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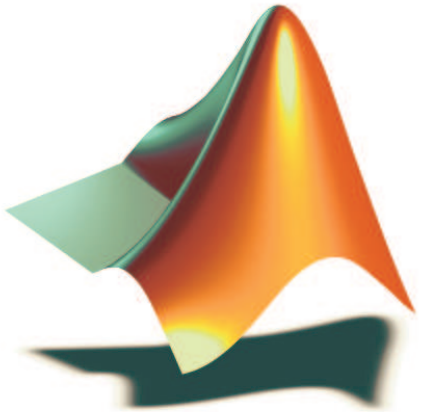
Tips & Tricks: Getting started with optimization in MATLAB®

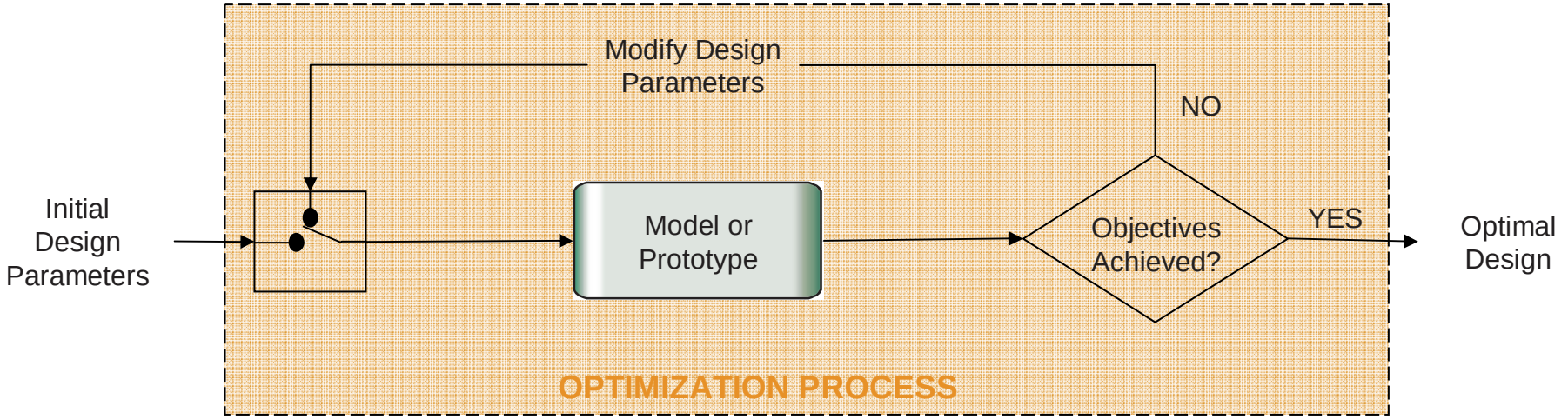
Stuart Kozola

Agenda

- Optimization: What is it, Why use it?
- Overview of MATLAB® Based Optimization Tools
- Demos: Tips, Tricks, and Best Practices
- Additional Resources
- Q&A

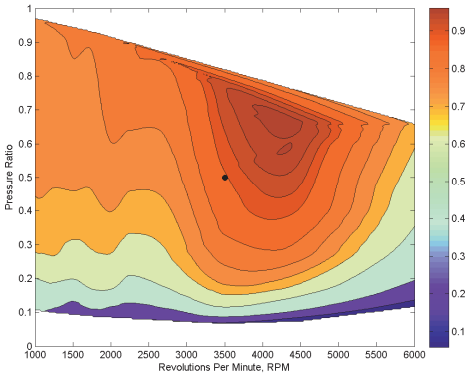


Optimization – Finding answers to problems *automatically*

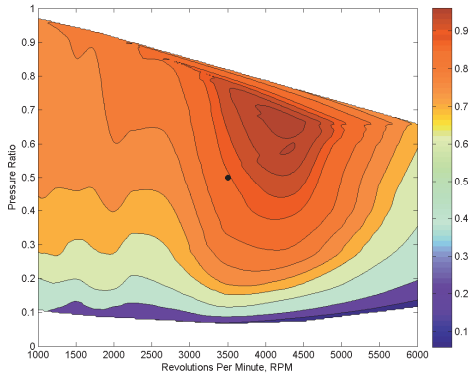


Design process can be performed:

Manually
(trial-and-error or iteratively)

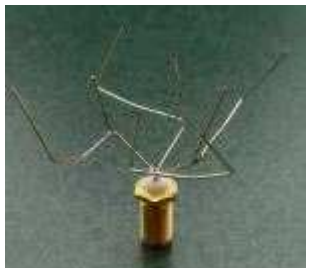


Automatically
(using optimization techniques)



Optimization benefits include:

- Finding better (optimal) designs
- Faster design evaluations
- Useful for trade-off analysis (N dimensions)
- Non-intuitive designs may be found



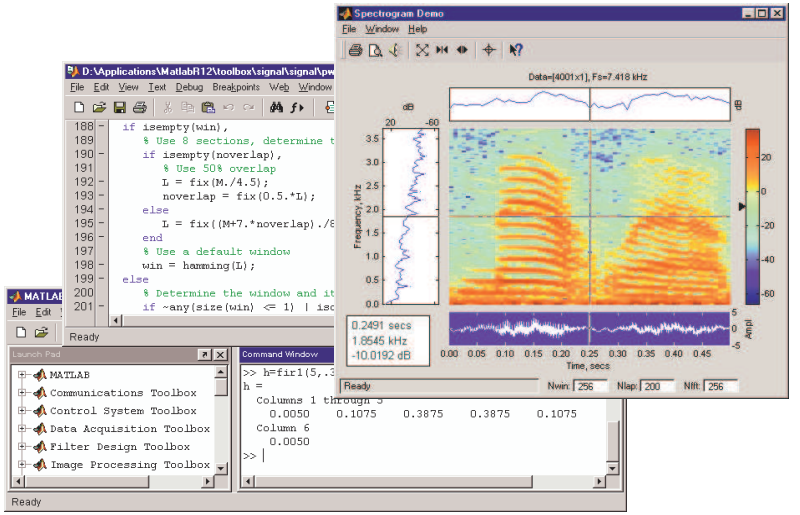
Antenna Design Using Genetic Algorithms
http://ic.arc.nasa.gov/projects/esg/research/antenna.htm

MATLAB Provides the Foundation for Optimization

MATLAB®

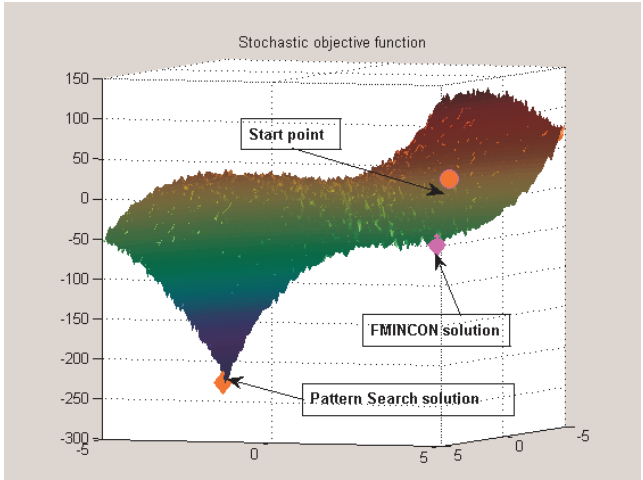
The leading environment for technical computing

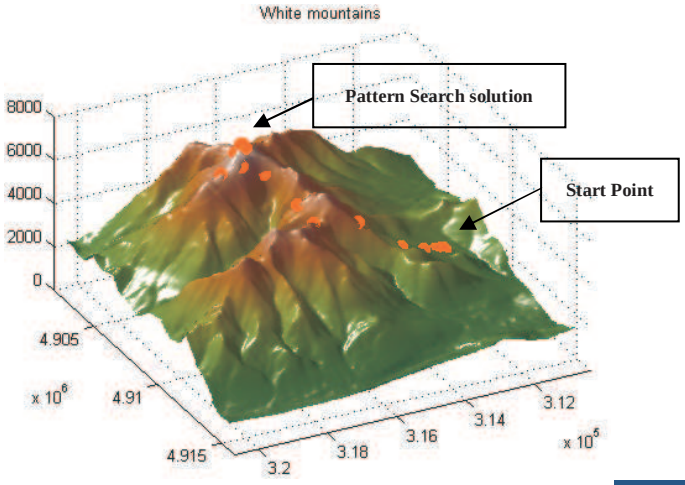
- Customizable
- Numeric computation
- Data analysis and visualization
- The *de facto* industry-standard, high-level programming language for algorithm development
- Toolboxes for statistics, optimization, symbolic math, signal and image processing, and other areas
- Foundation of the MathWorks product family



Optimization toolboxes support different problem types

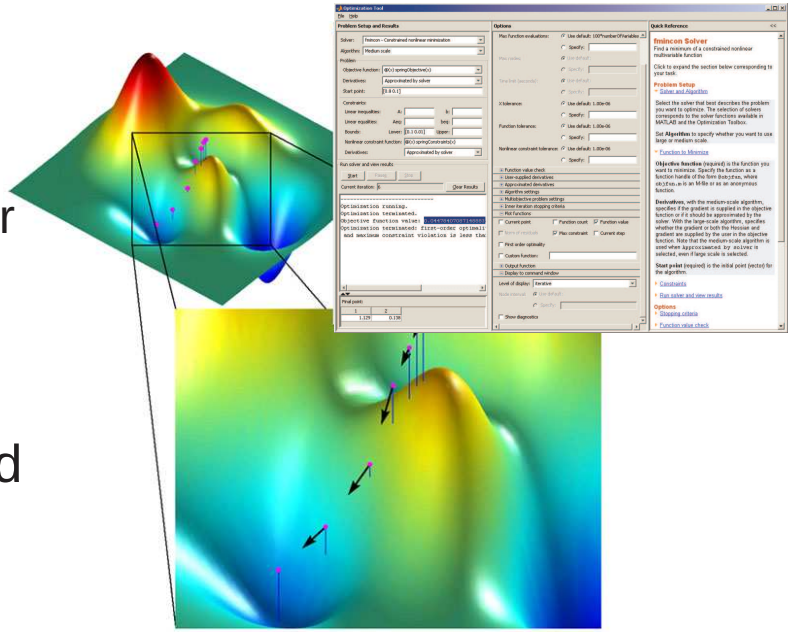
	Optimization Toolbox	Genetic Algorithm & Direct Search Toolbox
Faster	✓	
Larger Problems	✓	
Better on ▪ non-smooth ▪ noisy ▪ stochastic ▪ highly nonlinear ▪ ill-defined problems		✓
More “global”		✓
Custom data types		✓





Optimization Toolbox

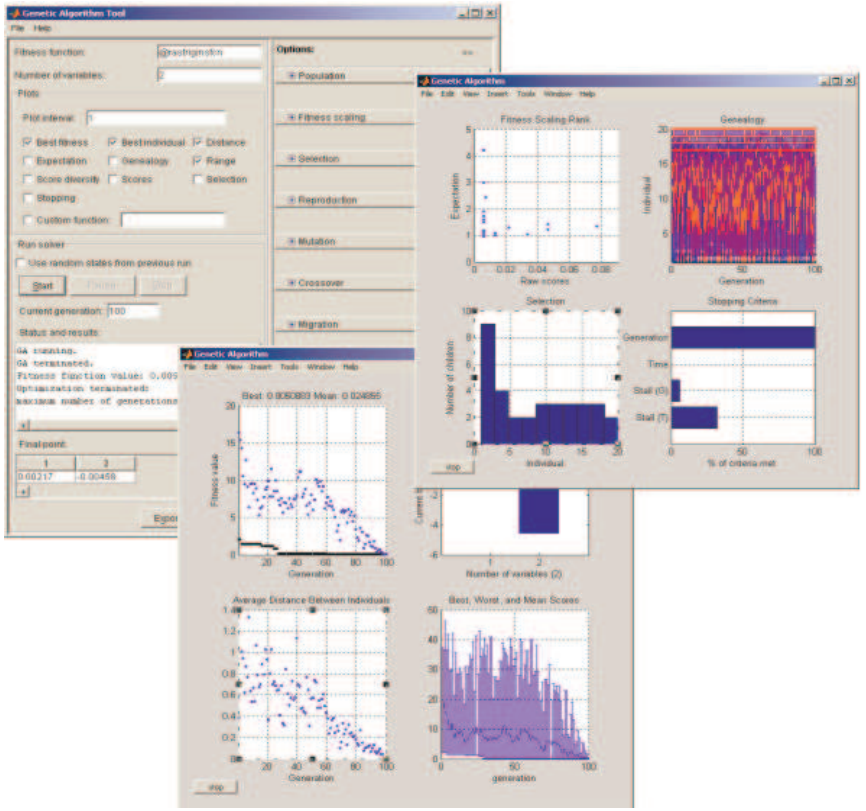
- Graphical user interface and command line functions for:
  - Linear and nonlinear programming
  - Quadratic programming
  - Nonlinear least squares and nonlinear equations
  - Multi-objective optimization
  - Binary integer programming
- Parallel computing support in selected solvers
- Customizable algorithm options
- Standard and large-scale algorithms
- Output diagnostics



Genetic Algorithm and Direct Search Toolbox

- Graphical user interface and command line functions for:
  - Genetic algorithm solver
    - Single objective
    - Multiobjective with Pareto front
  - Direct search solver
  - Simulated annealing solver

- Useful for problems not easily addressed with Optimization Toolbox:
  - Discontinuous
  - Highly nonlinear
  - Stochastic
  - Discrete or custom data types
  - Undefined derivatives



Demo

Curve Fitting Example

- MATLAB
  - Formulated as a linear system of equations

Problem Formulation

$$y(t) = c_1 + c_2 e^{-t}$$

$$y = \begin{bmatrix} 1 & e^{-t} \end{bmatrix} \begin{bmatrix} c1 \\ c2 \end{bmatrix} = Ec$$

$$c = y / E = E^{-1} y$$

MATLAB Problem (linear system form)

```
t = [0 .3 .8 1.1 1.6 2.3]';

y = [.82 .72 .63 .60 .55 .50]';

E = [ones(size(t)) exp(-t)];

c = E\y
```

Solve this overdetermined system of equations:

$$\begin{bmatrix} c1 \\ c2 \end{bmatrix} = \begin{bmatrix} 1 & e^{-0} \\ 1 & e^{-0.3} \\ 1 & e^{-0.8} \\ 1 & e^{-1.1} \\ 1 & e^{-1.6} \\ 1 & e^{-2.3} \end{bmatrix}^{-1} \begin{bmatrix} 0.82 \\ 0.72 \\ 0.63 \\ 0.60 \\ 0.55 \\ 0.50 \end{bmatrix}$$

How? Least Squares Minimization (an optimization problem)

$$y = Ec$$

$$Ec - y = 0 \quad \text{Can't solve this exactly on a computer}$$

$$\sum (Ec - y)^2 \le \varepsilon \quad \text{This can be solved with acceptable error}$$

$$\left\| Ec - y \right\|_2^2 \le \varepsilon$$

$$\min_c \left\| Ec - y \right\|_2^2 \quad \text{An optimization problem!}$$

Anatomy of an Optimization Problem

General Form Accepted by MATLAB Solvers

Objective Function

$$\min_x f(x)$$

Typically a linear or nonlinear function

Decision variables

Subject to Constraints (i.e. such that)

$$Ax \le b, \quad A_{eq}x = b_{eq}, \quad l \le x \le u$$

$$c(x) \le 0, \quad c_{eq}(x) = 0$$

Linear constraints
- inequalities
- equalities
- bounds

Nonlinear constraints
- inequalities
- equalities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Optimization Toolbox 3.1.2
Solve standard and large-scale optimization problems
The Optimization Toolbox extends the MATLAB technical computing environment with tools and widely used algorithms for standard and large-scale optimization. These algorithms solve constrained and unconstrained continuous and discrete problems. The toolbox includes functions for linear programming, quadratic programming, nonlinear optimization, nonlinear least squares, nonlinear equations, multi-objective optimization, and binary integer programming.
Introduction and Key Features
Defining, Solving, and Assessing Optimization Problems
Nonlinear Optimization and Multi-Objective Optimization
Nonlinear Least-Squares, Data Fitting, and Nonlinear Equations
Quadratic and Linear Programming
Binary Integer Programming
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MATLAB is virtually the only program that can handle the large-scale problems that we model. It is a powerful tool that provides a very flexible environment in which to build models rapidly.
- Alexander Eydeland
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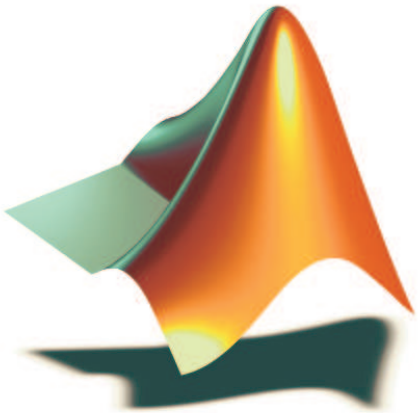
Additional Resources

Upcoming webinars

- TBD

Recorded webinars

- Introduction to Optimization Toolbox
- Reliability Analysis and Robust Design with MATLAB products
- Genetic Algorithms in Financial Applications



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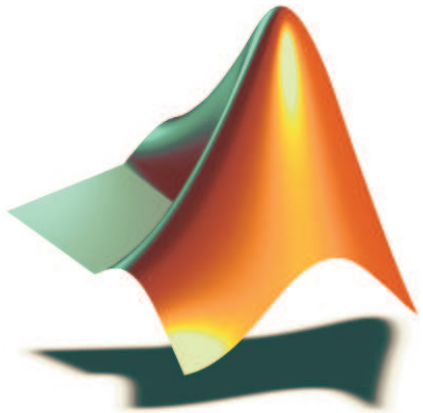

Questions?