Optimizing Engineering Methods with Isight

Isight 2018
Course objectives
Upon completion of this course you will be able to:

Understand nonlinear optimization theories and techniques:
- How does exploring the design space can assist with optimization
- The capabilities of different optimization techniques and exploration strategies
- Methodologies for Multidisciplinary Design Optimization (MDO)

Targeted Audience
- Simulation Analysts
- Scientists

Prerequisites
- Introduction to Isight

About this Course

2 days
Lesson 1  Review of Isight

Lesson 2  Overview
Workshop 1  Design Space Exploration

Lesson 3  Exploration and Gradient Based Methods
Workshop 2  Gradient Methods Workshop

Lesson 4  Pattern Methods
Workshop 3  Pattern Methods Workshop

Lesson 5  Single Objective Exploratory Methods
Workshop 4  Exploratory Methods

Lesson 6  Multi Objective Optimization
Workshop 5  Multi Objective Optimization Workshop
Day 2

- Lesson 7: Nested Exploration
- Workshop 6: Nested Exploration Workshop
- Lesson 8: Optimization Selection Strategy
- Workshop 7: Optimization Selection Workshop
- Lesson 9: Pointer and Exploration
- Workshop 8: Expert System Optimization Workshop
- Lesson 10: Adaptive DOE
- Lesson 11: Multidisciplinary Optimization
- Workshop 9: Multidisciplinary Optimization Workshop
- Workshop 10: Selecting Functions for Optimization
- Lesson 12: Summary
Additional Material

- Appendix 1 References
- Appendix 2 Optimizer Examples
- Appendix 3 Optimization Application - Data Matching
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- Abaqus, Isight, Tosca, fe-safe, Simpack

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SIMULIA’s Power of the Portfolio

**Abaqus**
- Routine and Advanced Simulation
- Linear and Nonlinear, Static and Dynamic
- Fluid, Thermal, Electrical, Acoustics
- Extended Physics through Co-simulation
- Model Preparation and Visualization

**Isight**
- Process Integration
- Design Optimization
- Parametric Optimization
- Six Sigma and Design of Experiments

**Tosca**
- Non-Parametric Optimization
- Structural and Fluid Flow Optimization
- Topology, Sizing, Shape, Bead Optimization

**fe-safe**
- Durability Simulation
- Low Cycle and High Cycle Fatigue
- Weld, High Temperature, Non-metallics

**Simpack**
- 3D Multibody Dynamics Simulation
- Mechanical or Mechatronic Systems
- Detailed Transient Simulation (Offline and Realtime)

**Realistic Human Simulation**
- High Speed Crash & Impact
- Noise & Vibration

**Material Calibration**
- Workflow Automation
- Design Exploration

**Conceptual/Detailed Design**
- Weight, Stiffness, Stress
- Pressure Loss Reduction

**Safety Factors**
- Creep-Fatigue Interaction
- Weld Fatigue

**Complete System Analyses**
- (Quasi-)Static, Dynamics, NVH, Flex Bodies, Advanced Contact
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Lesson 1: Review

Lesson content:
- Process Automation and Design Exploration
- Optimization Techniques
- Damper Application Example
  - Gradient Based Damper Optimization
  - Pattern Search Damper Optimization
  - Heuristic Search Damper Optimization
  - Expert Strategy Damper Optimization
  - Adaptive DOE Damper Optimization
  - Damper Application Summary
- Multi Objective Optimization Techniques
- Multi Disciplinary Optimization

20 Minutes
Lesson 2: Overview

Lesson content:

- Optimization Terminology
- Two Crude Petroleum Problem
- Optimize with Isight
- Objective Function
- Constraints
- Understanding a Design Space
- Why Should we Know
- Workshop Preliminaries
In this workshop, you will complete a design exploration of a set of equations in an Excel workbook using the Excel component in Isight. The Design of Experiments (DOE) technique to be used is Optimal Latin Hypercube.

Upon completion of this workshop you will be able to:
1. Select the DOE technique and configure the design space for 5 responses
2. Investigate the design space using postprocessing
3. Understand the effects of each variable on each response
Lesson 3: Exploration and Gradient Based Methods

Lesson content:

- Types of Optimization Problems
- Exploration Approaches
- Handling Constraints Direct Methods
- Penalty Methods
- Gradient Methods
- Modified Method of Feasible Directions (MMFD)
- The Quadratic Function Example
- Sequential Quadratic Programming (NLPQL)
- Large Scale Generalized Reduced Gradient (LSGRG)
- Multifunction Optimization System Tool (MOST)
- Mixed-Integer Sequential Quadratic Programming (MISQP)
- Gradient Method Optimization Technique Options
- Optimization Summary
- The Kuhn-Tucker Conditions

30 Minutes
Workshop 2: Gradient Methods Workshop

In this workshop, you will run and modify the provided Isight models using gradient method optimization techniques. Each model provided is already configured to optimize a function or application. The optimum design point for each job configured will be compared to understand the importance of each of the following:

1. Initial values
2. Optimization technique
3. Optimization technique options
4. Scale factor when applied to variables and/or constraints

Required files:
Files for this workshop are in the provided workshop files in directory ./Gradient_Methods.

A reminder about a few basic tasks is provided in the section titled Preliminaries.
Lesson 4: Pattern Methods

Lesson content:

- Pattern Search Overview
- Hooke-Jeeves Direct Search Method
  - Configuring the Hooke-Jeeves Technique
  - Hooke-Jeeves Illustration
- Downhill Simplex
  - Configuring the Downhill Simplex Technique
  - Downhill Simplex Illustration
- Parallelization in Hooke-Jeeves and Downhill Simplex
- Pattern Search Summary

- Damper Application Example
  - Damper Investigation with Hooke-Jeeves
  - Damper Investigation with Downhill Simplex
- Bonded Puck Application Example
  - Hooke-Jeeves vs Pointer-2 for Bonded Puck
  - Bonded Puck Job Duration
  - Bonded Puck Application Example Summary

1 hour
Workshop 3: Pattern Methods Workshop

In this workshop, you will run and modify the provided Isight models using pattern search optimization techniques. Each model is already configured to optimize a function.

Upon completion of this workshop you will be able to:
1. Describe the effect of relative step size and step size reduction factor options on the Hooke-Jeeves optimization technique.
2. Describe the difference between the Hooke Jeeves and Downhill Simplex methods for the models used.
3. Understand the difference between gradient and pattern search behavior.
Lesson 5: Single Objective Exploratory Methods

Lesson content:

- Global Optimization
- Gradient Based vs. Global Optimization Algorithms
- Exploratory Methods Overview
- Genetic Algorithms
- Multi-Island Genetic Algorithm (MIGA)
- Genetic Algorithm Advantages and Disadvantages
- Simulated Annealing Technique
- Adaptive Simulated Annealing (ASA)
- Evolutionary Optimization (Evol)
- MIGA – Duplicates and Parallelization
- Material Calibration Example with Isight and Abaqus
- MIGA Investigation of Relative Tournament Size
In this workshop, you will run and modify the provided Isight models using exploratory techniques. Each model provided is already configured to optimize a function. The parameters for the optimum design found during each job will be compared to understand the techniques and options.

Upon completion of this workshop you will be able to:
1. Select the exploratory optimization technique and configure the options to solve each optimization problem posed
2. Investigate each technique’s ability to find the optimum solution
3. Evaluate the impact of the initial values on the optimum solution
4. Compare the exploratory methods against the other methods used previously

Tips about a few general tasks that may be needed is provided in the section titled Preliminaries.
Lesson 6: Multi Objective Optimization

Lesson content:

- Multi Objective Optimization Problem (MOOP)
- Concept of Domination
- Pareto Optimality
- Multi Objective Optimization Approaches
- Multi Objective Algorithm
- Cantilever Beam Example
- MOOP in Isight
- Configuring the Multi-Objective Particle Swarm Technique
- Multi Objective Postprocessing
- Number of Generations Effect on Pareto Points
- Initializing from a Predetermined Population
- How to Save a Pareto File
In this workshop, you will complete multi objective optimization for three problems: one mechanical application and two test problems, using provided Isight models.

Upon completion of this workshop you will be able to:

1. Select the multi objective optimization technique and configure the options to minimize or maximize the objective functions
2. Understand the use of scale factors in multi objective optimization
3. Use postprocessing to understand the results
4. Investigate the population generated by the different multi objective techniques
5. Investigate the speed of optimization using different multi objective techniques and options
6. Gain experience generating and using the Pareto file
Lesson 7: Nested Exploration

Lesson content:

- Nested Exploration
- Encapsulation: Nesting a Process Component
- Nested Optimization in DOE
- Six Sigma Overview
- Exposing Process Component Options as Parameters
- Optimization Driving Stochastic Responses
- Circuit Board Drop Nested Optimization
Workshop 6: Nested Exploration Workshop

In this workshop, you will complete a nested exploration for two different types of process component in Isight, using two provided models.

Upon completion of this workshop you will be able to:
1. Encapsulate an existing process component
2. Compare DOE techniques and configurations used to drive optimization as a sub-flow
3. Use nested exploration to optimize reliability analysis with six-sigma
4. Use postprocessing to understand the results

30 Minutes
Lesson 8: Optimization Selection Strategy

**Lesson content:**

- Interdigitation – or Mix ‘n Match
- The Benefits of Interdigitation
- Building a Task Plan
- Building an Approximation for Optimization
This workshop will use the model of an I-beam in Excel to run a DOE, from which an approximation is to be generated for later optimization. The model including the initial DOE process component and Excel component is provided. The length of the beam as well as loads at the free end will remain constant, while the beam cross-sectional dimensions will be varied to find the optimum design responses.

Upon completion of this workshop you will be able to:
1. Create experimental data using a DOE
2. Create a new approximation component using the experimental data
3. Understand the optimization problem formulation
4. Run a multi-objective optimization based on the new approximation
5. Compare the results
Lesson content:
- The Challenge of Optimization in Isight
- Expert System Optimization Techniques
- Pointer Automatic Optimizer (Pointer)
- Exploration Component
- Exploration Component - Approximation Loop
  - Example
  - Branin Problem
  - Multi Objective Optimization Problem (MOOP)
- Pointer-2 Hybrid-Optimizer
  - Pointer-2 in Parallel
- Comparing Pointer, Pointer-2 and Approximation
- Exploration Component - Custom Strategy
In this workshop, you will use the Pointer optimization technique and/or the Exploration component to optimize two different Isight models provided.

Upon completion of this workshop you will be able to:
1. Compare Pointer and Pointer-2 to gradient-based optimization techniques
2. Configure an Exploration component to:
   a. Run the Pointer-2 technique
   b. Run an Approximation-based exploration strategy
Lesson 10: Adaptive DOE

Lesson content:

- Adaptive DOE Technique
- Configuring the Adaptive DOE Technique
- Generating and Using the Prior Design Points File
- Adaptive DOE as an Optimization Technique
Lesson 11: Multidisciplinary Optimization

Lesson content:

- Multidisciplinary Design Optimization
- Multidisciplinary Feasible (MDF)
- Individual Discipline Feasible (IDF)
- Collaborative Optimization (CO)
- Concurrent Subspace Optimization (CSSO)
- Bi-Level System Synthesis (BLISS)
- Comparison of MDO Methodologies
In this workshop, you will complete a multidisciplinary optimization of Rosenbrock’s valley function using optimization in Isight.

Upon completion of this workshop you will be able to:
1. Configure and run Multidisciplinary Optimization in Isight
2. Compare Multidisciplinary Feasible (MDF) to Collaborative Optimization (CO)
In applied mathematics, test functions (known as artificial landscapes) are useful to evaluate characteristics of optimization algorithms, such as:

1. Velocity of convergence
2. Precision
3. Robustness
4. General performance

Four such functions (two of them multi-objective optimization) are posed on the following slides to test your knowledge of the optimization methods discussed in this course.
Lesson 12: Summary

Lesson content:

- Optimization
- Optimization Technique Classification
- What to Do When Optimizer Is Not “Working”
- Limitations of Numerical Optimization
- Procedures to Solve an Optimization Problem
- Summary
Appendix 1: References

Appendix content:

- Isight Documentation
- References
Appendix 2: Optimizer Examples in Isight

Appendix content:

- Installed Optimization Example Files
- Optimizer Examples
- Summary of Included Models
- Practice
Appendix 3: Optimization Application - Data Matching

Appendix content:

- Data Matching Responses
- Damper Application Example
  - Optimization Technique Comparison for Damper
  - Effect of Starting Point on Damper Optimization
- Bonded Puck Application Example
  - Technique Comparison for Bonded Puck Application
- Material Calibration Example with Isight and Abaqus
- Parametric Optimization of Engine Mount Bushing

45 Minutes