

# **Optimization Toolbox™**

## **Release Notes**

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### *Optimization Toolbox™ Release Notes*

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<b>Summary by Version</b> .....	<b>1</b>
<b>Version 6.2 (R2012a) Optimization Toolbox Software</b> ..	<b>4</b>
<b>Version 6.1 (R2011b) Optimization Toolbox Software</b> ..	<b>6</b>
<b>Version 6.0 (R2011a) Optimization Toolbox Software</b> ..	<b>10</b>
<b>Version 5.1 (R2010b) Optimization Toolbox Software</b> ..	<b>14</b>
<b>Version 5.0 (R2010a) Optimization Toolbox Software</b> ..	<b>16</b>
<b>Version 4.3 (R2009b) Optimization Toolbox Software</b> ..	<b>18</b>
<b>Version 4.2 (R2009a) Optimization Toolbox Software</b> ..	<b>21</b>
<b>Version 4.1 (R2008b) Optimization Toolbox Software</b> ..	<b>25</b>
<b>Version 4.0 (R2008a) Optimization Toolbox Software</b> ..	<b>29</b>
<b>Version 3.1.2 (R2007b) Optimization Toolbox Software</b> .....	<b>32</b>
<b>Version 3.1.1 (R2007a) Optimization Toolbox Software</b> .....	<b>33</b>
<b>Version 3.1 (R2006b) Optimization Toolbox Software</b> ..	<b>35</b>
<b>Version 3.0.4 (R2006a) Optimization Toolbox Software</b> .....	<b>38</b>
<b>Version 3.0.3 (R14SP3) Optimization Toolbox Software</b> .....	<b>39</b>

<b>Compatibility Summary for Optimization Toolbox Software .....</b>	<b>40</b>
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## Summary by Version

This table provides quick access to what's new in each version. For clarification, see “Using Release Notes” on page 2.

<b>Version (Release)</b>	<b>New Features and Changes</b>	<b>Version Compatibility Considerations</b>	<b>Fixed Bugs and Known Problems</b>
<b>Latest Version V6.2 (R2012a)</b>	Yes Details	Yes Summary	Bug Reports Includes fixes
V6.1 (R2011b)	Yes Details	Yes Summary	Bug Reports Includes fixes
V6.0 (R2011a)	Yes Details	Yes Summary	Bug Reports Includes fixes
V5.1 (R2010b)	Yes Details	No	Bug Reports Includes fixes
V5.0 (R2010a)	Yes Details	Yes Summary	Bug Reports Includes fixes
V4.3 (R2009b)	Yes Details	Yes Summary	Bug Reports Includes fixes
V4.2 (R2009a)	Yes Details	Yes Summary	Bug Reports Includes fixes
V4.1 (R2008b)	Yes Details	Yes Summary	Bug Reports Includes fixes
V4.0 (R2008a)	Yes Details	Yes Summary	Bug Reports Includes fixes
V3.1.2 (R2007b)	No	No	Bug Reports Includes fixes
V3.1.1 (R2007a)	Yes Details	Yes Summary	Bug Reports Includes fixes
V3.1 (R2006b)	Yes Details	Yes Summary	Bug Reports Includes fixes

<b>Version (Release)</b>	<b>New Features and Changes</b>	<b>Version Compatibility Considerations</b>	<b>Fixed Bugs and Known Problems</b>
V3.0.4 (R2006a)	No	No	Bug Reports Includes fixes
V3.0.3 (R14SP3)	Yes Details	No	Bug Reports Includes fixes

## Using Release Notes

Use release notes when upgrading to a newer version to learn about:

- New features
- Changes
- Potential impact on your existing files and practices

Review the release notes for other MathWorks® products required for this product (for example, MATLAB® or Simulink®). Determine if enhancements, bugs, or compatibility considerations in other products impact you.

If you are upgrading from a software version other than the most recent one, review the current release notes and all interim versions. For example, when you upgrade from V1.0 to V1.2, review the release notes for V1.1 and V1.2.

## What Is in the Release Notes

### New Features and Changes

- New functionality
- Changes to existing functionality

### Version Compatibility Considerations

When a new feature or change introduces a reported incompatibility between versions, the **Compatibility Considerations** subsection explains the impact.

Compatibility issues reported after the product release appear under Bug Reports at the MathWorks Web site. Bug fixes can sometimes result in incompatibilities, so review the fixed bugs in Bug Reports for any compatibility impact.

### **Fixed Bugs and Known Problems**

MathWorks offers a user-searchable Bug Reports database so you can view Bug Reports. The development team updates this database at release time and as more information becomes available. Bug Reports include provisions for any known workarounds or file replacements. Information is available for bugs existing in or fixed in Release 14SP2 or later. Information is not available for all bugs in earlier releases.

Access Bug Reports using your MathWorks Account.

### **Documentation on the MathWorks Web Site**

Related documentation is available on [mathworks.com](http://mathworks.com) for the latest release and for previous releases:

- Latest product documentation
- Archived documentation

## Version 6.2 (R2012a) Optimization Toolbox Software

This table summarizes what's new in Version 6.2 (R2012a):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes Summary	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “Enhanced Robustness in `fminunc`” on page 4
- “`FinDiffRelStep` Option in Optimization Tool” on page 4
- “Levenberg-Marquardt Algorithm Tweak” on page 5
- “`fmincon sqp` Algorithm Tweak” on page 5

### Enhanced Robustness in `fminunc`

The `fminunc` medium-scale algorithm now attempts to recover from failures when evaluating the objective function during iteration steps, or during gradient estimation. Failure means the objective function returns NaN, a complex value, or Inf. If there is such a failure, the algorithm attempts to take different steps.

As part of robustness, the `fminunc` medium-scale algorithm now uses the `ObjectiveLimit` tolerance.

### Compatibility Considerations

When objective function values drop below `ObjectiveLimit` (default value:  $-1e20$ ), iterations end with a -3 exit flag. Use `optimset` to change the value of `ObjectiveLimit`. Set `ObjectiveLimit` to `-Inf` to disable this tolerance.

### `FinDiffRelStep` Option in Optimization Tool

The `FinDiffRelStep` option for choosing relative finite difference step sizes is now available in the Optimization Tool, in the **Approximated derivatives** pane. This option lets you tune the gradient estimation step in most solvers.



## **Levenberg-Marquardt Algorithm Tweak**

The `fsolve`, `lsqcurvefit`, and `lsqnonlin` solvers no longer use the magnitude of the Levenberg-Marquardt regularization parameter as a stopping criterion, so they no longer return an exit flag of -3 when using the `levenberg-marquardt` algorithm. Instead, they use the `TolX` tolerance in all internal calculations.

### **Compatibility Considerations**

The solvers now stop with exit flag 2 in most situations where previously they stopped with exit flag -3.

## **fmincon sqp Algorithm Tweak**

The `fmincon sqp` algorithm calculates its Lagrange multiplier estimates somewhat differently than before.

### **Compatibility Considerations**

The `fmincon sqp` algorithm can give slightly different results than before.

## Version 6.1 (R2011b) Optimization Toolbox Software

This table summarizes what's new in Version 6.1 (R2011b):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes Summary	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “Derivative Estimate Changes” on page 6
- “Gauss-Newton Algorithm Removed” on page 7
- “DerivativeCheck Changes” on page 7
- “fmincon ScaleProblem Default Changed” on page 8
- “fsolve trust-region-dogleg Algorithm Change” on page 8
- “Conversion of Error and Warning Message Identifiers” on page 8

### Derivative Estimate Changes

- The `fsolve`, `lsqcurvefit`, and `lsqnonlin` solvers now accept the `FinDiffType` option. Set `FinDiffType` to `'central'` with `optimset` to enable derivative estimation by central finite differences. Central finite differences are more accurate, but take more time than the default `'forward'` finite differences.
- `fsolve`, `lsqcurvefit`, and `lsqnonlin` now use the `TypicalX` option when estimating dense Jacobians via finite differences. In previous releases, these solvers used `TypicalX` only when checking derivatives.
- For algorithms that obey bounds, finite difference steps for derivative estimation now stay within any bounds you set for the decision variables. See “Iterations Can Violate Constraints”.
- The new `FinDiffRelStep` option allows you to set a vector of finite difference step sizes to better handle problems whose components have different scales. Use `FinDiffRelStep` at the command line for any solver

that uses finite differences. For details, see `FinDiffRelStep` in “Options Structure”.

## Gauss-Newton Algorithm Removed

The `fsolve`, `lsqcurvefit`, and `lsqnonlin` functions no longer use the Gauss-Newton algorithm.

## Compatibility Considerations

The previous way of selecting the Gauss-Newton algorithm was to set the `LargeScale` option to `'off'`, and in:

- `fsolve` — set the `NonlEqnAlgorithm` option to `'gn'`.
- `lsqcurvefit` or `lsqnonlin` — set the `LevenbergMarquardt` option to `'off'`.

To select an algorithm, use `optimset` to set the `Algorithm` option:

- `fsolve` — `trust-region-dogleg`, `trust-region-reflective`, or `levenberg-marquardt`
- `lsqcurvefit` or `lsqnonlin` — `trust-region-reflective` or `levenberg-marquardt`

Solvers no longer use the `LevenbergMarquardt`, `LineSearchType`, and `NonlEqnAlgorithm` options, since these options relate only to the Gauss-Newton algorithm.

## DerivativeCheck Changes

The `DerivativeCheck` option checks whether a solver’s finite-difference approximations match the gradient or Jacobian functions that you supply. When a solver finds a discrepancy between the computed derivatives and their finite-difference approximations, the solver now errors. Solvers used to pause in this situation instead of erroring.

Additionally, solvers now compare derivatives at a point near the initial point `x0`, but not exactly at `x0`. Previously, solvers performed the comparison at `x0`. This change usually gives more reliable `DerivativeCheck` decisions. For details, see “Checking Validity of Gradients or Jacobians”.

Solvers do not include the computations for `DerivativeCheck` in the function count. See “Iterations and Function Counts”.

### **Compatibility Considerations**

Solvers compare the derivatives at a different point than before, so can change their decision on whether the derivatives match. Solvers now error instead of pause when they encounter a discrepancy.

### **fmincon ScaleProblem Default Changed**

The `fmincon` interior-point and `sqp` algorithms can use the `ScaleProblem` option. The default value of `ScaleProblem` is now `'none'` instead of `'obj-and-constr'`.

### **Compatibility Considerations**

Because of a bug in previous releases, when you did not provide gradients of the objective and nonlinear constraint functions, `fmincon` did not scale these functions. `fmincon` did scale linear constraints. So, if you do not provide gradients and have no linear constraints, the current `fmincon` behavior is the same as in previous releases. However, the current behavior can differ if you do provide gradients (`GradObj` or `GradConstr` is `'on'`). If you provide gradients, have no linear constraints, and want to obtain the previous behavior, set `ScaleProblem` to `'obj-and-constr'` with `optimset`.

### **fsolve trust-region-dogleg Algorithm Change**

The `fsolve` trust-region-dogleg algorithm no longer performs an internal calculation of conditioning. This change usually speeds `fsolve`.

### **Compatibility Considerations**

`fsolve` iterations differ from previous versions. Additionally, the solution and all associated outputs can differ from previous versions. Usually, results are numerically equivalent to previous results.

### **Conversion of Error and Warning Message Identifiers**

For R2011b, error and warning message identifiers have changed in Optimization Toolbox™.

## Compatibility Considerations

If you have scripts or functions that use message identifiers that changed, you must update the code to use the new identifiers. Typically, message identifiers are used to turn off specific warning messages, or in code that uses a try/catch statement and performs an action based on a specific error identifier.

For example, the 'optim:fmincon:ConstrainedProblemsOnly' identifier has changed to 'optimlib:fmincon:ConstrainedProblemsOnly'. If your code checks for 'optim:fmincon:ConstrainedProblemsOnly', you must update it to check for 'optimlib:fmincon:ConstrainedProblemsOnly' instead.

To determine the identifier for a warning, run the following command just after you see the warning:

```
[MSG,MSGID] = lastwarn;
```

This command saves the message identifier to the variable MSGID.

To determine the identifier for an error, run the following command just after you see the error:

```
exception = MException.last;  
MSGID = exception.identifier;
```

---

**Tip** Warning messages indicate a potential issue with your code. While you can turn off a warning, a suggested alternative is to change your code so it runs warning free.

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## Version 6.0 (R2011a) Optimization Toolbox Software

This table summarizes what's new in Version 6.0 (R2011a):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes Summary	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “New Quadratic Programming Algorithm” on page 10
- “Enhanced Robustness in Nonlinear Solvers” on page 11
- “New Defaults in DiffMinChange and DiffMaxChange Options” on page 12
- “Output Structure Tweak” on page 12
- “ktrlink Compatible with KNITRO 7” on page 13
- “New quadprog Demo” on page 13

### New Quadratic Programming Algorithm

quadprog has a new algorithm named 'interior-point-convex'. It has these features:

- The algorithm has fast internal linear algebra.
- The algorithm handles sparse problems.
- There is a new presolve module that can improve speed, numerical stability, and detection of infeasibility.
- The algorithm handles large convex problems, and accepts and uses sparse inputs. See “Large-Scale vs. Medium-Scale Algorithms”.
- The algorithm optionally gives iterative display.
- The algorithm has enhanced exit messages.

For details on the algorithm, see “interior-point-convex quadprog Algorithm”. For help choosing the algorithm to use, see “Quadratic Programming Algorithms”.

## Compatibility Considerations

You now choose the quadprog algorithm by using `optimset` to set the `Algorithm` option instead of the `LargeScale` option. If you don't set `Algorithm` or `LargeScale`, quadprog behaves as before.

Algorithm option choices are:

- `trust-region-reflective` (formerly `LargeScale = 'on'`), the default
- `active-set` (formerly `LargeScale = 'off'`)
- `interior-point-convex`

The previous way of choosing the quadprog algorithm at the command line was to set the `LargeScale` option to `'on'` or `'off'`. quadprog now ignores the `LargeScale` option, except when you set the inconsistent values `LargeScale = 'off'` and `Algorithm = 'trust-region-reflective'`. In this case, to avoid backward incompatibility, quadprog honors the `LargeScale` option, and uses the `'active-set'` algorithm.

quadprog now checks whether any inputs are complex, and, if so, it errors. The only exception is the `Hinfo` argument for the `HessMult` option is allowed to be complex.

## Enhanced Robustness in Nonlinear Solvers

More solvers now attempt to recover from errors in the evaluation of objective functions and nonlinear constraint functions during iteration steps, or, for some algorithms, during gradient estimation. The errors include results that are NaN or Inf for all solvers, or complex for `fmincon` and `fminunc`. If there is such an error, the algorithms attempt to take different steps. The following solvers are enhanced:

- `fmincon` trust-region-reflective algorithm (the interior-point and sqp algorithms already had this robustness)
- `fminunc` `LargeScale` algorithm

- `fsolve` trust-region-reflective, trust-region-dogleg, and levenberg-marquardt algorithms
- `lsqcurvefit` trust-region-reflective and levenberg-marquardt algorithms
- `lsqnonlin` trust-region-reflective and levenberg-marquardt algorithms

## New Defaults in `DiffMinChange` and `DiffMaxChange` Options

The `DiffMinChange` and `DiffMaxChange` options set the minimum and maximum possible step sizes for finite differences in gradient estimation. The defaults are now:

- `DiffMinChange` = 0 (formerly  $1e-8$ )
- `DiffMaxChange` = Inf (formerly 0.1)

Solvers have mechanisms that ensure nonzero and non-infinite step sizes, so the new defaults simply mean that the step size adjustment algorithms have fewer constraints.

The new defaults remove the previous arbitrary choices. The previous values can be inappropriate when components are too large or small in magnitude. Tests show these new defaults are good for most situations.

## Compatibility Considerations

Some solver iterations can differ from previous ones. To obtain the previous behavior:

```
options = optimset('DiffMinChange',1e-8,'DiffMaxChange',0.1);
```

## Output Structure Tweak

For the trust-region-reflective algorithm, the `algorithm` field of the output structure is now 'trust-region-reflective'. This value differs slightly from the previous values returned by `fmincon`, `fsolve`, `lsqcurvefit`, `lsqnonlin`, and `quadprog`.



## **Compatibility Considerations**

To avoid errors or unexpected results, update any code that depends on the exact value of the `output.algorithm` string.

## **ktrlink Compatible with KNITRO 7**

`ktrlink` is compatible with KNITRO® 7. For details, see “`ktrlink`: An Interface to KNITRO® Libraries”, or the Ziena Optimization web site <http://www.ziena.com/>.

## **New quadprog Demo**

A new demo shows how to solve portfolio optimization problems using `quadprog`. View the demo at the command line by entering

```
showdemo portfoptimdemo
```

## Version 5.1 (R2010b) Optimization Toolbox Software

This table summarizes what's new in Version 5.1 (R2010b):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	No	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “Enhanced fmincon Finite Difference Algorithms Add Robustness” on page 14
- “ktrlink Available for Macintosh 64-Bit Systems” on page 14
- “Output Structure Tweaks” on page 14
- “New Video Demo on Modeling” on page 15

### Enhanced fmincon Finite Difference Algorithms Add Robustness

The fmincon interior-point and sqp algorithms now attempt to recover from errors in the evaluation of objective functions and nonlinear constraint functions during gradient estimation. The errors include results that are NaN, Inf, or complex. If there is such an error, the finite differencing routines attempt to take different steps.

### ktrlink Available for Macintosh 64-Bit Systems

The ktrlink function now works with Macintosh® 64-bit systems. Therefore, ktrlink works on the same systems as all other Optimization Toolbox functions.

### Output Structure Tweaks

All linprog and quadprog algorithms now create a firstorderopt field in the output structure. This field contains the value of the first-order optimality measure at the final point.

All `fmincon` and `quadprog` algorithms now create a `constrviolation` field in the output structure. This field contains the largest value of the constraint functions at the final point: bounds, linear constraints, and nonlinear constraints. (Some algorithms return the larger of the constraint functions and 0.) See “Writing Constraints”.

## **New Video Demo on Modeling**

There is a new two-part demo on modeling and solving optimization problems. View the first part from the MATLAB command line by entering

```
playbackdemo('Optimization-Modeling-1','toolbox/optim/web/demos');
```

View the second part by entering

```
playbackdemo('Optimization-Modeling-2-Converting-To-Solver-Form',...  
'toolbox/optim/web/demos');
```

## Version 5.0 (R2010a) Optimization Toolbox Software

This table summarizes what's new in Version 5.0 (R2010a):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes Summary	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “New fmincon Algorithm” on page 16
- “lsqnonneg No Longer Uses x0” on page 16

### New fmincon Algorithm

fmincon has a new algorithm called SQP for Sequential Quadratic Programming. The algorithm has the following features:

- Honors bounds at all iterations
- Attempts a different step if one leads to an objective or constraint function returning a NaN, Inf, or complex result
- Fast internal linear algebra for solving quadratic programs

Choose the algorithm at the command line by setting the `Algorithm` option to 'sqp' with `optimset`. For more information about the algorithm, see “fmincon SQP Algorithm” in the Optimization Toolbox documentation.

### lsqnonneg No Longer Uses x0

The `lsqnonneg` solver no longer accepts a start point `x0` as an optional input.

### Compatibility Considerations

The Optimization Tool no longer has an input region for accepting a start point. If you import or run a problem that contains a start point `x0`, MATLAB issues a warning. Also, the Optimization Tool and `lsqnonneg` ignore `x0`,

and instead use a start point of a vector of zeroes. If you export a problem structure from the Optimization Tool, there is no  $x_0$  field.

## Version 4.3 (R2009b) Optimization Toolbox Software

This table summarizes what's new in Version 4.3 (R2009b):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes Summary	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “Enhanced Exit Messages in Selected Solvers” on page 18
- “fmincon Interior-Point Algorithm Robust to Certain Errors” on page 18
- “Changes in quadprog” on page 19
- “Changes in linprog” on page 19
- “Multiobjective optimValues Changes” on page 19

### Enhanced Exit Messages in Selected Solvers

Enhanced, clearer exit messages in `fsolve`, `lsqnonlin`, and `lsqcurvefit`, with links for more information. For more information about the enhancements, see “Exit Flags and Exit Messages”.

### Compatibility Considerations

For solvers with enhanced exit messages, the content of `output.message` contains many more characters than before. User code that relies on this field might need to be modified in order to display the larger exit message satisfactorily.

### fmincon Interior-Point Algorithm Robust to Certain Errors

The `fmincon` interior-point algorithm attempts to continue when a user-supplied objective or constraint function returns `Inf`, `NaN`, or a complex result. For more information, see “fmincon Interior Point Algorithm”.

## Changes in quadprog

The large-scale quadprog algorithm now uses the TolFun and MaxIter tolerances for deciding when to end iterations when there are only linear equality constraints, instead of the TolPCG and MaxPCGIter tolerances.

The quadprog output structure now contains the constrviolation field, which reports the maximum constraint function at the final point.

## Compatibility Considerations

For large-scale linear equality constrained problems, the default values of the tolerances are much tighter than before, so quadprog can take more iterations, but the resulting solution should be more accurate.

## Changes in linprog

The large-scale interior-point algorithm of linprog now has a backtracking mechanism for the case of stalling, and performs LDL factorization when there is rank deficiency. For more information, see “Large Scale Linear Programming”.

The linprog output structure now contains the constrviolation field, which reports the maximum constraint function at the final point.

## Compatibility Considerations

The interior-point algorithm of linprog might arrive at different solutions than before, and can solve more problems than before.

## Multiobjective optimValues Changes

The optimValues structure, used by output functions, has two new fields to better reflect the state of multiobjective solvers:

- For fgoalattain, the optimValues.atainfactor field contains the value of  $\gamma$ , the attainment factor.
- For fminimax, the optimValues.maxfval field contains the value  $\max_i F_i$ , where  $F$  is the vector of objectives.

Furthermore, the value stored in `optimValues.fval` has changed. Now `optimValues.fval` contains the vector  $F$  of objective function values. For a complete description of the current `optimValues` structure, see “Fields in `optimValues`”.

### **Compatibility Considerations**

User code that uses the `optimValues.fval` field within an output function in `fgoalattain` and `fminimax` might need to be updated to avoid errors



## Version 4.2 (R2009a) Optimization Toolbox Software

This table summarizes what's new in Version 4.2 (R2009a):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes Summary	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “Parallel Gradient Estimation Available in fmincon Interior-Point Algorithm” on page 21
- “Enhanced Exit Messages in Selected Solvers” on page 21
- “Change in linprog Simplex Algorithm” on page 23
- “Change in fminunc Exit Flag” on page 23
- “New demos” on page 23

### Parallel Gradient Estimation Available in fmincon Interior-Point Algorithm

The fmincon solver's interior-point algorithm can now compute finite differences in parallel in order to speed the estimation of gradients. For details on how to use this parallel gradient estimation, see the “Parallel Computing for Optimization” chapter in the User's Guide.

### Enhanced Exit Messages in Selected Solvers

Solvers print exit messages by default at the end of their runs. The exit messages are different in R2009a for several solvers, and the messages have been enhanced with new functionality. The following sections describe the new features and changes. There is more information in the “Exit Flags and Exit Messages” section of the User's Guide.

The following solvers have enhanced exit messages:

- fgoalattain

- `fmincon`
- `fminimax`
- `fminunc`
- `fseminf`

### **Links to More Information Window**

The enhanced exit messages include hyperlinks within their exit messages. These hyperlinks bring up a window containing further information about the terms used in the exit messages.

### **Link for More Detail in Command Window**

A `<stopping criteria details>` hyperlink may appear at the end of an exit message, depending on the solver and setting of the `Display` option. This link causes the solver to print more detail about the exit conditions to the MATLAB Command Window.

### **New Display Option Values Control Default Detail**

There are new values of the `Display` option to control whether detailed exit messages appear instead of the default (simpler) messages. The new values are:

- `'final-detailed'`
- `'iter-detailed'`
- `'notify-detailed'`

These settings have the same effect as the corresponding settings without `'-detailed'`, but give detailed exit messages instead of the default exit messages. For solvers without the new exit messages, the `'-detailed'` options give the same behavior as without `'-detailed'`.

### **Messages in Output Structure**

For solvers with enhanced exit messages, the `message` field of the output structure contains both the default (simpler) and the detailed exit messages,

separated by a line of text stating `Stopping criteria details:`. The message field does not contain hyperlinks; it contains only text.

### **Compatibility Considerations**

For solvers with enhanced exit messages, the content of `output.message` contains many more characters than before. User code that relies on this field may need to be modified in order to display the larger exit message satisfactorily.

## **Change in `linprog` Simplex Algorithm**

The simplex algorithm of `linprog` now detects when there is no progress in the solution process. It attempts to continue by performing bound perturbation.

### **Compatibility Considerations**

The simplex algorithm of `linprog` might arrive at different solutions than before, and can solve more problems than before.

## **Change in `fminunc` Exit Flag**

One exit flag in the `fminunc` medium-scale solver was changed from `-2` to `5`. This flag appears when the solver predicts a change in function value at the next step in its iterations will be less than the `TolFun` tolerance. This condition can occur at a relative minimum, which should be reported by a positive flag.

### **Compatibility Considerations**

This change might cause users (or code) that examine exit flags to evaluate a result more favorably than previously, since positive exit flags represent normal termination of solvers.

## **New demos**

There are two new demos:

- A demo showing how to use Symbolic Math Toolbox™ functions to help calculate gradients and Hessians. Run the demo at the MATLAB command line by entering `echodemo symbolic_optim_demo`.

- A demo showing how to use `fseminf` for investigating the effect of parameter uncertainty. Run the demo at the MATLAB command line by entering `echodemo airpollution`.

Furthermore, the optimization tutorial demo now shows how to include extra parameters. Run the demo at the MATLAB command line by entering `echodemo tutdemo`.

## Version 4.1 (R2008b) Optimization Toolbox Software

This table summarizes what's new in Version 4.1 (R2008b):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes Summary	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “`fsolve`, `lsqcurvefit`, `lsqnonlin` Algorithm and Options Changes” on page 25
- “Optimization Tool Enables Parallel Functionality” on page 26
- “Central Finite Differences Available in Selected Solvers” on page 26
- “`lsqnonneg` Refactored” on page 27
- “Finite Difference Algorithm Tweaked” on page 27
- “DerivativeCheck Tolerance Changed” on page 28

### **`fsolve`, `lsqcurvefit`, `lsqnonlin` Algorithm and Options Changes**

- The Levenberg-Marquardt algorithm was refactored in the solvers `fsolve`, `lsqcurvefit` and `lsqnonlin`. It is now a more standard implementation, that accepts and preserves sparse Jacobians.
- Choose between the algorithms used in `fsolve`, `lsqcurvefit` and `lsqnonlin` using the new `Algorithm` option.
- There is a new `ScaleProblem` option that can sometimes help the Levenberg-Marquardt algorithm converge.
- The default `fsolve` algorithm, `'trust-region-dogleg'`, has been validated to work with sparse Jacobians.

## Compatibility Considerations

- The refactored Levenberg-Marquardt algorithm can cause `fsolve`, `lsqcurvefit` and `lsqnonlin` to yield different answers than before.
- The previous way of choosing the algorithm at the command line was to set the `LargeScale` option to 'on' or 'off', and, for all solvers but `fsolve`, to set the `LevenbergMarquardt` option to 'on' or 'off'. For `fsolve`, in addition to the `LargeScale` option, you needed to set the `NonlEqnAlgorithm` option appropriately. `LargeScale`, `NonlEqnAlgorithm`, and `LevenbergMarquardt` are now ignored, except when choosing to use the Gauss-Newton algorithm.
- The Gauss-Newton algorithm warns that soon it may no longer be available.
- The default value of the `MaxFunEvals` option in the refactored Levenberg-Marquardt algorithm is now  $200 \times \text{numberOfVariables}$ ; the previous value was  $100 \times \text{numberOfVariables}$ .

## Optimization Tool Enables Parallel Functionality

You can now access built-in parallel functionality in Optimization Tool for relevant Optimization Toolbox solvers and, if licensed, Global Optimization Toolbox solvers. The option is available when you have a license for Parallel Computing Toolbox™ functions.

## Central Finite Differences Available in Selected Solvers

The following solvers can now use central finite differences for gradient estimation:

- `fgoalattain`
- `fmincon`
- `fminimax`
- `fminunc`
- `fseminf`

The `fmincon` active-set algorithm and `fminunc` medium-scale algorithm gained central finite differences this release. The `fmincon` interior-point

algorithm already had them, and the trust-region-reflective algorithm for both solvers requires a user-supplied gradient, so does not use finite differences.

To use central finite differences, use `optimset` to set the `FinDiffType` option to 'central' instead of the default 'forward'. This causes the solver to estimate gradients by formulae such as

$$\nabla f(x) \approx \left[ \frac{f(x + \Delta_1 e_1) - f(x - \Delta_1 e_1)}{2\Delta_1}, \dots, \frac{f(x + \Delta_n e_n) - f(x - \Delta_n e_n)}{2\Delta_n} \right],$$

instead of

$$\nabla f(x) \approx \left[ \frac{f(x + \Delta_1 e_1) - f(x)}{\Delta_1}, \frac{f(x + \Delta_2 e_2) - f(x)}{\Delta_2}, \dots, \frac{f(x + \Delta_n e_n) - f(x)}{\Delta_n} \right].$$

Central finite differences take twice as many function evaluations as forward finite differences, but are usually much more accurate.

Central finite differences can work in parallel for gradient estimation in `fgoalattain`, `fmincon` active-set algorithm, and `fminimax`. For details on how to use this parallel gradient estimation, see the “Parallel Computing for Optimization” chapter in the User’s Guide.

## Isqnonneg Refactored

`Isqnonneg` was refactored. It can now use sparse matrices, and it preserves sparsity during its execution.

## Finite Difference Algorithm Tweaked

A subroutine for gradient estimation by forward finite differences in nonlinear solvers had a bug that affected it when the current point `x` had a component with the value 0. Forward finite differences are typically calculated with a step size proportional to `sqrt(eps)`, which is about  $1.5 \cdot 10^{-8}$ . When a component of `x` was 0, the step size would instead be proportional to `DiffMinChange`, which has a default value of  $10^{-8}$ . There is now no difference in step size when `x` is 0.

### **Compatibility Considerations**

Nonlinear solvers can run slightly differently whenever an iteration causes a component of  $x$  to be zero, and gradients are estimated by forward finite differences.

### **DerivativeCheck Tolerance Changed**

The `DerivativeCheck` option enables you to ascertain whether the derivative (gradient) functions that you supply for objective or constraint functions give *approximately* the same values as those estimated by a solver using finite differences. The meaning of “approximately” has changed. Now it means the relative error of each component of the gradient is less than  $10^{-6}$ , unless the size of an analytically given component is smaller than 1, in which case it means the absolute difference is less than  $10^{-6}$ . Previously, the gradients were considered approximately equal if the maximum absolute error in any component of the gradient was less than  $(10^{-6} * \text{norm of analytic gradient}) + 10^{-5}$ .

### **Compatibility Considerations**

Some problems will now report violations of the `DerivativeCheck` condition, when previously they would not.



## Version 4.0 (R2008a) Optimization Toolbox Software

This table summarizes what's new in Version 4.0 (R2008a):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes Summary	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “Parallel Computing Toolbox Support in `fmincon`, `fminimax`, and `fgoalattain`” on page 29
- “Combined and Extended `optimtool`” on page 29
- “New `fmincon` Solver, New Option Algorithm for `fmincon`, Option `LargeScale` Changed” on page 30
- “External Interface to KNITRO Libraries” on page 30
- “Default `PrecondBandWidth` = Inf in `lsqcurvefit`, `lsqnonlin`, and `fsolve`” on page 31
- “New Option `TolConSQP` with Incompatible Default Value” on page 31
- “Field `constrviolation` in Output Structure” on page 31

### Parallel Computing Toolbox Support in `fmincon`, `fminimax`, and `fgoalattain`

`fmincon`, `fminimax`, and `fgoalattain` can take finite differences in parallel in order to speed the estimation of gradients. For details on how to use this parallel gradient estimation, see the “Parallel Computing for Optimization” chapter in the User’s Guide.

### Combined and Extended `optimtool`

The Global Optimization Toolbox GUIs `gatool` and `psearchtool` have been combined into the Optimization Tool GUI. To access these GUIs, type `optimtool` at the command line, and choose the appropriate solver.

Furthermore, three new Global Optimization Toolbox solvers were added to Optimization Tool: `gamultiobj`, `simulannealbnd`, and `threshacceptbnd`.

Optimization Tool shows Global Optimization Toolbox solvers only if these solvers are licensed.

## **New `fmincon` Solver, New Option Algorithm for `fmincon`, Option `LargeScale` Changed**

The new interior-point algorithm is a large-scale algorithm that can handle all types of constraints. It has several new options, explained in the `fmincon` function reference pages.

`fmincon` now has three algorithms. Choose between them by setting the new option `Algorithm` to:

- `'trust-region-reflective'` (formerly known as `'large scale'`)
- `'active-set'` (formerly known as `'medium scale'`)
- `'interior-point'`

By default, `Algorithm = 'trust-region-reflective'`.

### **Compatibility Considerations**

The previous way of choosing the algorithm at the command line was to set option `LargeScale` to `'on'` or `'off'`. `LargeScale` is now ignored, except when `LargeScale = 'off'` and `Algorithm = 'trust-region-reflective'`. In this case, the `'active-set'` algorithm is used, to minimize backward incompatibility.

### **External Interface to KNITRO Libraries**

Use the new `ktrlink` function to call KNITRO optimization libraries from Ziena Optimization, Inc. KNITRO libraries must be purchased separately. The External Interface chapter of the User's Guide describes the `ktrlink` function.

## Default PrecondBandWidth = Inf in lsqcurvefit, lsqnonlin, and fsolve

The default value of the PrecondBandWidth option changed from 0 to Inf for the lsqcurvefit, lsqnonlin, and fsolve solvers. This change was beneficial in the vast majority of tested problems.

In Optimization Tool, the default in **Algorithm settings > Subproblem algorithm** is now **Cholesky factorization**, instead of **Preconditioned CG = 0**.

### Compatibility Considerations

The new default can lead to slower performance for problems with high-dimensional nonlinearities. If this happens, change the default to another value such as 0 (the previous default).

## New Option TolConSQP with Incompatible Default Value

The new TolConSQP option exposes a parameter that was fixed at eps before. The parameter is used in the fmincon, fminimax, fgoalattain, and fseminf solvers.

### Compatibility Considerations

The new default value is TolConSQP = 1e-6. This did not affect a vast majority of tested cases, and was beneficial in some. If you want exactly the same behavior as before, set TolConSQP = eps using optimset.

## Field constrviolation in Output Structure

The constrviolation field now exists in the output structure for the fgoalattain, fmincon, fminimax, and fseminf functions; it measures the nonlinear constraint violation.

## Version 3.1.2 (R2007b) Optimization Toolbox Software

This table summarizes what's new in Version 3.1.2 (R2007b):

<b>New Features and Changes</b>	<b>Version Compatibility Considerations</b>	<b>Fixed Bugs and Known Problems</b>
No	No	Bug Reports Includes fixes

## Version 3.1.1 (R2007a) Optimization Toolbox Software

This table summarizes what's new in Version 3.1.1 (R2007a):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes Summary	Bug Reports Includes fixes

Changes introduced in this version are:

### Changes to Outputs of Multiobjective Solvers

- `fminimax` now returns the value of `max(fval)` in the output `maxfval`.
- The iterative display of `fminimax` and `fgoalattain` have changed.

### Compatibility Considerations

- The third output argument of the solver `fminimax`, `maxfval`, is described in the documentation as the maximum of the objective functions in the input `fun` evaluated at the solution `x`, that is, `max(fval)`. Before this release, `fminimax` actually returned the maximum of the objective functions in the reformulated minimax problem internally constructed by the algorithm. This value was typically very close to, but not necessarily equal to, `max(fval)`. `fminimax` now returns the exact value of `max(fval)` in the output `maxfval`.
- The iterative display for `fminimax` includes a new column with header `Objective value` that reports the objective function value of the nonlinear programming reformulation of the minimax problem. The column header `Max{F, constraints}` has been changed to `Max constraint`, and the column now contains the maximum violation among all constraints, both internally constructed and user-provided.

The iterative display for `fgoalattain` now shows the value of the attainment factor in the `Attainment factor` column. A new column, `Max`

`constraint`, contains the maximum violation among all constraints, both internally constructed and user-provided.

## Version 3.1 (R2006b) Optimization Toolbox Software

This table summarizes what's new in Version 3.1 (R2006b):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	Yes—Details labeled as <b>Compatibility Considerations</b> , below. See also Summary.	Bug Reports Includes fixes

New features and changes introduced in this version are:

- “New Optimization Tool” on page 35
- “Plot Functions Option Added” on page 36
- “Output Function Option Enhanced to Accept Multiple Functions” on page 36
- “Changes to the Output Function” on page 36

### New Optimization Tool

The Optimization Tool is a graphical user interface (GUI) for performing common optimization tasks with the Optimization Toolbox. Using the `optimtool`, you can do the following:

- Select a solver and define your optimization problem.
- Set and inspect optimization options and their default values.
- Run problems and visualize results.
- Import and export problem definitions, algorithm options, and results between the MATLAB workspace and the Optimization Tool.
- Automatically generate M-code to capture, automate, and recreate your problem.
- Access built-in help.

## Plot Functions Option Added

You can now specify the `PlotFcns` option in the `optimset` function or using the Optimization Tool for use with an Optimization Toolbox solver. With this option, you can plot various measures of progress while the algorithm executes. You can select from several predefined plots, or you can write your own.

## Output Function Option Enhanced to Accept Multiple Functions

You can now specify more than one output function in the `OutputFcn` option.

## Changes to the Output Function

The output function input `x` and fields in the `optimValues` structure have the following changes that address bugs in previous releases:

- `residual` now returns the residual vector for `lsqnonlin` and `lsqcurvefit`.
- `resnorm` contains the sum of squares and has been added for `lsqnonlin` and `lsqcurvefit`. The previous field `fval` has been removed for these functions.
- `procedure` has been removed for `lsqnonlin`, `lsqcurvefit`, and `fsolve`.
- `x` now returns the expected shape and size for `fgoalattain` and `fminimax`.

## Compatibility Considerations

The above changes to the input `x` and `optimValues` structure have the following compatibility considerations in the output function:

- If you have references to the `residual` in a previous version, note that the value of this field has changed for `lsqnonlin` and `lsqcurvefit`. This fixes the problem addressed by the bug report S-289285.
- Any references to `fval` for `lsqnonlin` and `lsqcurvefit` need to be updated to `resnorm`. This fixes the problem addressed by the bug report S-289285.
- Any references to `procedure` for `lsqnonlin` and `lsqcurvefit` need to be removed. This fixes the problem addressed by the bug report S-291974.



- Previously, for `fgoalattain` and `fminimax`, `x` returned a column vector with an additional last element. If you have references to the values for `x` in a previous version, the extra element must be removed and the output vector may need to be reshaped. This fixes the problem addressed by the bug report S-315658.

## Version 3.0.4 (R2006a) Optimization Toolbox Software

This table summarizes what's new in Version 3.0.4 (R2006a):

<b>New Features and Changes</b>	<b>Version Compatibility Considerations</b>	<b>Fixed Bugs and Known Problems</b>
No	No	Bug Reports Includes fixes

## Version 3.0.3 (R14SP3) Optimization Toolbox Software

This table summarizes what's new in Version 3.0.3 (R14SP3):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems
Yes Details below	No	Bug Reports Includes fixes

New features and changes introduced in this version are:

### Notify Parameter Added to Display Option for Five Functions

You can now set the optimization option `Display` to `'notify'` for the functions `fmincon`, `fminunc`, `fminimax`, `fgoalattain`, and `fseminf`. When `Display` is set to `'notify'`, the output is displayed only if the function does not converge.

## Compatibility Summary for Optimization Toolbox Software

This table summarizes new features and changes that might cause incompatibilities when you upgrade from an earlier version, or when you use files on multiple versions. Details are provided in the description of the new feature or change.

Version (Release)	New Features and Changes with Version Compatibility Impact
<b>Latest Version</b> <b>V6.2 (R2012a)</b>	See the <b>Compatibility Considerations</b> subheading for each of these changes or new features: <ul style="list-style-type: none"> <li>• “Enhanced Robustness in fminunc” on page 4</li> <li>• “Levenberg-Marquardt Algorithm Tweak” on page 5</li> <li>• “fmincon sqp Algorithm Tweak” on page 5</li> </ul>
<b>V6.1 (R2011b)</b>	See the <b>Compatibility Considerations</b> subheading for each of these changes or new features: <ul style="list-style-type: none"> <li>• “Gauss-Newton Algorithm Removed” on page 7</li> <li>• “DerivativeCheck Changes” on page 7</li> <li>• “fmincon ScaleProblem Default Changed” on page 8</li> <li>• “fsolve trust-region-dogleg Algorithm Change” on page 8</li> </ul>

Version (Release)	New Features and Changes with Version Compatibility Impact
	<ul style="list-style-type: none"> <li>• “Conversion of Error and Warning Message Identifiers” on page 8</li> </ul>
V6.0 (R2011a)	<p>See the <b>Compatibility Considerations</b> subheading for each of these changes or new features:</p> <ul style="list-style-type: none"> <li>• “New Quadratic Programming Algorithm” on page 10</li> <li>• “New Defaults in DiffMinChange and DiffMaxChange Options” on page 12</li> <li>• “Output Structure Tweak” on page 12</li> </ul>
V5.1 (R2010b)	None
V5.0 (R2010a)	<p>See the <b>Compatibility Considerations</b> subheading for this change:</p> <ul style="list-style-type: none"> <li>• “lsqnonneg No Longer Uses x0” on page 16</li> </ul>
V4.3 (R2009b)	<p>See the <b>Compatibility Considerations</b> subheading for each of these new features or changes:</p> <ul style="list-style-type: none"> <li>• “Enhanced Exit Messages in Selected Solvers” on page 18</li> <li>• “Changes in quadprog” on page 19</li> <li>• “Changes in linprog” on page 19</li> <li>• “Multiobjective optimValues Changes” on page 19</li> </ul>

<b>Version (Release)</b>	<b>New Features and Changes with Version Compatibility Impact</b>
V4.2 (R2009a)	<p>See the <b>Compatibility Considerations</b> subheading for each of these new features or changes:</p> <ul style="list-style-type: none"><li>• “Enhanced Exit Messages in Selected Solvers” on page 21</li><li>• “Change in linprog Simplex Algorithm” on page 23</li><li>• “Change in fminunc Exit Flag” on page 23</li></ul>
V4.1 (R2008b)	<p>See the <b>Compatibility Considerations</b> subheading for each of these new features or changes:</p> <ul style="list-style-type: none"><li>• “fsolve, lsqcurvefit, lsqnonlin Algorithm and Options Changes” on page 25</li><li>• “Finite Difference Algorithm Tweaked” on page 27</li><li>• “DerivativeCheck Tolerance Changed” on page 28</li></ul>

<b>Version (Release)</b>	<b>New Features and Changes with Version Compatibility Impact</b>
V4.0 (R2008a)	<p>See the <b>Compatibility Considerations</b> subheading for each of these new features or changes:</p> <ul style="list-style-type: none"> <li>• “New fmincon Solver, New Option Algorithm for fmincon, Option LargeScale Changed” on page 30</li> <li>• “Default PrecondBandWidth = Inf in lsqcurvefit, lsqnonlin, and fsolve” on page 31</li> <li>• “New Option TolConSQP with Incompatible Default Value” on page 31</li> </ul>
V3.1.2 (R2007b)	None
V3.1.1 (R2007a)	<p>See the <b>Compatibility Considerations</b> subheading for this change:</p> <ul style="list-style-type: none"> <li>• “Changes to Outputs of Multiobjective Solvers” on page 33</li> </ul>
V3.1 (R2006b)	<p>See the <b>Compatibility Considerations</b> subheading for this change:</p> <ul style="list-style-type: none"> <li>• “Changes to the Output Function” on page 36</li> </ul>
V3.0.4 (R2006a)	None
V3.0.3 (R14SP3)	None