

Genetic Algorithm and Direct Search Toolbox 2

Solve optimization problems using genetic or direct search algorithms

The Genetic Algorithm and Direct Search Toolbox extends the optimization capabilities in MATLAB® and the Optimization Toolbox with tools for using the genetic and direct search algorithms. You can use these algorithms for problems that are difficult to solve with traditional optimization techniques, including problems that are not well defined or are difficult to model mathematically. You can also use them when computation of the objective function is discontinuous, highly nonlinear, stochastic, or has unreliable or undefined derivatives.

The Genetic Algorithm and Direct Search Toolbox complements other optimization methods to help you find good starting points. You can then use traditional optimization techniques to refine your solution.

Toolbox functions, which can be accessed through a graphical user interface (GUI) or the MATLAB command line, are written in the open MATLAB language. This means that you can inspect the algorithms, modify the source code, and create your own custom functions.

Graphical User Interface and Command-Line Functions

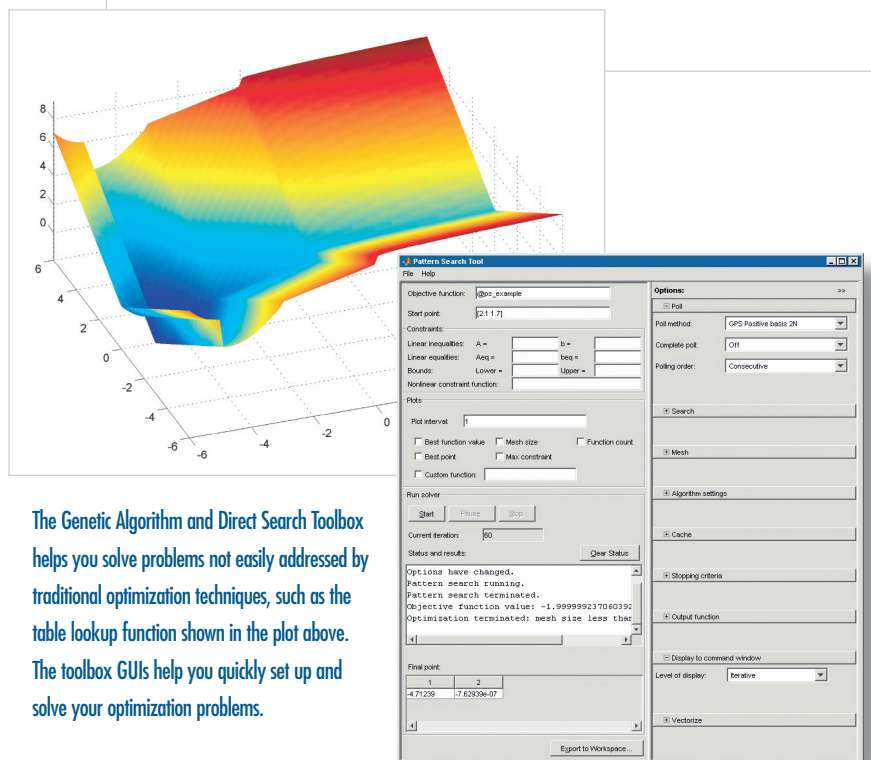
You can access the Genetic Algorithm and Direct Search Toolbox functions from the command line and from the GUIs—one for the genetic algorithm and one for direct search. The GUIs let you quickly define your problem and set a variety of algorithm options to fine-tune your optimization.

Tools for managing your optimization, monitoring performance, and defining stopping criteria are also included.

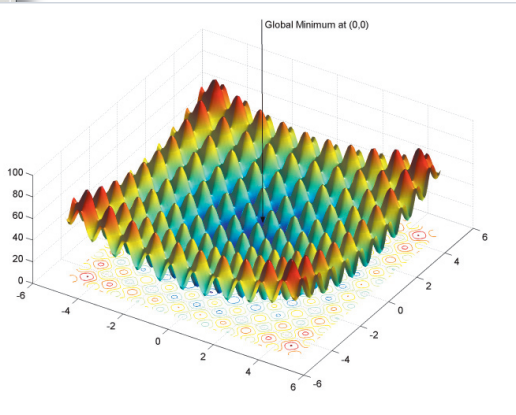
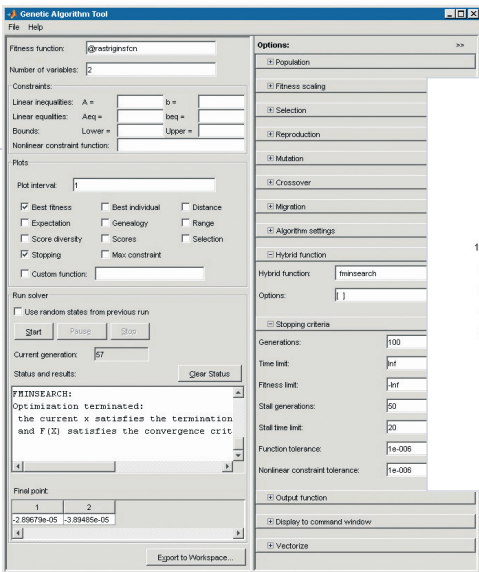
While your optimization is running, you can change options to refine the solution and update performance results. You can also customize the toolbox by providing your own algorithm options.

KEY FEATURES

- Graphical user interfaces and command-line functions for quickly setting up problems, setting algorithm options, and monitoring progress
- Genetic algorithm tools with options for creating initial population, fitness scaling, parent selection, crossover, and mutation
- Direct search tools that implement a pattern search method, with options for defining mesh size, polling technique, and search method
- Ability to solve optimization problems with nonlinear, linear, and bound constraints
- Functions for integrating Optimization Toolbox and MATLAB routines with the genetic or direct search algorithm
- Support for automatic M-code generation



The Genetic Algorithm and Direct Search Toolbox helps you solve problems not easily addressed by traditional optimization techniques, such as the table lookup function shown in the plot above. The toolbox GUIs help you quickly set up and solve your optimization problems.



Visualization of Rastrigin's function, which contains many local minima and one global minimum. The genetic algorithm helps you determine the best solution for functions with several local minima, while the Genetic Algorithm Tool provides access to all key components for defining your problem, including the algorithm options.

Genetic Algorithm Tools

The genetic algorithm solves optimization problems by mimicking the principles of biological evolution, repeatedly modifying a population of individual points using rules modeled on gene combinations in biological reproduction. Due to its random nature, the genetic algorithm improves your chances of finding a global solution.

The Genetic Algorithm and Direct Search Toolbox provides the following standard algorithm options.

Step	Algorithm Options
Creation	Uniform
Fitness scaling	Rank-based, proportional, top (truncation), linear scaling, shift
Selection	Roulette, stochastic uniform selection (SUS), tournament, uniform
Crossover	Arithmetic, heuristic, intermediate, scattered, single-point, two-point
Mutation	Adaptive feasible, Gaussian, uniform
Plotting	Best fitness, best individual, distance among individuals, expectation of individuals, range, diversity of population, selection index, stopping conditions

The toolbox also lets you specify:

- Constraints for your optimization problem
- Population size
- Number of elite children
- Crossover fraction
- Migration among subpopulations (using ring topology)

You can customize these algorithm options by providing user-defined functions and represent your problem in a variety of data formats, for example by using variables that are either mixed-integer or complex.

You can base the stopping criteria for the algorithm on time, stalling, fitness limit, or number of generations. Finally, you can vectorize your fitness function to improve execution speed.

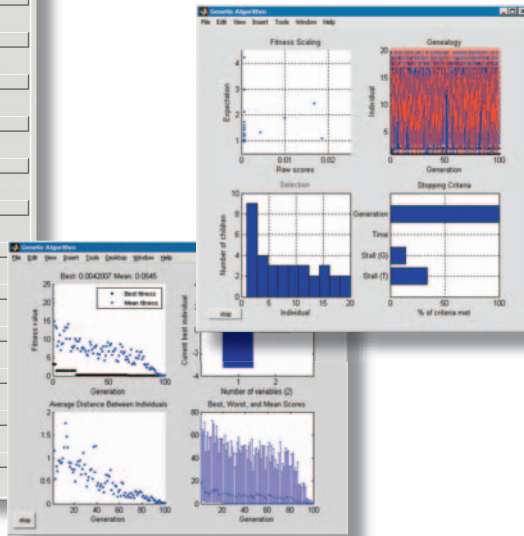
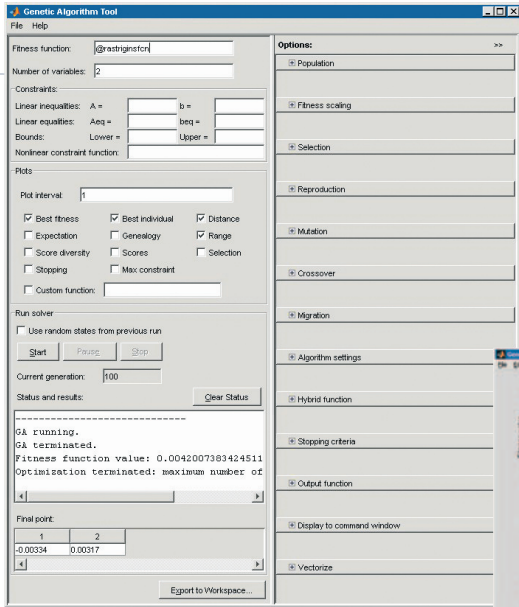
Direct Search Algorithm Tools

The Genetic Algorithm and Direct Search Toolbox contains two direct search algorithms: the generalized pattern search algorithm (GPS) and mesh adaptive search algorithm (MADS). While more traditional optimization algorithms use information about the gradient or higher derivatives to search for an optimal point, these toolbox algorithms use a pattern search method that implements a minimal and maximal positive basis pattern. The pattern search method handles optimization problems with nonlinear, linear, and bound constraints, and does not require functions to be differentiable or continuous.

The pattern search algorithms include the following options:

- **Polling methods** let you decide how to generate and evaluate the points in a pattern and the maximum number of points generated at each step. You can also control the polling order of the points to improve efficiency.
- **Search methods** let you choose a search method that is more efficient than a poll step. You can perform a search in a pattern or in the entire search space. Global search methods, like the genetic algorithm, can be used to obtain a good starting point.
- **Mesh** lets you control how the pattern changes over iterations and adjusts the mesh for problems that vary in scale across dimensions. You can choose the initial mesh size, mesh refining factor, or mesh contraction factor. The mesh accelerator speeds up convergence when it is near a minimum.
- **Cache** lets you store points evaluated during optimization of expensive objective functions. You can specify the size and tolerance of the cache that the pattern search algorithm uses and vary the cache tolerance as the algorithm proceeds, improving optimization speed and efficiency.
- **Nonlinear constraint algorithm settings** let you specify a penalty parameter for the nonlinear constraints as well as a penalty update factor.

You can change any of these options from the command line or the GUI.



Run-time visualizations, generated while the function is being optimized, using plot functions in the Genetic Algorithm Tool.

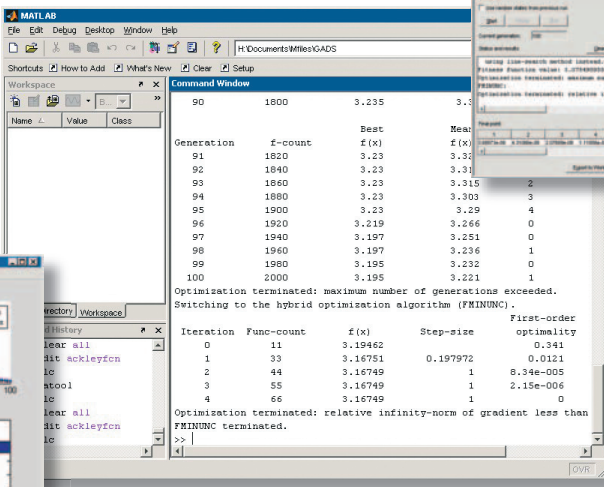
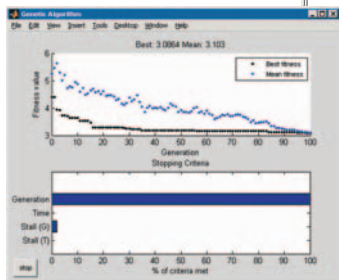
Solving Constrained Optimization Problems

The genetic and direct search algorithms implemented in the toolbox let you solve optimization problems with nonlinear, linear, and bound constraints. For linearly constrained optimization problems, the algorithms identify active linear constraints and bounds to generate search directions, or mutants for the genetic algorithm. For nonlinearly constrained problems, the algorithms formulate a subproblem subject to linear constraints and bounds using penalty and Lagrange parameters. They find an approximate solution to the subproblem, update the penalty and Lagrange parameters to formulate a new subproblem, and iterate until it is solved within a specified accuracy.

Using Other Functions and Solvers

The Genetic Algorithm and Direct Search Toolbox is closely integrated with MATLAB and the Optimization Toolbox. You can use the genetic algorithm and pattern search to find good starting points and then use the Optimization Toolbox solvers or MATLAB routines to further refine your optimization. Solvers are available for both constrained and unconstrained optimization problems.

By combining algorithms, you can leverage the strengths of the toolboxes and MATLAB to improve the quality of your solutions.



Output showing solutions reached when using only the genetic algorithm and when using the genetic algorithm with a function from the Optimization Toolbox. Combining algorithms can produce more accurate results.

```
function [X,FVAL,REASON,OUTPUT,POPULATION,SCORES] = gaMfile
%% This is an auto generated M file to do optimization with the Genetic
%% Algorithm and Direct Search Toolbox. Use GAOPTIMSET for default GA
%% options structure.
```

```
%%Fitness function
fitnessFunction = @objfun;
%%Number of Variables
nvars = 2 ;
%%Linear inequality constraints
Aineq = [];
Bineq = [];
%%Linear equality constraints
Aeq = [];
Beq = [];
```

```
%%Bounds
LB = [-10 -10 ];
UB = [2 2 ];
```

```
%%Nonlinear constraints
nonlconFunction = @confun;
%%Start with default options
options = gaoptimset;
```

```
%%Modify some parameters
```

```
options = gaoptimset(options,'MutationFcn' ,@mutationadaptfeasible);
options = gaoptimset(options,'Display' , 'iter');
options = gaoptimset(options,'PlotFcns' ,{ @gaplotbestf @gaplotmaxconstr });
options = gaoptimset(options,'HybridFcn' ,{ @fmincon [] });
```

```
%%Run GA
```

```
[X,FVAL,REASON,OUTPUT,POPULATION,SCORES] = ga(fitnessFunction,...
nvars,Aineq,Bineq,Aeq,Beq, LB,UB,nonlconFunction,options);
```

Algorithm options

Visualization options

Call to Optimization Toolbox

M-file of an optimization created using the automatic code generation feature in the Genetic Algorithm and Direct Search Toolbox. You can export your optimization from the GUI as commented code that can be called from the command line and used to automate routines and preserve your work.

Displaying, Monitoring, and Outputting Results

The toolbox includes a number of plotting functions for visualizing your optimization. These visualizations give you live feedback about your optimization, enabling you to make modifications while executing. Specific plotting functions are provided for both the genetic algorithm and direct search algorithms. They include function value, score histogram, genealogy, fitness value, mesh size, and function evaluations. You can show multiple plots together, select specific plots for closer examination, or add your own plotting functions.

Using the output function, you can write results to files, create your own stopping criteria, and write your own GUIs to run the toolbox solvers. You can also export the algorithm options of a completed problem and later import them back into the GUI.

Required Products

MATLAB

Optimization Toolbox

Related Products

Statistics Toolbox. Apply statistical algorithms and probability models

Neural Network Toolbox. Design and simulate neural networks

Fuzzy Logic Toolbox. Design and simulate systems based on fuzzy logic

Financial Toolbox. Analyze financial data and develop financial algorithms

Platform and System Requirements

For platform and system requirements, visit www.mathworks.com/products/gads ■

For demos, application examples, tutorials, user stories, and pricing:

- Visit www.mathworks.com

- Contact The MathWorks directly

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