Automatic creation of reduced-order models using Thermal Desktop

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Motivation

- Why Reduced-Order Models (ROMs)
Why Reduced-Order Models

• Advantages
  – Rapid analysis: 1000s of simulations in seconds
  – Intuitive user interface encourages collaboration
  – More effective data exploration through advanced analysis capabilities

• Built for Thermal Desktop®
  – Relates input factors (e.g. power) to output responses (e.g. temperature)
  – Leverages TD 6.0 API
What is a ROM?

• What is a reduced order model?
  – An accurate surrogate of a high fidelity model
  – Based on intelligent sampling then data fitting
  – Acts as a statistical emulator
  – Sampling based on Latin Hypercube methods
  – Data fitting based on Gaussian-Process methods
ROM Creation Process

- Sampling then data fitting

\[ y = 10x + 10 \]

- Reduced-Order Model
- Select number of samples
- Model 'Shape' Unknown
- Multiple Input Factors

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ROM Creation

- **Latin Hypercube Sampling**
  - A method for efficiently filling a design space
  - The range of each Input Factor (e.g. X) is divided into N intervals
    - \( N \) = number of samples
    - Each interval is used only once
  - Maximize the minimum distance between points

- **Gaussian Process model**
  - Does not impose specific model structure
    - E.g. ‘\( f(x) = mx + c \)’ not needed
    - Can fit a wide-range of data without prior knowledge of ‘shape’
  - Based on training data
    - Covariance matrix populated using squared exponential function
    - Optimized hyperparameters needed
  - Can fit data exactly
    - Useful for computer simulations
  - Provide confidence intervals

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Examples

• Orion Crew Exploration Vehicle (CEV)
  – External fluid loop
  – Temperature: 1.6 K max residual mean and 5.0 K standard deviation
  – Power: 0.2 W max residual mean and 1.93 W standard deviation
  – Did poor job of replicating output responses with discontinuities

• Air Force Hex Bus
  – Standard deviation of 5.1 K (Tmax), 2.4 K (Tmin), and 2.5 K (Tmaxd)

• 3U CubeSat
  – Evaluated heat pipe performance

• JPL Mars Helicopter
  – Tomorrow 2:45 pm in Spinnaker
Process Flowchart

**Thermal Desktop® Model**

- Set-up and Generate Sampling Points
- Run Sampling Points to generate Training Data
- Run Training Data through a Data-fitting Algorithm
- ROM Testing
  - ROM Creation is complete
  - Accuracy of ROM is verified

**Creation Tool**

- Select and Set-up Input Factors and Output Responses
- Run using Thermal Desktop®

**Exploration Tool**

- Use any of the five analysis features to perform rapid thermal analysis
TD API Capabilities

• Thermal Desktop® 6.X API
  – Provides improved capabilities

• Supports creating and modifying the following entities
  – Case Sets
  – Conductors
  – Fluid Submodels
  – Heater/Heatloads
  – User Arrays/Code
  – Nodes
  – Optical Properties
  – Symbols
  – Thermophysical Properties

TD features
  – Expressions
  – Network Logic
  – Registers
  – Units
  – Others

• Miscellaneous functionality
  – Capture Graphics area
  – Run Case Set
  – SaveAs
  – Others

• Contact CR Tech for a demo
Path Forward

• Exploration Tool
  – Product release (August 2017)
  – Product update v2.0 (November 2017)
  – Working with customers to integrate new features

• Creation Tool
  – Beta version available
  – Currently having users testing and using – interested?
  – Commercial release (August 2018)
  – LoadPath ROM creation
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