic, fax, and telephone systems to quickly provide the information you need. Our electronic services include a bulletin board service, an FTP site, a fax-on-demand system, and e-mail support. If you have a hardware or software problem, first try the electronic support systems. If the information available on these systems does not answer your questions, we offer fax and telephone support through our technical support centers, which are staffed by applications engineers.

## Electronic Services

### Bulletin Board Support

National Instruments has BBS and FTP sites dedicated for 24-hour support with a collection of files and documents to answer most common customer questions. From these sites, you can also download the latest instrument drivers, updates, and example programs. For recorded instructions on how to use the bulletin board and FTP services and for BBS automated information, call 512 795 6990. You can access these services at:

United States: 512 794 5422
Up to 14,400 baud, 8 data bits, 1 stop bit, no parity

United Kingdom: 01635 551422
Up to 9,600 baud, 8 data bits, 1 stop bit, no parity

France: 01 48 65 15 59
Up to 9,600 baud, 8 data bits, 1 stop bit, no parity

### FTP Support

To access our FTP site, log on to our Internet host, `ftp.natinst.com`, as `anonymous` and use your Internet address, such as `joesmith@anywhere.com`, as your password. The support files and documents are located in the `/support` directories.

### Fax-on-Demand Support

Fax-on-Demand is a 24-hour information retrieval system containing a library of documents on a wide range of technical information. You can access Fax-on-Demand from a touch-tone telephone at 512 418 1111.

### E-Mail Support (Currently USA Only)

You can submit technical support questions to the applications engineering team through e-mail at the Internet address listed below. Remember to include your name, address, and phone number so we can contact you with solutions and suggestions.

`support@natinst.com`

## Telephone and Fax Support

National Instruments has branch offices all over the world. Use the list below to find the technical support number for your country. If there is no National Instruments office in your country, contact the source from which you purchased your software to obtain support.

| Country | Telephone | Fax |
|---|---|---|
| Australia | 03 9879 5166 | 03 9879 6277 |
| Austria | 0662 45 79 90 0 | 0662 45 79 90 19 |
| Belgium | 02 757 00 20 | 02 757 03 11 |
| Brazil | 011 288 3336 | 011 288 8528 |
| Canada (Ontario) | 905 785 0085 | 905 785 0086 |
| Canada (Quebec) | 514 694 8521 | 514 694 4399 |
| Denmark | 45 76 26 00 | 45 76 26 02 |
| Finland | 09 725 725 11 | 09 725 725 55 |
| France | 01 48 14 24 24 | 01 48 14 24 14 |
| Germany | 089 741 31 30 | 089 714 60 35 |
| Hong Kong | 2645 3186 | 2686 8505 |
| Israel | 03 6120092 | 03 6120095 |
| Italy | 02 413091 | 02 41309215 |
| Japan | 03 5472 2970 | 03 5472 2977 |
| Korea | 02 596 7456 | 02 596 7455 |
| Mexico | 5 520 2635 | 5 520 3282 |
| Netherlands | 0348 433466 | 0348 430673 |
| Norway | 32 84 84 00 | 32 84 86 00 |
| Singapore | 2265886 | 2265887 |
| Spain | 91 640 0085 | 91 640 0533 |
| Sweden | 08 730 49 70 | 08 730 43 70 |
| Switzerland | 056 200 51 51 | 056 200 51 55 |
| Taiwan | 02 377 1200 | 02 737 4644 |
| United Kingdom | 01635 523545 | 01635 523154 |
| United States | 512 795 8248 | 512 794 5678 |

# Technical Support Form

Photocopy this form and update it each time you make changes to your software or hardware, and use the completed copy of this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

If you are using any National Instruments hardware or software products related to this problem, include the configuration forms from their user manuals. Include additional pages if necessary.

Name ______________________________________________

Company ______________________________________________

Address ______________________________________________

______________________________________________

Fax ( ___ ) ________________Phone ( ___ ) ______________________________

Computer brand____________ Model ___________________Processor_____________________

Operating system (include version number) ______________________________

Clock speed ______MHz RAM _____MB Display adapter ______________________

Mouse ___yes ___no Other adapters installed______________________________

Hard disk capacity _____MB Brand______________________________

Instruments used ______________________________________________

______________________________________________

National Instruments hardware product model_____________ Revision ____________________

Configuration ______________________________________________

National Instruments software product ___________________ Version ____________________

Configuration ______________________________________________

The problem is: ______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

List any error messages: ______________________________________________

______________________________________________

______________________________________________

The following steps reproduce the problem: ______________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

# HiQ Hardware and Software Configuration Form

Record the settings and revisions of your hardware and software on the line to the right of each item. Complete a new copy of this form each time you revise your software or hardware configuration, and use this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

## National Instruments Products

Hardware revision ______________________________

Interrupt level of hardware ______________________________

DMA channels of hardware ______________________________

Base I/O address of hardware ______________________________

Programming choice ______________________________

National Instruments software ______________________________

Other boards in system ______________________________

Base I/O address of other boards ______________________________

DMA channels of other boards ______________________________

Interrupt level of other boards ______________________________

## Other Products

Computer make and model ______________________________

Microprocessor ______________________________

Clock frequency or speed ______________________________

Type of video board installed ______________________________

Operating system version ______________________________

Operating system mode ______________________________

Programming language ______________________________

Programming language version ______________________________

Other boards in system ______________________________

Base I/O address of other boards ______________________________

DMA channels of other boards ______________________________

Interrupt level of other boards ______________________________

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**Title:** *HiQ™ Reference Manual*

**Edition Date:** April 1998

**Part Number:** 321885A-01

Please comment on the completeness, clarity, and organization of the manual.

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If you find errors in the manual, please record the page numbers and describe the errors.

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# Glossary

| Prefix | Meanings | Value |
|---|---|---|
| p- | pico | $10^{-12}$ |
| n- | nano- | $10^{-9}$ |
| µ- | micro- | $10^{-6}$ |
| m- | milli- | $10^{-3}$ |
| k- | kilo- | $10^{3}$ |
| M- | mega- | $10^{6}$ |
| G- | giga- | $10^{9}$ |
| t- | tera- | $10^{12}$ |

## A

| | |
|---|---|
| ActiveX (Microsoft ActiveX) | A programming system and user interface that lets you work with interactive objects. Formerly called OLE. |
| ActiveX control | A standard software tool that adds additional functionality to any compatible ActiveX container. |
| ActiveX Control object | An object in HiQ that represents an inserted ActiveX control. |
| ActiveX embedded object | An object placed into a container and unconnected to any other object or application. *See also* embedded. |
| ActiveX Interface object | An object in HiQ that represents an interface to an ActiveX automation server application. See the `createInterface` function in Chapter 7, *Function Reference*. |
| ActiveX linked object | An object placed into a container and connected to another object or application in the same container or in a separate container. *See also* linked. |
| ActiveX object | An object in HiQ that represents an inserted ActiveX object. |
| argument | *See* parameter. |

| | |
|---|---|
| assignment | A script statement that sets a value to a variable. |
| attribute | *See* property. |

## B

| | |
|---|---|
| built-in function | One of many programming utilities in HiQ-Script that perform analysis, graphical, or utility operations. |

## C

| | |
|---|---|
| caret | *See* insertion point. |
| cell | In a matrix or vector, the intersection of a row and column that contains a numerical value. |
| Color object | A HiQ object that sets the color attributes of graphs and plots. |
| Command Window | *See* HiQ Command Window. |
| comment | An explanatory line or portion of a line in HiQ-Script. |
| compiled script | A HiQ object containing HiQ-Script language that has been converted to code that a computer uses to execute the program. |
| ComponentWorks | A collection of 32-bit ActiveX controls designed for building virtual instrumentation systems. |
| constant | A predefined value in HiQ-Script. |
| cursor | The pointer or other image that displays on screen to show the location of your mouse, trackball, or other pointing device. |

## D

| | |
|---|---|
| data type | *See* numeric type. |
| debug | To check and correct invalid code in a HiQ script in order to eliminate errors during the compilation or execution of the script. |
| declaration | A HiQ-Script statement that defines the scope of variables. Can be either project or local. |

| | |
|---|---|
| dialog box | A window containing a message, interactive options, and buttons. |
| drag and drop | To move an object to a specific location, using the mouse to click on, drag, and release the object. Depending on the location of release, a specific action can occur. |

## E

| | |
|---|---|
| embedded | Inserted into a container object and unconnected to any other object or application. Compare this term to linked. *See also* ActiveX embedded object. |
| error message | An information box that appears when HiQ cannot complete an action due to an internal error, compile error, run-time error, or user error. |
| Explorer | *See* HiQ Explorer. |
| expression | A mathematical operator and its operands. |

## F

| | |
|---|---|
| Font object | A HiQ object type used to set the font attributes of graphs and plots. |
| For Loop | A statement or block of statements that repeats until a condition is matched. |
| function | A block of code that performs a specific task in HiQ-Script; can be a HiQ built-in function or a user-defined function. |
| function call | Specific HiQ-Script syntax that calls a user or built-in function with given parameters. |
| Function object | An object that represents the executable pseudocode of a complied Script object. |

## G

| | |
|---|---|
| grab handle | A site on a selected object that you click on and drag to move, size, or reshape the object. |
| Graph object | The HiQ object that contains a two-dimensional or three-dimensional collection of plots. *See* plot. |

## H

| | |
|---|---|
| handle | *See* grab handle. |
| HiQ Command Window | An intuitive window where you type HiQ-Script to get immediate results. |
| HiQ Constant object | A HiQ object that represents a constant in HiQ-Script. |
| HiQ Explorer | An interactive window displaying the objects, sections, and pages of an open Notebook. |
| HiQ Log Window | A window to which you can post messages from HiQ-Script. |
| HiQ Object Browser | A browser window in which you can view all the interfaces for ActiveX servers, objects, and controls installed on your computer. |
| HiQ-Script | An intuitive programming language for mathematics. |
| HiQ Tools toolbar | Part of the HiQ user interface that contains icons for objects you can place in a Notebook. Depending on your preference, the toolbar can appear on any edge of the interface, or as a floating palette. |

## I

| | |
|---|---|
| If-Then-Else statement | Flow control construct that executes a statement or block of statements only when a condition is true. |
| initialization | In HiQ-Script, a designated syntax which creates a particular type of object, for example, vector, matrix, color, and others. |
| insertion point | The location where text will be inserted (also referred to as the *caret*). |

## K

| | |
|---|---|
| keyword | A reserved word in HiQ Script, such as `if`, `then`, or `while`, that is used for constructing specific types of programming statements. |

## L

| | |
|---|---|
| LabVIEW | Laboratory Virtual Instrument Engineering Workbench. Program development application based on the programming language G used commonly for test and measurement applications. |
| LabWindows\CVI | An integrated ANSI C environment designed for engineers and scientists creating virtual instrumentation applications. |
| linked | Inserted into a container object and connected with another object or application. Compare this term to embedded. *See also* ActiveX linked object. |
| local | Describes the scope of an object. An object with local scope is not associated with the Notebook. |
| Log Window | *See* HiQ Log Window. |
| loop | A statement in HiQ-Script consisting of keywords and nested statements that performs a repetitive function. Also known as an iteration statement. |

## M

| | |
|---|---|
| MATLAB | Third-party software product for programming and working with data. |
| Matrix object | A HiQ numeric object containing an array of elements with rows and columns. *See* vector. |
| message box | A secondary window that appears containing information about the status of a HiQ operation. *See* dialog box. |

## N

| | |
|---|---|
| Notebook | The workspace in HiQ that stores, organizes, and displays all the components of an analysis and visualization problem. |
| Numeric object | A HiQ object type that is defined in terms of a numeric type (integer, real, or complex) and an object type (matrix, vector, polynomial, or scalar). |
| numeric type | One of three types of a numeric object (integer, real, or complex). |

## O

| | |
|---|---|
| object | An entity in a HiQ Notebook that contains data of a specific type, for example, numeric, graphic, text, or HiQ-Script. Objects work together in a Notebook to generate and display solutions to analysis and visualization problems. Objects are always stored in a Notebook, but are not always visible on a Notebook page. *See* object view. |
| Object Browser | *See* HiQ Object Browser. |
| Object List | A window in HiQ that displays all the objects in a HiQ Notebook. |
| object view | A HiQ object that is visible on a Notebook page. |
| OLE (Microsoft OLE) | Object Linking and Embedding. A programming system and user interface that lets you work with interactive objects. *See* ActiveX. |
| operand | An object (or objects) modified by an operator. |
| operator | Code in HiQ-Script that is specific to basic mathematical operations and structure of HiQ-Script language. Often represented as a symbol, for example, "`/`" represents division. |

## P

| | |
|---|---|
| parameter | An independent variable passed to a user-defined or built-in function call in a parameter list. |
| Plot object | A HiQ object type that graphically represents a two-dimensional or three-dimensional function or data set used in conjunction with a graph object. *See* graph. |
| Polynomial object | A HiQ numeric object represented by an equation in the polynomial form $ax^n + bx^{n-1}+cx^{n-2} + ...$ |
| pop-up menu | A context-sensitive menu that you can access by right clicking with your mouse on an object or on the Notebook. |
| Problem Solver | A HiQ Notebook containing objects, including HiQ-Script, that allows you to interactively perform analysis of data and display results for a broad class of problems. For example, the expression evaluator problem solver can display the results of any expression. |

| | |
|---|---|
| project | Describes the scope of an object. An object with project scope is saved with the Notebook. |
| Properties dialog box | A window in HiQ with tabbed pages (property pages) where you can quickly set a wide variety of attributes for a given object. |
| property | Attributes of a HiQ object. Examples include the color of a plot, the size of a matrix, and the type of any object. |
| property page | A tabbed subsection of a property dialog box containing a collection of object attributes. |

## R

| | |
|---|---|
| Return statement | A statement that causes the function to be exited. If an expression is specified, the expression is returned to the calling function. |

## S

| | |
|---|---|
| Scalar object | A HiQ numeric object represented as a number. *See* vector and matrix. |
| scope | In HiQ-Script, a HiQ-object declaration that specifies whether the object is available to the entire Notebook (project) or is temporarily available (local). |
| script | A block of code that performs a certain task. *See* compiled script. In HiQ, a block of programming code that can perform mathematical analysis and display its output textually, graphically, and numerically. |
| Script object | A HiQ object type containing HiQ-Script and from which you compile and execute your program. |
| section tabs | An organizing tool in a HiQ Notebook that lets you label and quickly access different parts of your Notebook. |
| Select statement | A statement that selects a group of statements to be executed based on the evaluation of an expression. |
| selection handle | A graphical control point of an object that provides direct manipulation support for operations of that object, such as moving, sizing, or scaling. |
| selection tool | The mouse cursor in HiQ shaped like a standard pointer arrow that lets you select, move, and manipulate objects on the Notebook. |

| | |
|---|---|
| shortcut key | A key or combination of keys that you press to invoke a command. |
| Standard toolbar | Site on the user interface of HiQ that contains basic utility tools, for example, Save, Open, Cut, Paste, and, Print. Depending on your preference, the toolbar can appear on any edge of the interface, or as a floating window. |
| statement | In HiQ-Script, a line of code consisting of various keywords, functions, and/or operators that performs a certain task. |
| status bar | A region, usually the bottom of a window, containing information about HiQ and any selected object. |
| symbol | The name for *objects* in HiQ for the Macintosh. |

## T

| | |
|---|---|
| Text object | A HiQ object type where you can enter and edit text. |
| toolbar | Site on an application interface that contains various buttons and other controls. Depending on your preference, a toolbar can appear on any edge of the interface, or a floating window. |
| tooltip | A small, descriptive pop-up window that appears when you position the mouse cursor over a toolbar icon. |
| type | A classification of an object based on its characteristics, behavior, and attributes. |

## U

| | |
|---|---|
| Untyped object | A HiQ object that has not been assigned a value. |
| user-defined function | A function that a user creates in HiQ-Script to perform customized analysis, graphical, or utility operations. |

## V

| | |
|---|---|
| Vector object | A HiQ numeric object containing an array with one row or column. Compare with matrix. |

## W

| | |
|---|---|
| While Loop | A statement or block of statements that executes while a particular condition is true. The condition is evaluated before the statement or block of statements is executed. |

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