Visualisierung von Ergebnissen aus Optimierungs- und DOE-Studien

Katharina Witowski, Heiner Müllerschön
DYNAmore GmbH, Stuttgart, Germany

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Overview

- Example: Optimization of a crash management system
  - Problem description
  - Visualization of Pareto optimal solutions
    - SOM
    - Parallel coordinate plot
  - Visualization of history curves and predicted histories

- Example: DOE study of a front crash
  - Problem description
  - Visualization of sensitivities
    - Correlation matrix
    - Linear ANOVA
    - Global sensitivities (Sobol)
    - Interpolator plot

Summary
Optimization of a Crash Management System

- Load case 1: AZT crash repair test
  - Mass barrier: 1000 kg
  - Mass vehicle: 1514.53 kg
- Load case 2: RCAR test

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Objective: optimize the energy absorption by plastic deformation of the bumper

Given maximal force level for load case AZT (barrier contact force)

Bumper has extruded section $\rightarrow$ constant cross section
Problem Description

- 9 design variables
  - 4 Morphing parameters (ANSA as preprocessor in LS-OPT)
  - 5 sheet thicknesses

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Some resulting bumper shapes of ANSA morphing
3 Objectives

- MSE_Force (load case AZT)
  \[ \text{sum of squares error between calculated contact force curve and given constant contact force } c \]
Problem Description

- 3 objectives
  - Max_Intrusion (load case RCAR)
    - Intrusion = displacement of center of mass of vehicle
    - displacement of inner edge of bumper
  - Total mass of the bumper
  - constraint: contact force < C

Multi-Objective optimization → set of Pareto optimal solutions (metamodel-based)
Self organizing maps (SOM) → Conflicting objectives
- Unsupervised neural network algorithm
- Projects n-dimensional data onto two-dimensional array of nodes
- Each node is associated with n-dimensional weight vector
- Algorithm sorts and adapts weight vectors such that similar data is mapped to the closest node
- Component map: visualizes one component of weight vector by coloring the grid according to the value of selected component
Visualization

- SOM (Self Organizing Maps) → (inverse) correlation of entities
- Component maps of objectives and constraint

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Visualization

- Parallel Coordinate Plot → Reduce number of suitable solutions by restricting ranges of objectives

Feasible points Infeasible points with respect to selected ranges

variables constraint objectives
Visualization

- History curves: contact force curve

  - All iterations, colored by feasibility
  - Only feasible runs

  - All iterations, colored by variable

  - All iterations, colored by iterations

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Visualization

- Predicted Histories – extension of metamodel concept to curve data

histories from simulation runs

time = t

calculation for equidistant time values → predicted history

Response surface to get values for predicted history at time t
Visualization

- Predicted History colored by variable
  - curves for the whole range of the selected variable are displayed
  - visualizes the effect of a single parameter on the curve
Visualization

- Predicted History Plot with variable values evaluated from a selected Pareto optimal point

- Selection of suitable points out of the set of Pareto optimal solutions
  - Store variable values in a .csv file
  - user-defined sampling in LS-OPT
  - verification runs for the predicted results can be performed
DOE Study of a Front Crash

- Load case: frontal impact of a car on a rigid barrier
- Model from NCAC (National Crash Analysis Center)
  http://www.ncac.gwu.edu
Problem description

- 6 design variables
  - sheet thicknesses of highlighted parts

- Responses
  - Chest acceleration of dummy
  - Forces evaluated at 2 cross sections
  - Constraint on mass of vehicle

- 250 LS-DYNA simulations
- Sensitivities evaluated on RBF metamodel
Visualization

- Correlation Matrix
  - Scatter plots, histograms, linear correlation coefficient evaluated using values from simulations

→ *lb1* has a strong effect onto the section forces
→ all variables are insignificant on the chest acceleration
Visualization

- **ANOVA (Analysis of Variance)** calculated on metamodel

- Not meaningful → large red error bars

- *lb1* strong effect on section forces → agreement with correlation matrix results
Visualization

- Non-linear sensitivities: global sensitivities (Sobol)
- Each bar represents the contribution of a particular variable to the variance of the respective response

\[ lb1 \]
strongest effect on whole problem

\[ lb1 \]
strongest effect on section forces
Nonlinear sensitivities

\( lb1 \) also has a strong effect on the chest acceleration.

Total variance of chest acceleration small → correlation coefficient small.
- linear and non-linear sensitivities → \( lb1 \) is the most sensitive variable on \( SECFORC\_front\_resp \),
- percentage in comparison to the other variables is higher for the non-linear correlation

→ quadratic correlation is not detected completely by linear correlation
Visualization

- Interpolator Plot – 2D surface plots
  - comparing the influence of variables on several responses
  - find feasible regions in the design space

- feasible
- infeasible
- predicted value for selected variable values
The post-processing features of LS-OPT 4.1 have improvements in

- visualizing results of multi-objective optimization
  - SOM plot completes the visualization of high dimensional data together with
    - Tradeoff Plot
    - Parallel Coordinate Plot
    - HRV Plot
  already available in LS-OPT 4.0

- visualization of curve data
  - histories from simulation results
  - extension of the meta-models on curve data
    → predicted histories

- visualization of sensitivities
  - features to visualize non-linear sensitivities (Sobol)