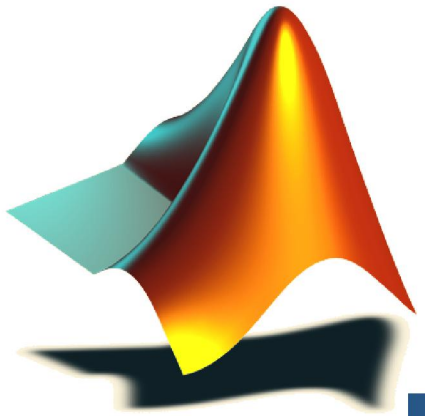
Introduction to Optimization with MATLAB® Products

Presented by: Dan Doherty

Stuart Kozola

Agenda

- Optimization Software Requirements
- Overview of MATLAB® Based Optimization Tools
- Demonstration: Optimization of a Suspension Model
- Summary
- Q&A



Optimization Software Requirements

Problem Formulation

- Easy-to-use modeling and programming environment
- Advanced numeric algorithms and math functions
- Communication with external files, software, and hardware

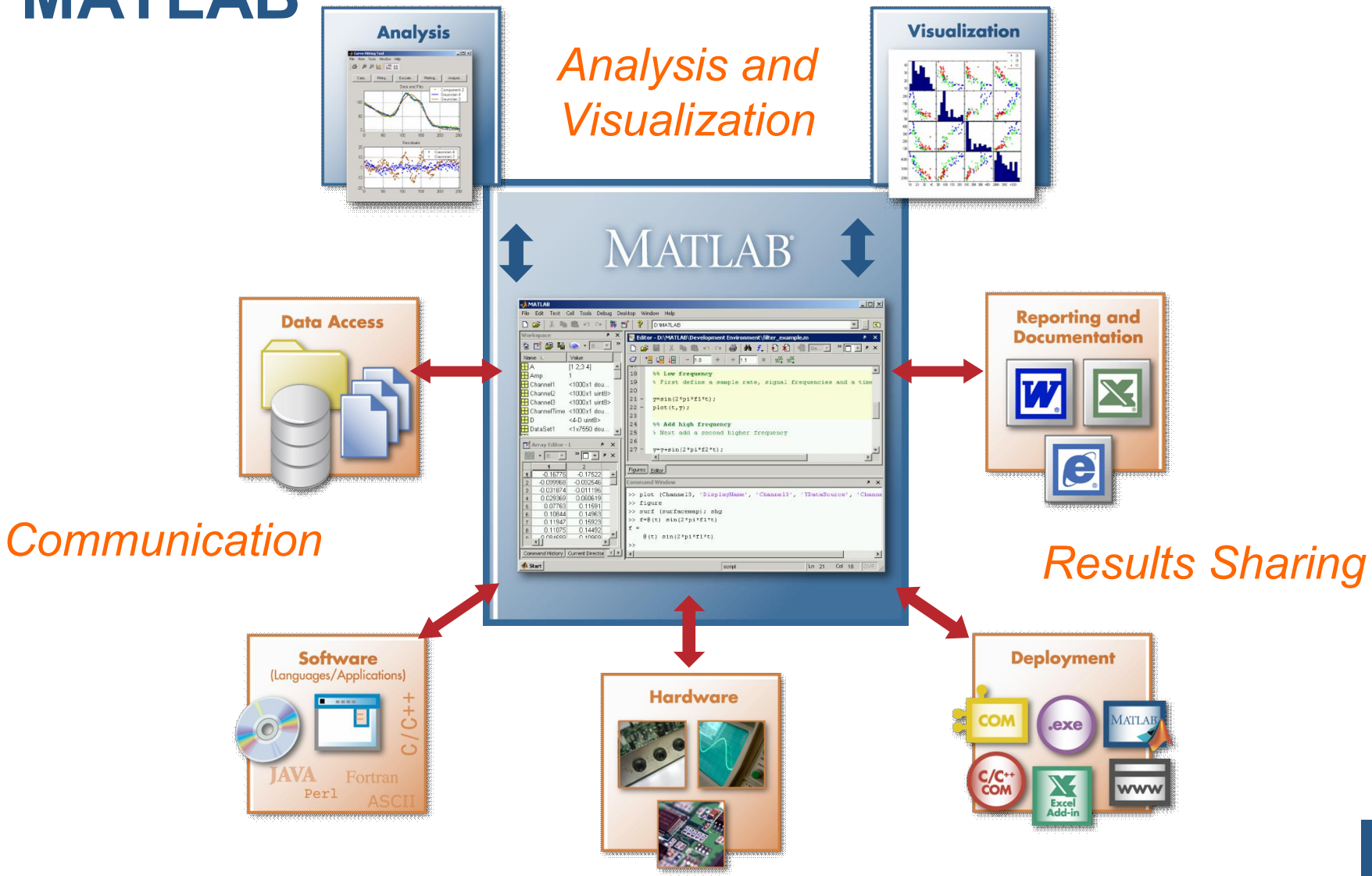
Problem Solution

- Robust solvers
- Customizable solver settings

Analysis and Visualization

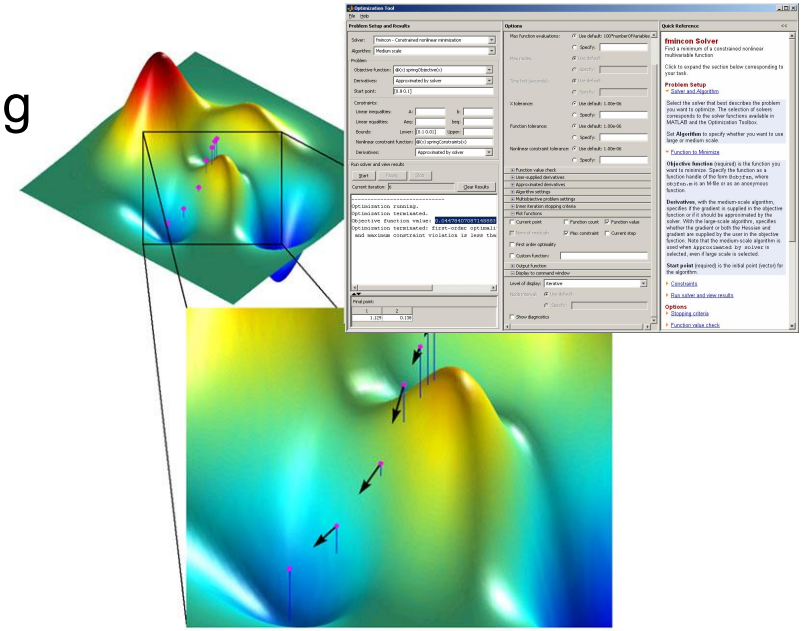
- Visualization of optimization progress
- Custom analysis and graphics

Technical Computing and Optimization with MATLAB



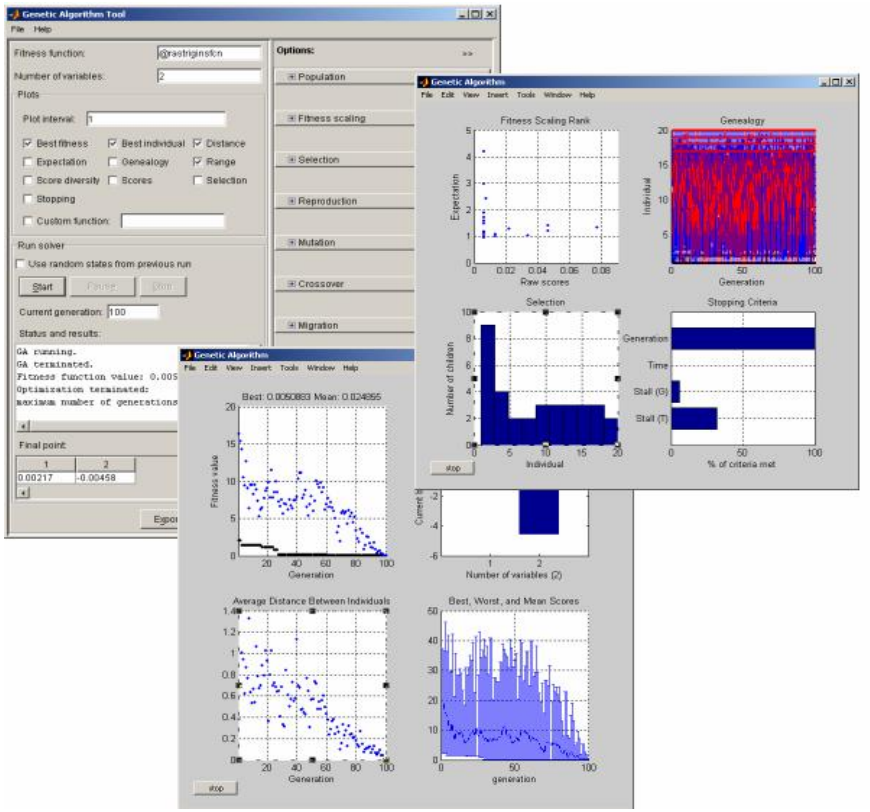
Optimization Toolbox

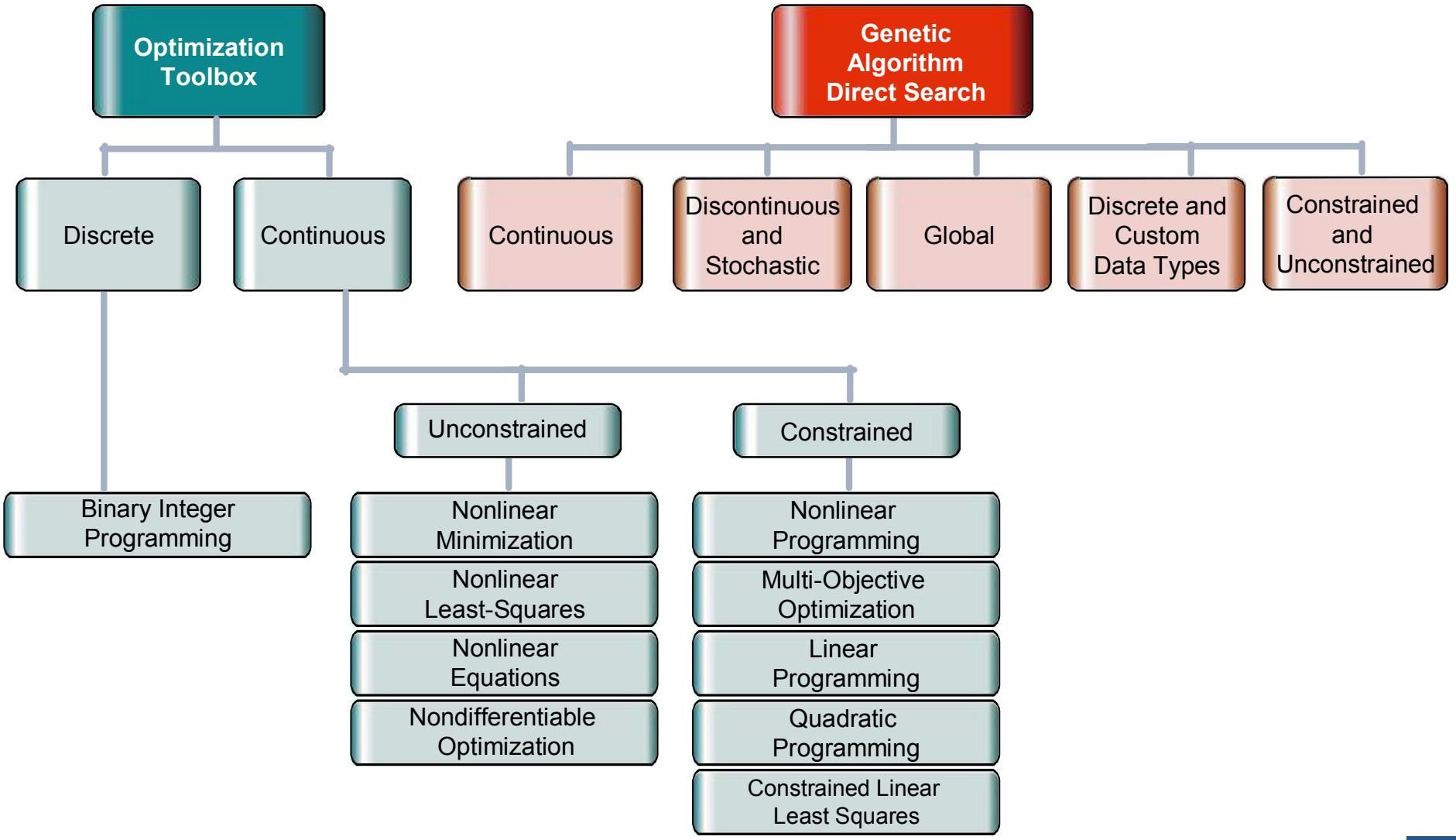
- Graphical user interface and command line functions for:
  - Linear and nonlinear programming
  - Quadratic programming
  - Nonlinear least squares and nonlinear equations
  - Multi-objective optimization
  - Binary integer programming
- Customizable algorithm options
- Standard and large-scale algorithms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



Genetic Algorithm and Direct Search Toolbox

- Graphical user interface and command line functions for:
  - Genetic algorithm solver
  - Direct search solver
- Useful for problems not easily addressed with Optimization Toolbox:
  - Discontinuous
  - Highly nonlinear
  - Stochastic
  - Discrete or custom data types
  - Undefined derivatives

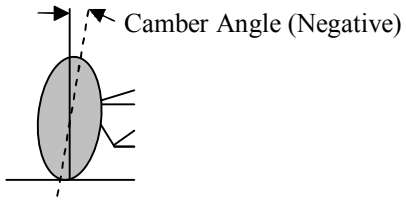



Optimization Toolbox
Genetic Algorithm Direct Search
Discrete
Continuous
Continuous
Discontinuous and Stochastic
Global
Discrete and Custom Data Types
Constrained and Unconstrained
Unconstrained
Constrained
Binary Integer Programming
Nonlinear Minimization
Nonlinear Least-Squares
Nonlinear Equations
Nondifferentiable Optimization
Nonlinear Programming
Multi-Objective Optimization
Linear Programming
Quadratic Programming
Constrained Linear Least Squares

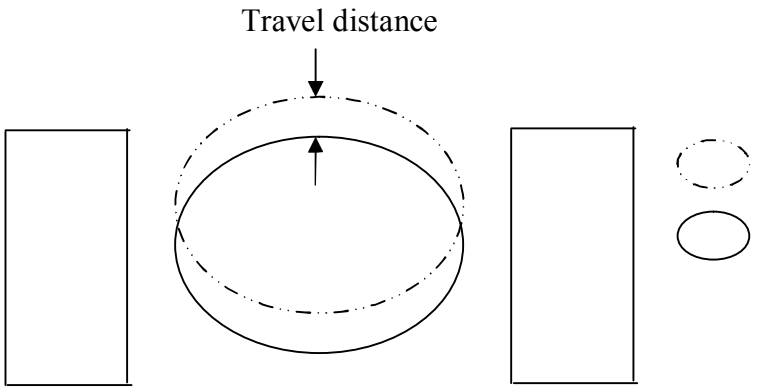
Demonstration: Optimization of a Double Wishbone Suspension System

Objective: Optimize the design of a double wishbone suspension system to achieve a desired camber angle vs. travel distance profile

Camber Angle – Tire angle with respect to the vertical

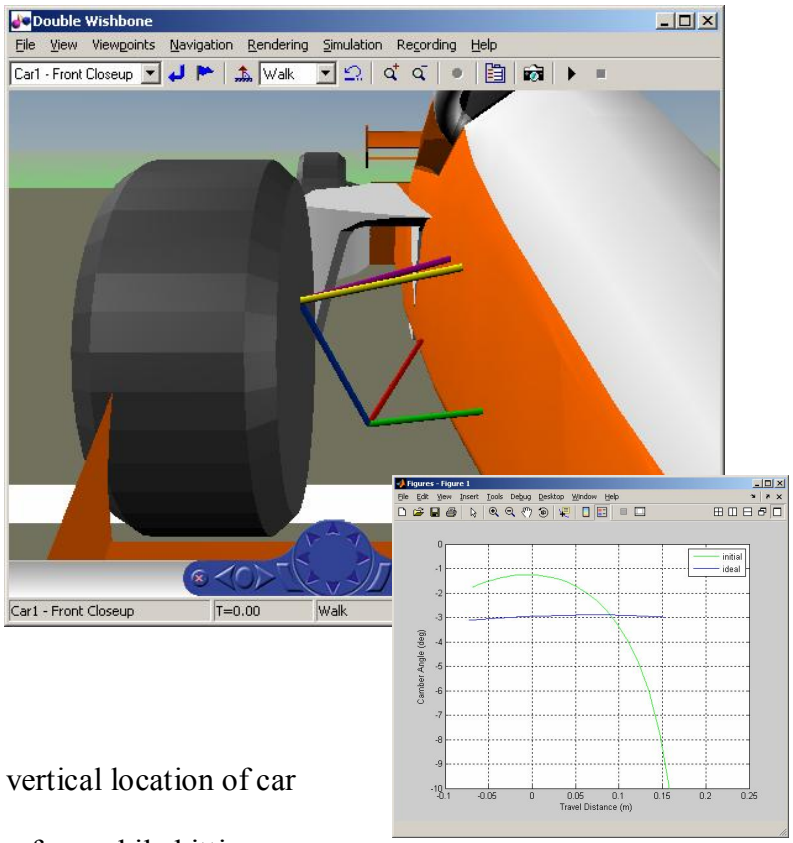


Travel Distance – Vehicle vertical distance traveled after encountering a pothole or bump



Original vertical location of car

Location of car while hitting a bump



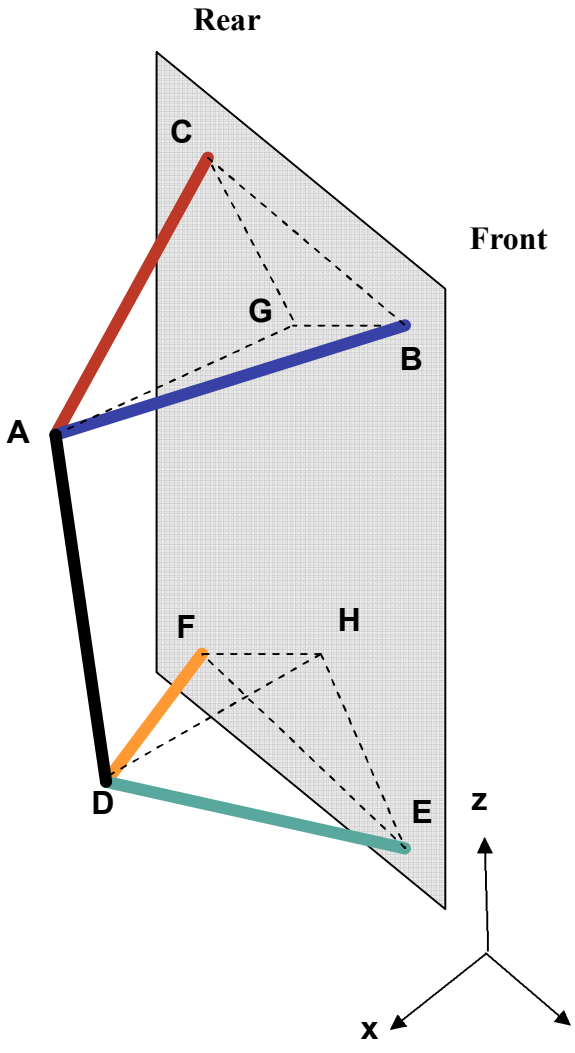
Demonstration: Problem Formulation – Inputs and Constraints

Design (Input) Variables

Upper Arm Length	$X_1 = AG$
Upper Arm Connection Point B	$(X_2, X_3, X_4) = (x_B, y_B, z_B)$
Upper Arm Connection Point C	$(X_5, X_6, X_7) = (x_C, y_C, z_C)$
Lower Arm Length	$X_8 = DG$
Upper Arm Connection Point E	$(X_9, X_{10}, X_{11}) = (x_E, y_E, z_E)$
Upper Arm Connection Point F	$(X_{12}, X_{13}, X_{14}) = (x_F, y_F, z_F)$
Connecting Ling Length	$X_{15} = AD$

Constraints

BAC Angle	$15^o \leq \theta_{BAC} \leq 30^o$
EDF Angle	$15^o \leq \theta_{EDF} \leq 30^o$
Point B/C rotation	$\theta_{BC} \leq 15^o$
Point E/F rotation	$\theta_{EF} \leq 15^o$
Upper Arm Length Limits	$6 \leq X_1 \leq 16$
Point B X-Axis Limits	$10 \leq X_2 \leq 16$
Point C X-Axis Limits	$10 \leq X_5 \leq 16$
Lower Arm Length Limits	$8 \leq X_8 \leq 18$
Point E X-Axis Limits	$6 \leq X_9 \leq 14$
Point F X-Axis Limits	$12 \leq X_{12} \leq 18$



Demonstration: Problem Formulation

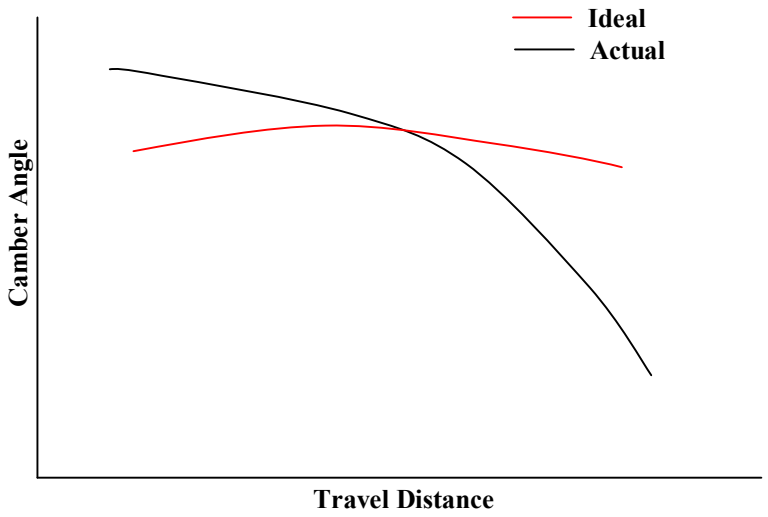
Objective function

$$\min f(x)$$

Subject to

$$A \cdot x \le 0$$

$$lb \le x \le ub$$



f(x) is a function returning the norm of the current profile relative to the ideal profile (single value)

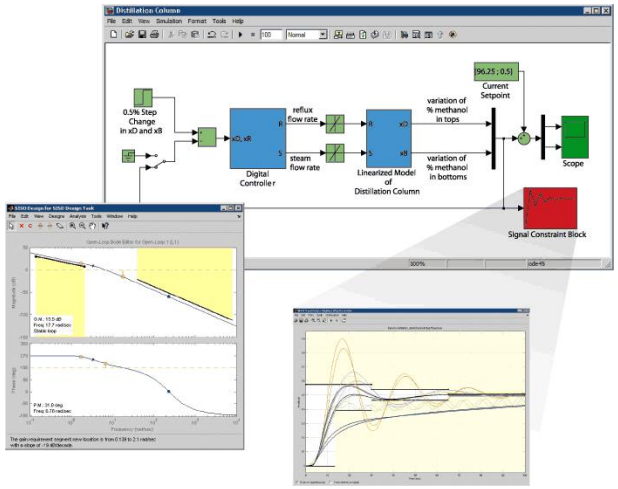
$$f(x) = norm\left[\left(\text{CamberAngle}_{Actual} - \text{CamberAngle}_{Ideal}\right) + \left(\text{TravelDistance}_{Actual} - \text{TravelDistance}_{Ideal}\right)\right]$$

Demo

Simulink Based Optimization Products

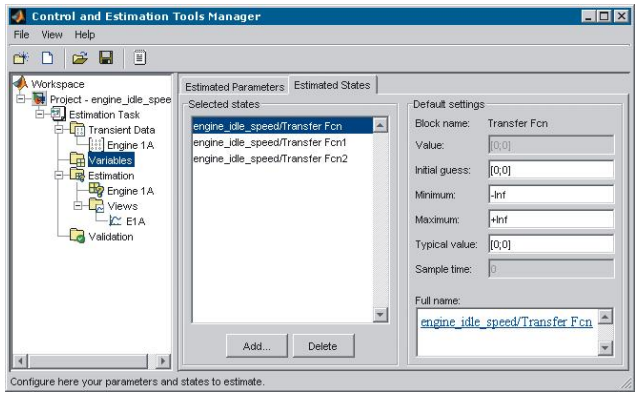
Simulink Response Optimization

- Optimize system behavior by tuning design parameters



Simulink Parameter Estimation

- Estimate model parameters using test data



Summary

Problem Formulation

- ☑ Easy-to-use modeling and programming environment
- ☑ Access to advanced numeric algorithms and math functions
- ☑ Communicate with a variety of file types, software, and hardware

Problem Solution

- ☑ Access to a variety of robust solvers
- ☑ Customizable solver settings

Analysis and Visualization

- ☑ Quickly visualize intermediate results and final solutions
- ☑ Create custom analysis and graphics

Product Overview
Description
Function List
Demos and Webinars
Related Products
System Requirements
Latest Features
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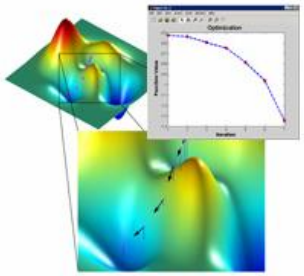
Optimization Toolbox 3.1

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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University of Waterloo
"Without Simulink, it probably would have taken us until the end of the three-year competition to complete the work required in the first year alone!"
- Matthew Stevens
» Read this story

News and Events

- Webinar: Introduction to Optimization with MATLAB® Products
- Seminar: Using MATLAB to Develop and Deploy Financial Models
- Video: Learn how Toyota Racing Development uses the Optimization Toolbox to balance design tradeoffs
- Video: Hear how IAV uses the Optimization Toolbox for their engine calibration projects
- Technical Article: Optimization with MATLAB and the Genetic Algorithm and Direct Search Toolbox

Contact Information

- North America
  - Phone: 508-647-7000
  - E-mail: support@mathworks.com
- Outside North America
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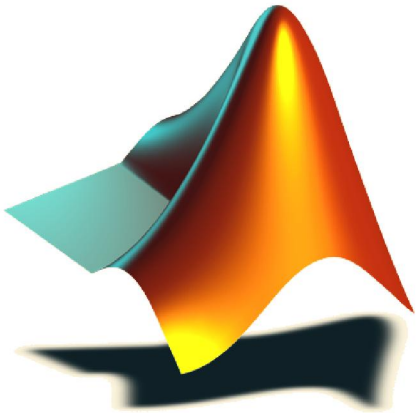

Questions?