

Design Exploration and Optimization of Systems of Systems Applications

How to apply optimization techniques when requirements are not fully known or understood

Scott Woyak, President

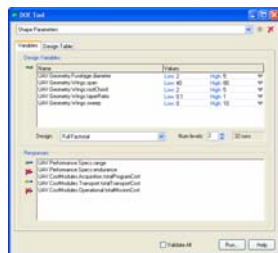


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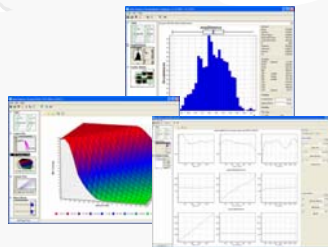
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Design of Experiments



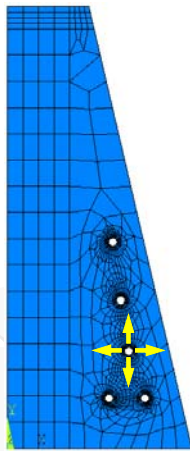
Run Matrix



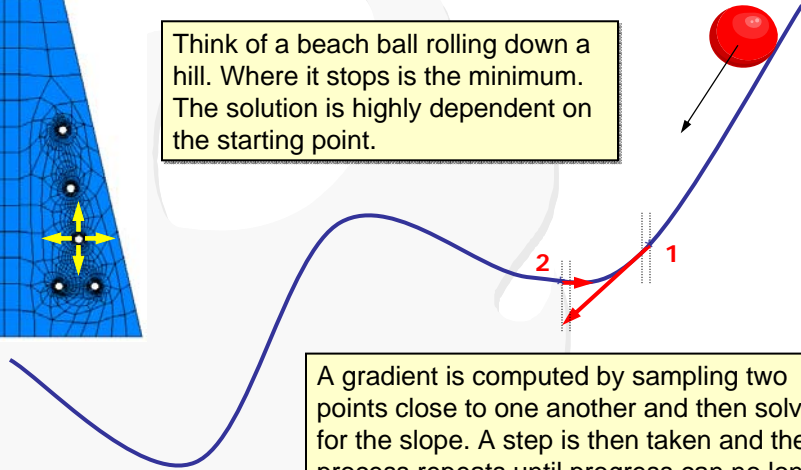
ModelCenter

Sensitivity Analysis
Parameter Scans
Optimization
Risk Analysis

Traditional Optimization: Gradient Algorithms




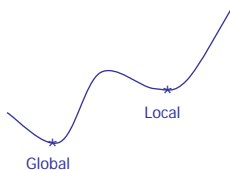


Think of a beach ball rolling down a hill. Where it stops is the minimum. The solution is highly dependent on the starting point.



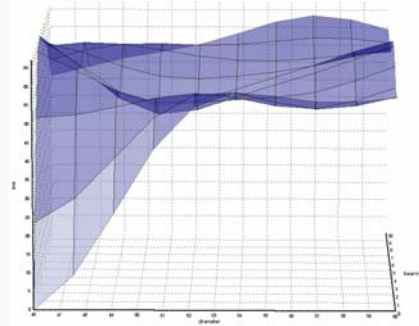
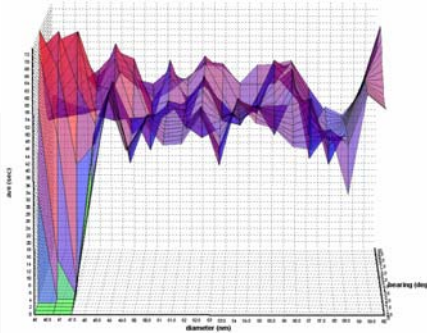
A gradient is computed by sampling two points close to one another and then solving for the slope. A step is then taken and the process repeats until progress can no longer be made.

Optimization Challenges

Smooth/Non-Smooth Data			Global/Local Minima
			
Smooth	Discrete Values	Non-Smooth/ Noisy	Global Local

Optimizing with Surrogate Models

- No issues with calculating gradients
- Quickly evaluate surrogate models



- Potential problems with model accuracy, local optima

State of the Art

Algorithm	Examples	Fixes	Problems
Gradient	DOT SQP		Noisy Data Local Minima Long Running Codes
Surrogate	Polynomial Kriging Radial Basis	Noisy Data Long Running Codes	Inaccurate Results Local Minima
Genetic	Darwin	Local Minima	Long Running Codes
Adaptive Surrogate	Design Explorer	Noisy Data Local Minima Long Running Codes	

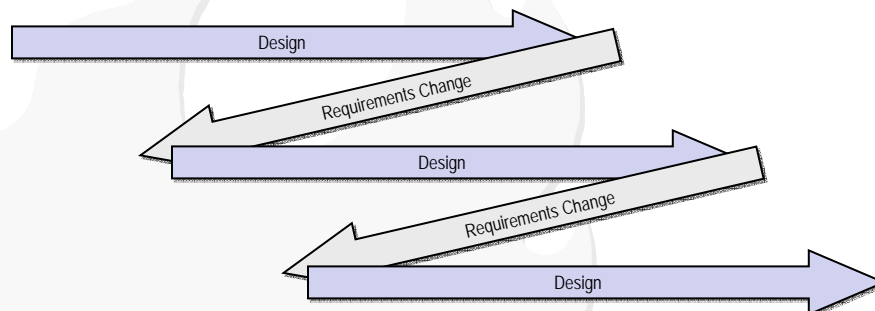
Traditional approaches are mature, but they all assume you start with a well defined problem.

The Problem with Requirements

- As soon as they're set, you've narrowed your design space
- Soft items are difficult to capture
 - Aesthetics
 - Ease of use
 - Operations
- People outsmart the system
 - Gravitate towards measurable things
 - Absolve themselves of responsibility

Optimizing Systems of Systems

- Vague, evolving requirements



- Result in lots of wasted effort

Systems of Systems

- Challenges:
 - Requirements are not known and may never be known
 - Requirements will include subjective criteria
 - Requirements will change as more is learned
- Capability Engineering

These Problems Are Not New!

- Real world inspirations:
 - Buying a home
 - Renting a movie
- Themes
 - Requirements are not known and may never be known
 - Requirements will include subjective criteria
 - Requirements will change as more is learned

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Buying a Home

REALTOR.com Official Site of the National Association of REALTORS®

Welcome Guest | Sign In

Find a Home Rentals Home Finance Moving Home & Garden

Featured Homes™

163 properties match your search
There are 236 available properties in 19087

Property Types:

- Single Family Home (163)
- Condo/Townhouse/Co-Op (35)
- Multi-Family Home (0)
- Mfd/Mobile Home (0)
- Farms (0)
- Land (8)
- Rentals (30)

Choose a search option:

View on Map View as List

Too many results? Too few results? [Advanced Search](#)

163 properties match your search, 72 with multiple photos
There are 336 available properties in 19087

Sort results by:

Number of Photos	Price	Location	Property Details
	\$875,000	Wayne, PA 19087	4 Bed, 2.5 Bath 1.01 acre
	\$665,000	Wayne, PA 19087	3 Bed, 2 Bath 0.01 acre
	\$550,000	Wayne, PA 19087	3 Bed, 2 Bath 2,884 Sq. Ft. 0.71 acre
	\$325,000	Wayne, PA 19087	3 Bed, 2.5 Bath 1.08 acre

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Renting a Movie

Blockbuster Online My Rental History Windows Internet Explorer

Blockbuster Online Recommendations Windows Internet Explorer

Blockbuster Movies

My Rental History

TITLE	RENTAL DATE	DATE RETURNED
The Sandlot Part 2	08/24/07	
Shrek 2	08/24/07	
The Hot Chick	08/24/07	
The Hot Chick	08/24/07	
The Hot Chick	08/24/07	
The Hot Chick	08/24/07	
The Hot Chick	08/24/07	
The Hot Chick	08/24/07	
The Hot Chick	08/24/07	
The Hot Chick	08/24/07	

Recommendations

Based on the 16 movies you've rented, we think you'll like these titles

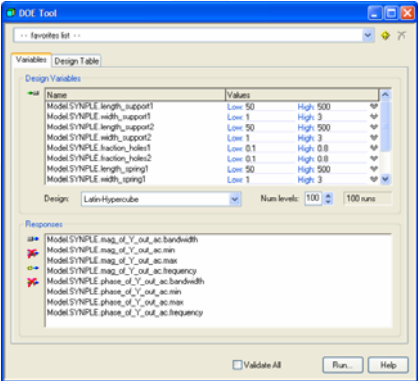
Movie Title	Rating
The Hot Chick	4.5
The Hot Chick	4.5
The Hot Chick	4.5
The Hot Chick	4.5
The Hot Chick	4.5
The Hot Chick	4.5
The Hot Chick	4.5
The Hot Chick	4.5
The Hot Chick	4.5
The Hot Chick	4.5

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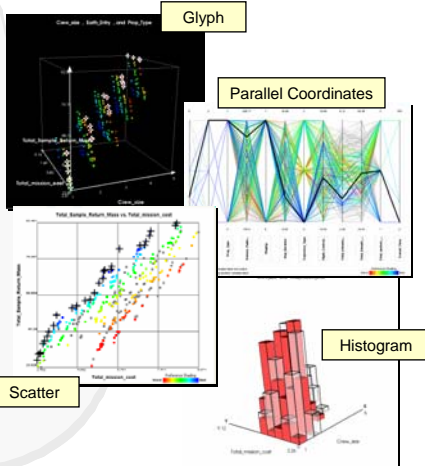
Design by Shopping

Precompute and Compare



Design of Experiments

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Glyph

Parallel Coordinates


Scatter

Histogram

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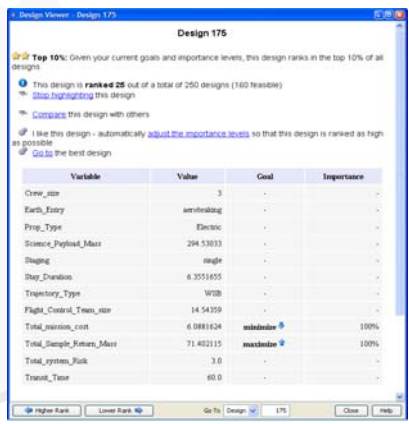
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Guided Search



Preferences

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Ranking

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Science_Payload_Mass	Minimize	0	Maximize
Stay_Duration	Minimize	0	Maximize
Flight_Control_Team_size	Minimize	0	Maximize
Total_revision_cost	Minimize	100	Maximize
Total_Sample_Return_Mass	Minimize	100	Maximize
Total_system_Risk	Minimize	0	Maximize
Transit_Time	Minimize	0	Maximize
Crew_size	Minimize	0	Maximize

Design 175

Top 10%: Given your current goals and importance levels, this design ranks in the top 10% of all designs.

This design is ranked **25** out of a total of 250 designs (160 feasible).

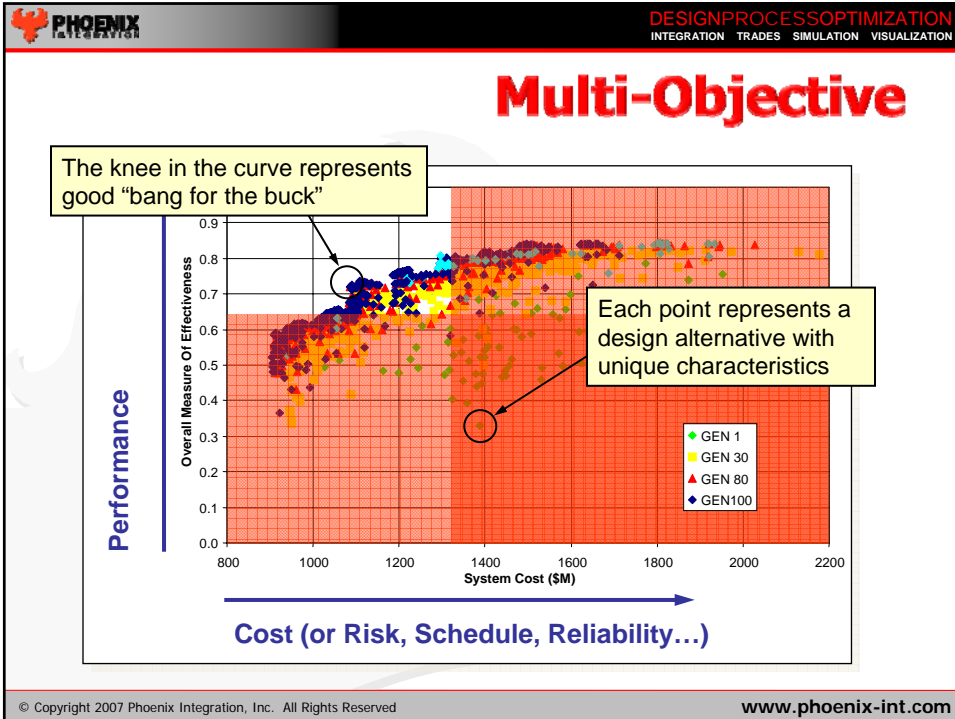
Compare this design with others

I like this design - automatically **adjust the importance levels** so that this design is ranked as high as possible

Go to the best design

Variable	Value	Goal	Importance
Crew_size	3	-	-
Earth_Easy	aerobanding	-	-
Prop_Type	Electric	-	-
Science_Payload_Mass	294.53033	-	-
Staging	single	-	-
Stay_Duration	6.3551625	-	-
Trajectory_Type	WOB	-	-
Flight_Control_Team_size	14.54359	-	-
Total_revision_cost	6.0881624	minimize	100%
Total_Sample_Return_Mass	71.402115	maximize	100%
Total_system_Risk	3.0	-	-
Transit_Time	60.0	-	-

Higher Rank Lower Rank Go To Design 175 Close Help



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Summary

- Trying to force requirements too early can lengthen the process.
- Traditional optimization approaches are based on well defined requirements and don't work well for Systems of Systems
- Alternate optimization approaches work well:
 - Design by Shopping
 - Guided Search
 - Multi-Objective
 - Cascading Targets

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