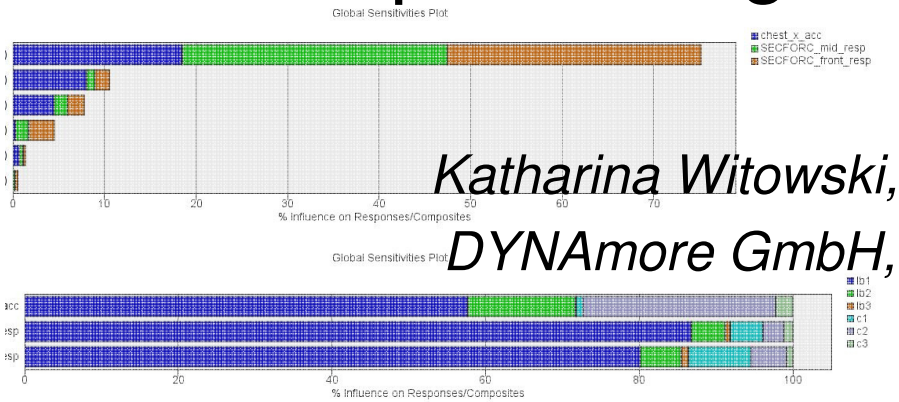
Visualisierung von Ergebnissen aus Optimierungs- und DOE-Studien



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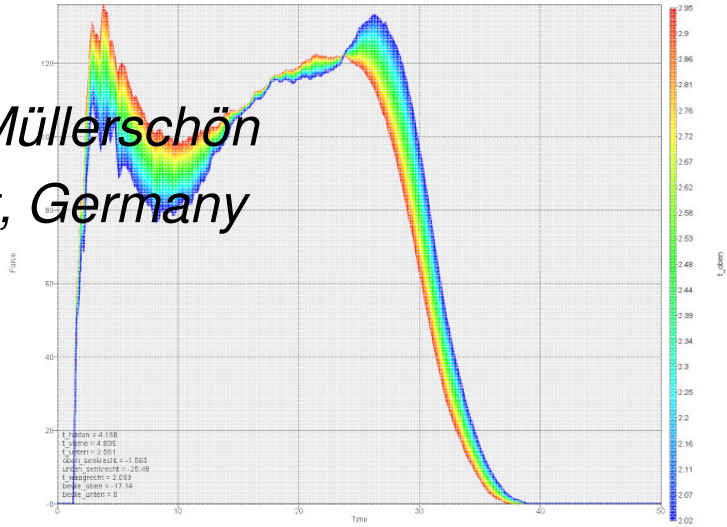
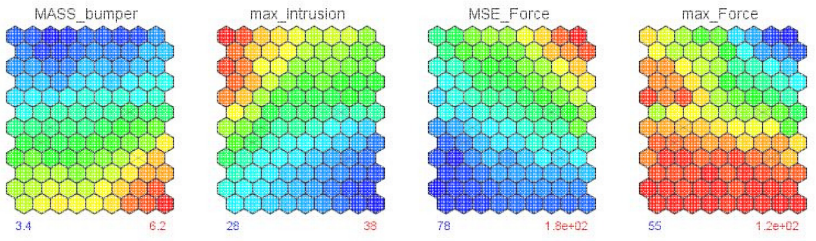




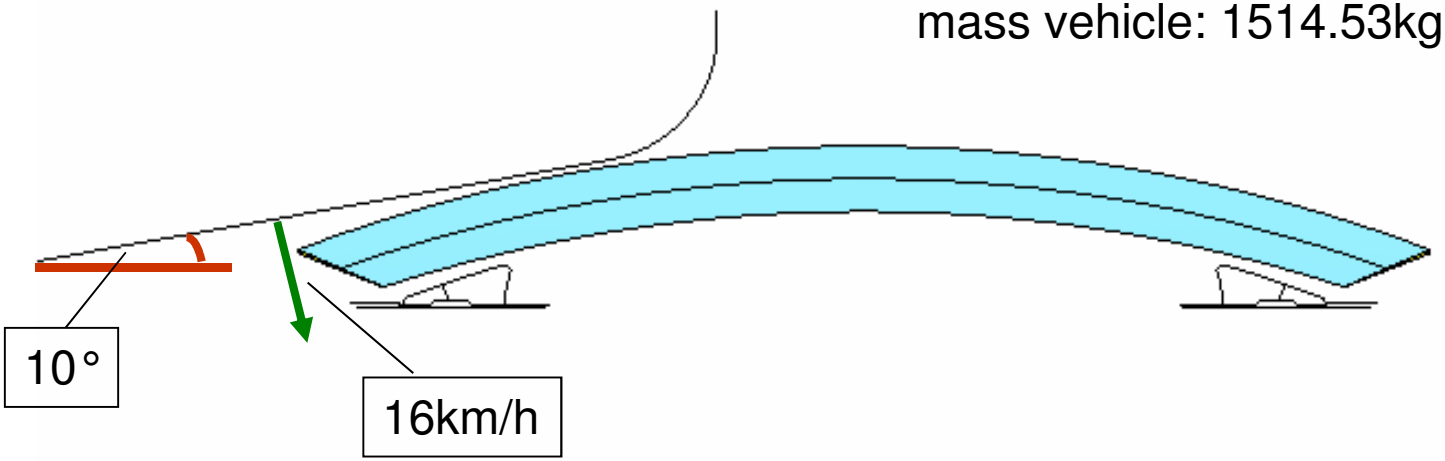
Overview

- 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

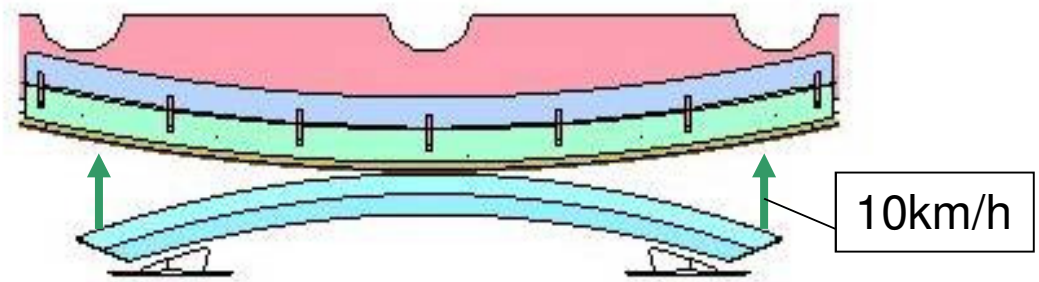
Optimization of a Crash Management System

- Load case 1: AZT crash repair test

mass barrier: 1000kg
mass vehicle: 1514.53kg



- Load case 2: RCAR test

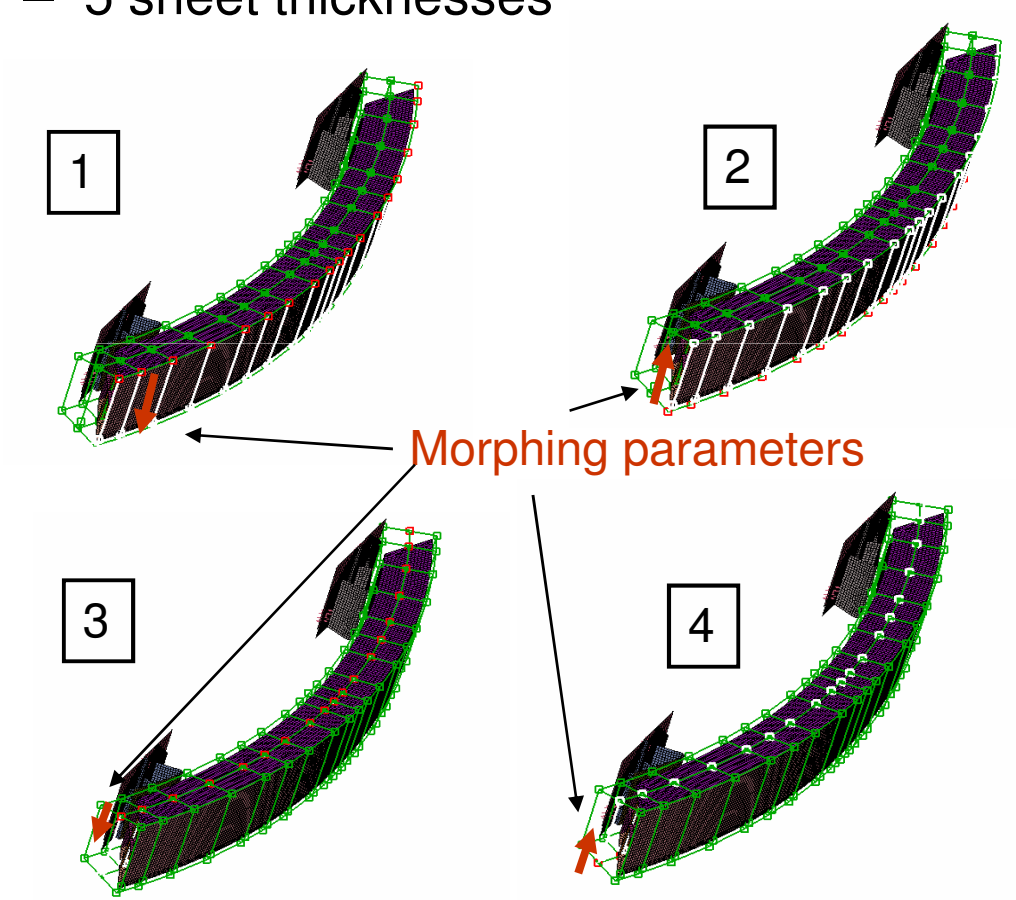


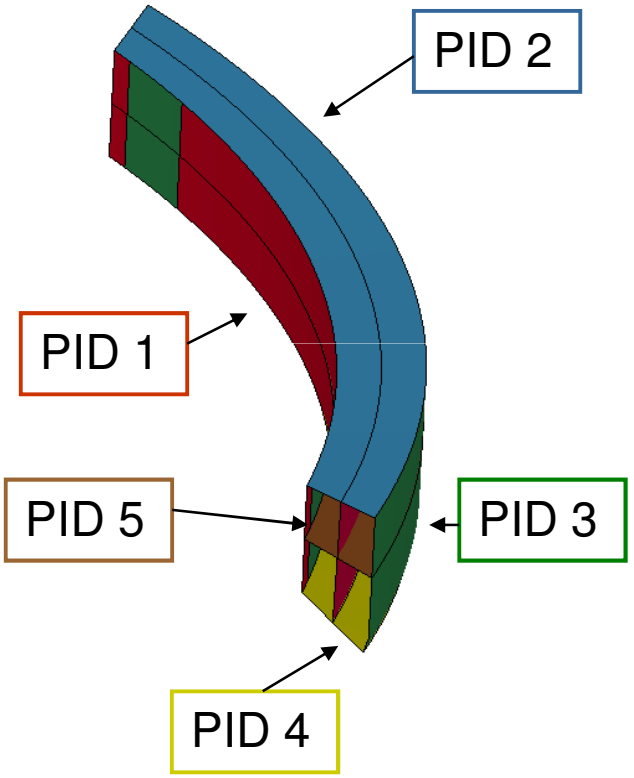
Problem Description

- 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 → constant cross section

Problem Description

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

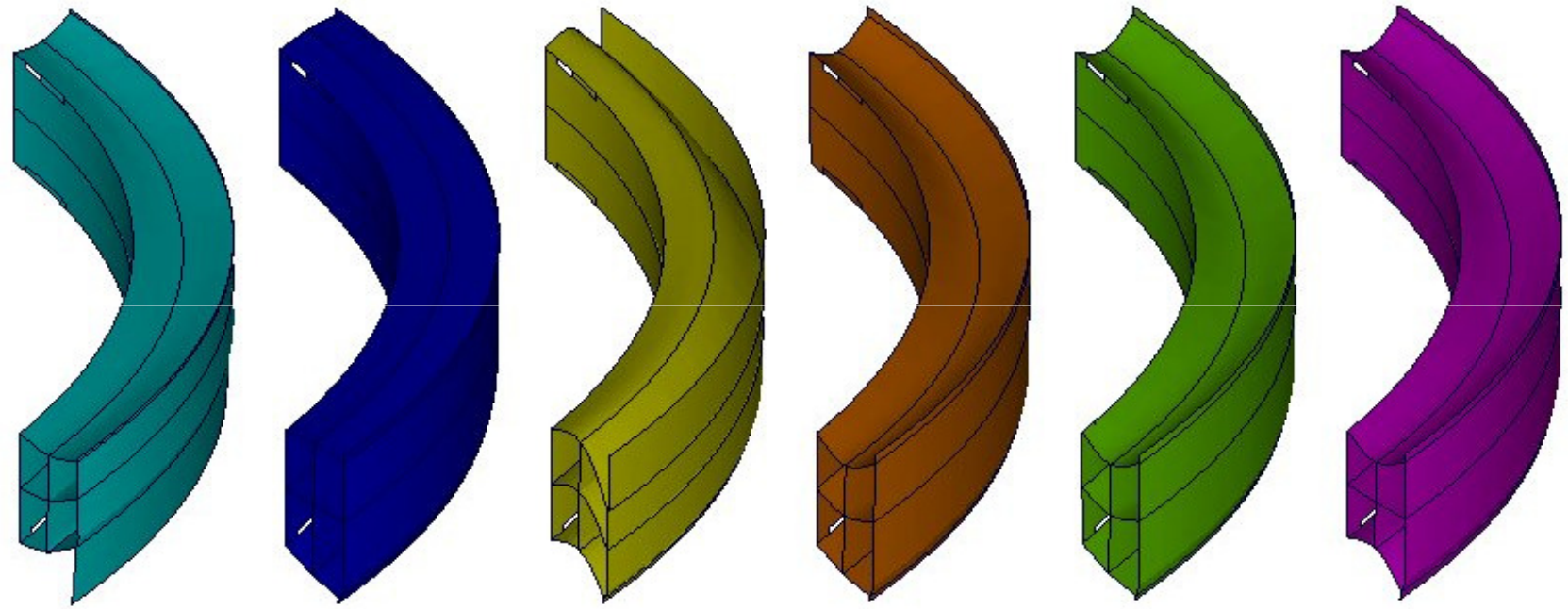




Modified sheet thicknesses

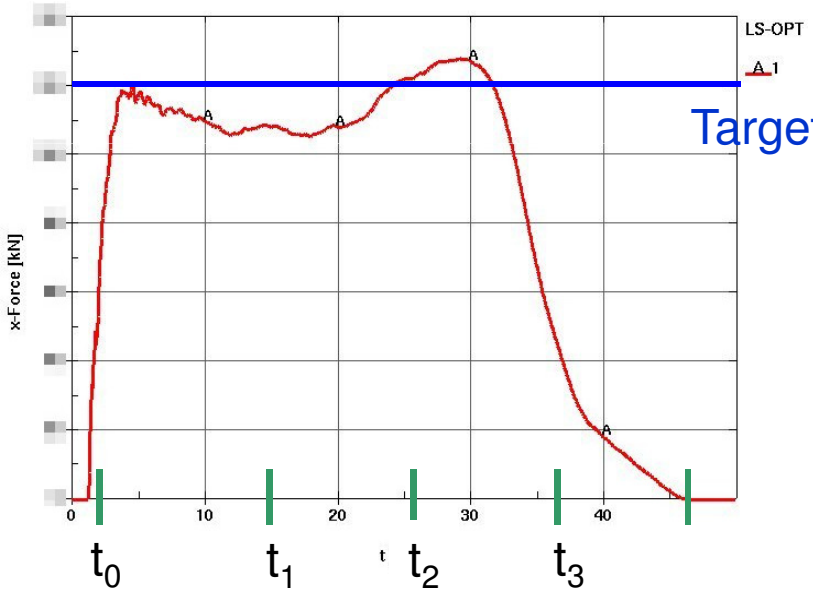
Resulting Bumper Shapes

- Some resulting bumper shapes of ANSA morphing



Problem Description

- 3 Objectives
  - MSE_Force (load case AZT)
    → sum of squares error between calculated contact force curve and given constant contact force c



Target curve

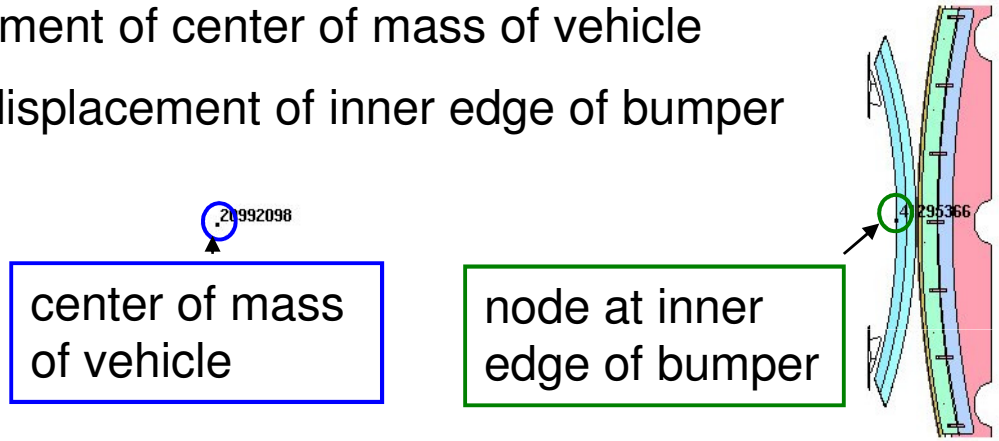
$$\text{MSE\_Force} = \sqrt{\sum_{i=0}^{3}\left(F(t_i)-c\right)^2}$$

Problem Description

- 3 objectives
  - Max_Intrusion (load case RCAR)

    → Intrusion = displacement of center of mass of vehicle

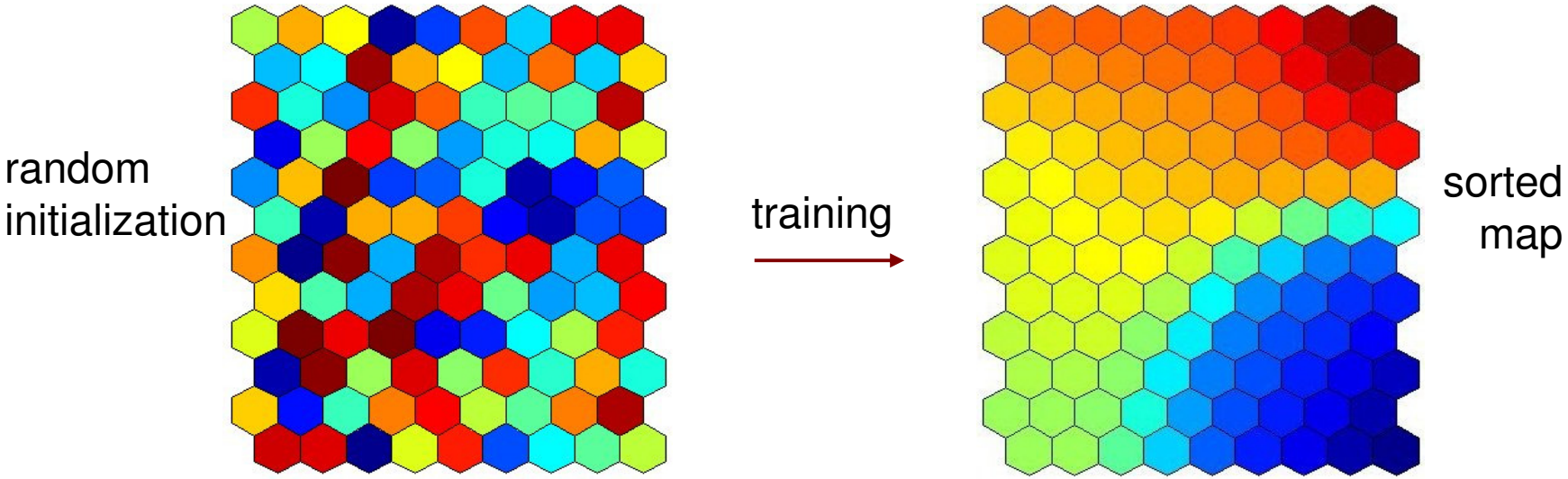
    - displacement of inner edge of bumper



  - Total mass of the bumper
- constraint: contact force < C
- Multi-Objective optimization → set of Pareto optimal solutions (metamodel-based)

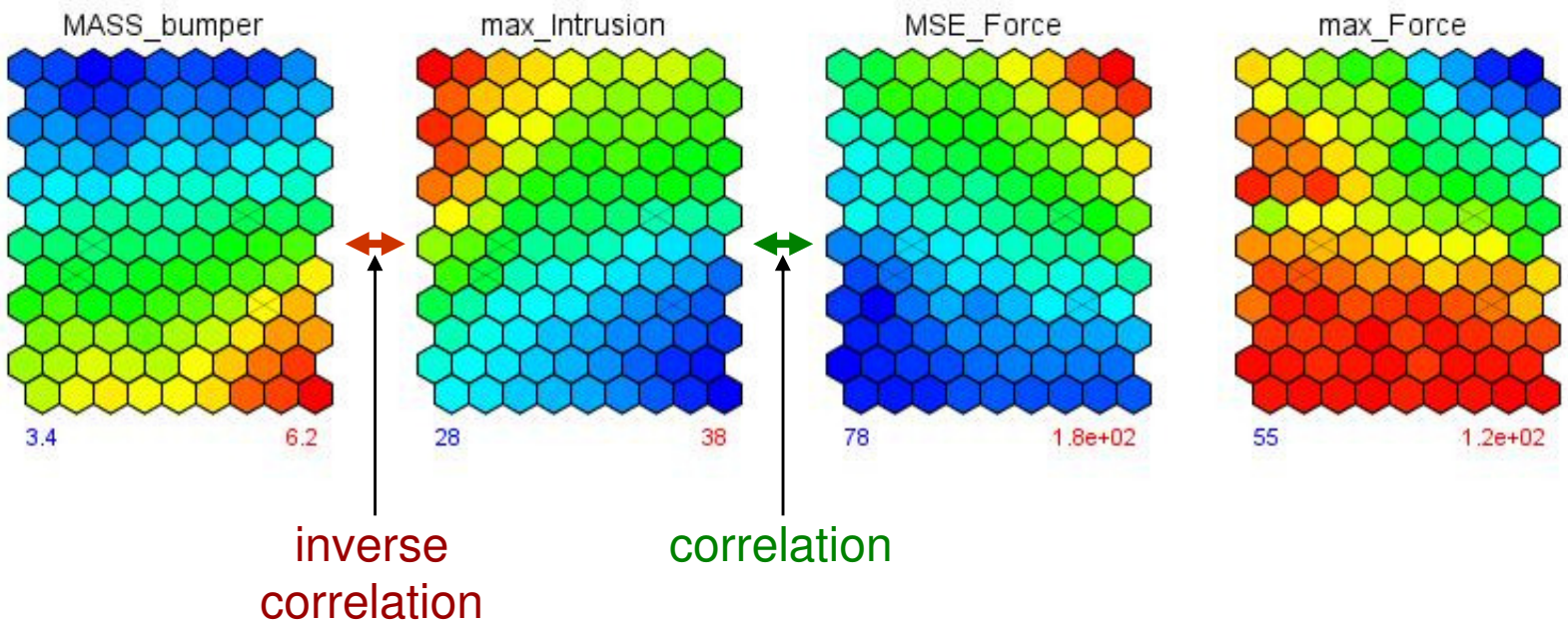
Visualization

- 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



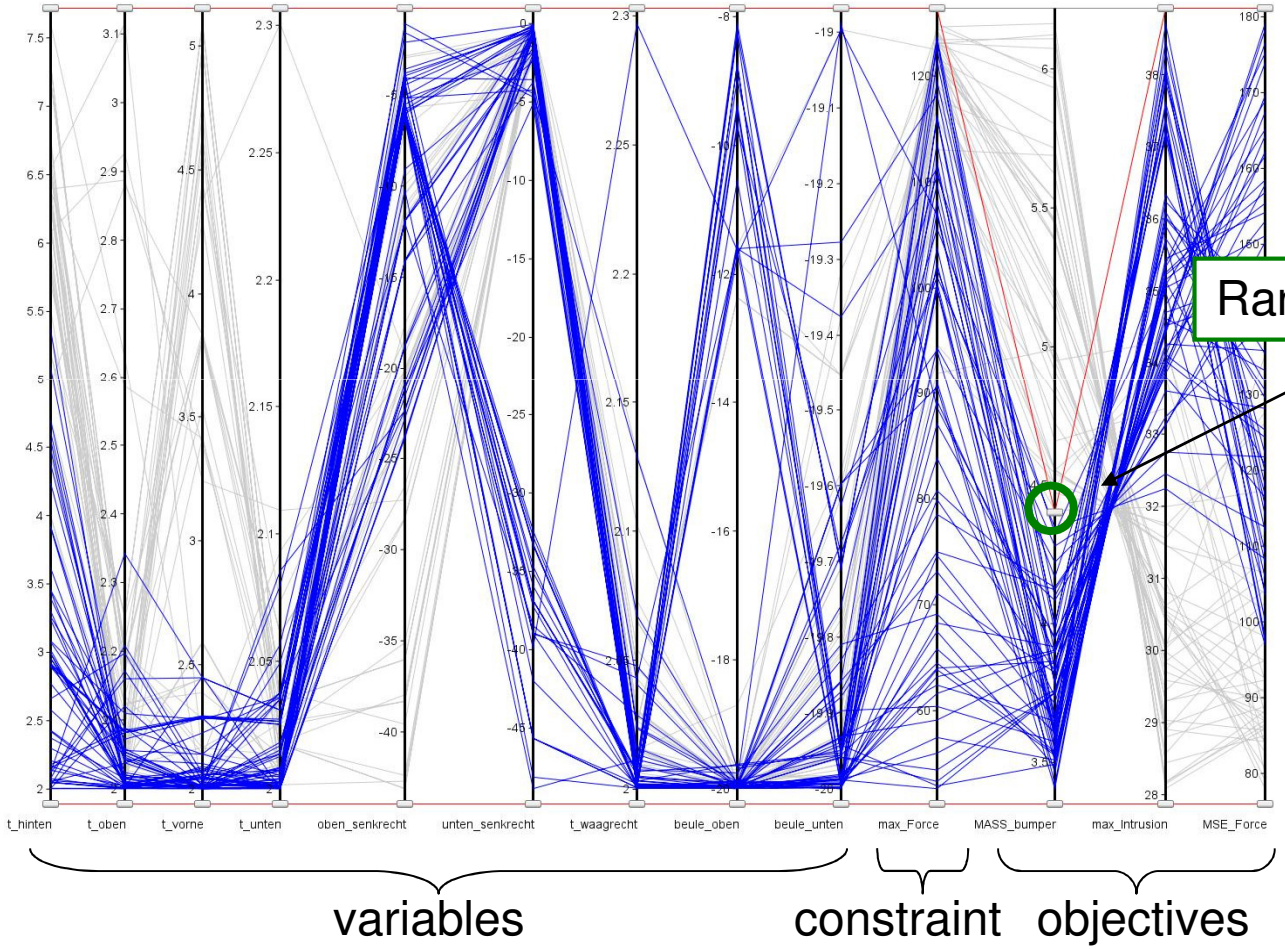
Visualization

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



Visualization

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



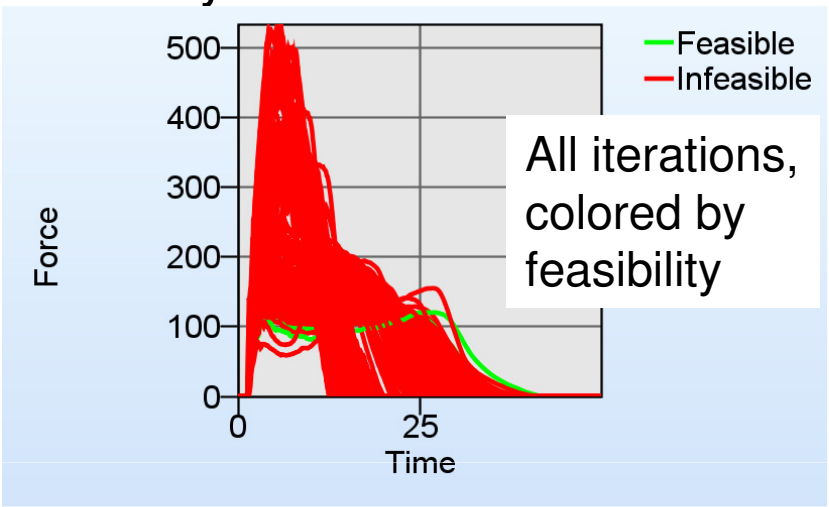
Range restriction

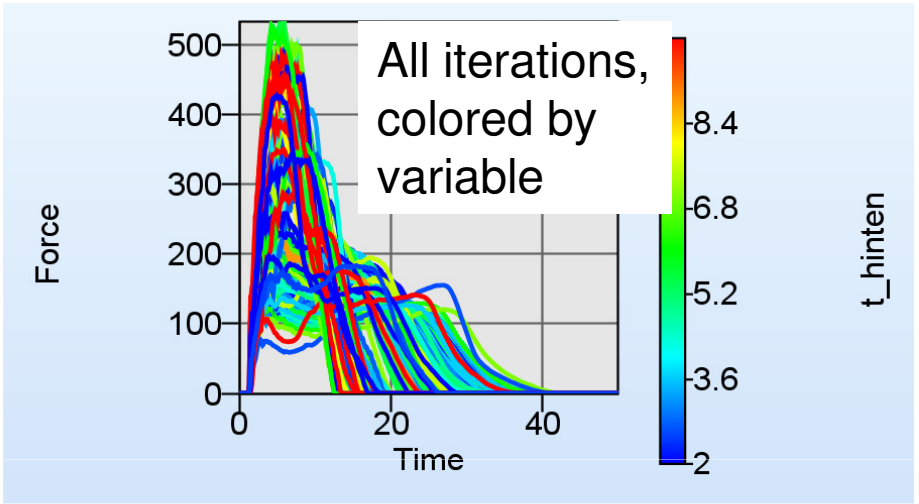
Feasible points

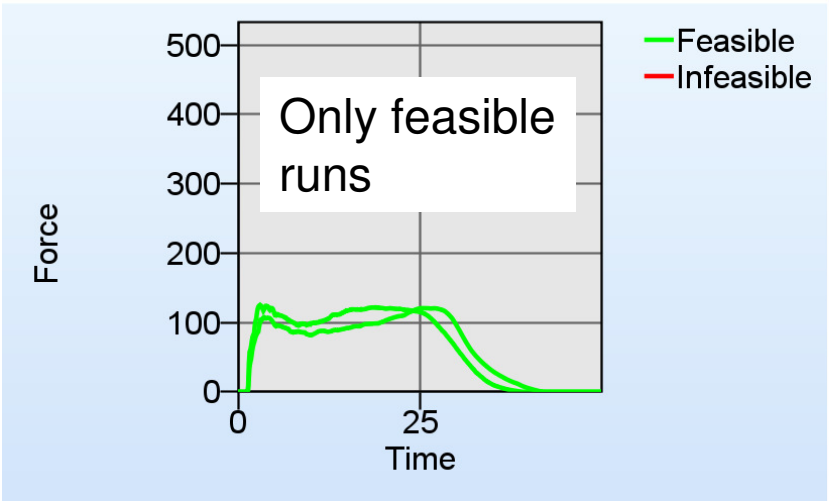
Infeasible points with respect to selected ranges

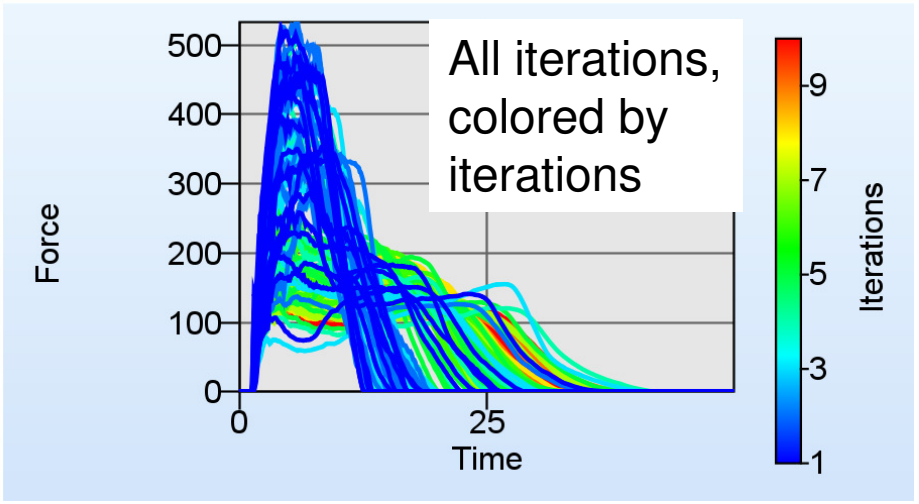
Visualization

- History curves: contact force curve



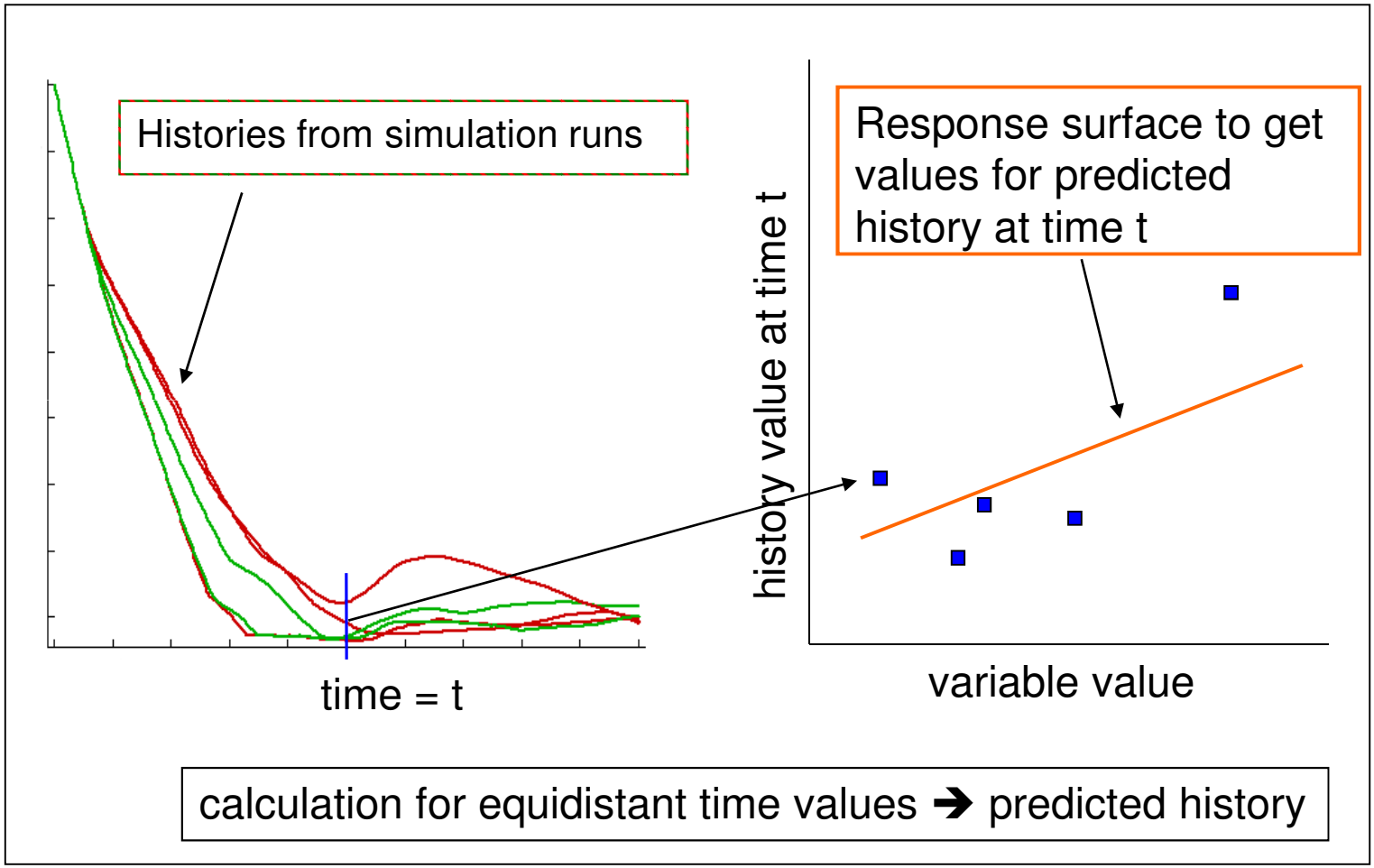






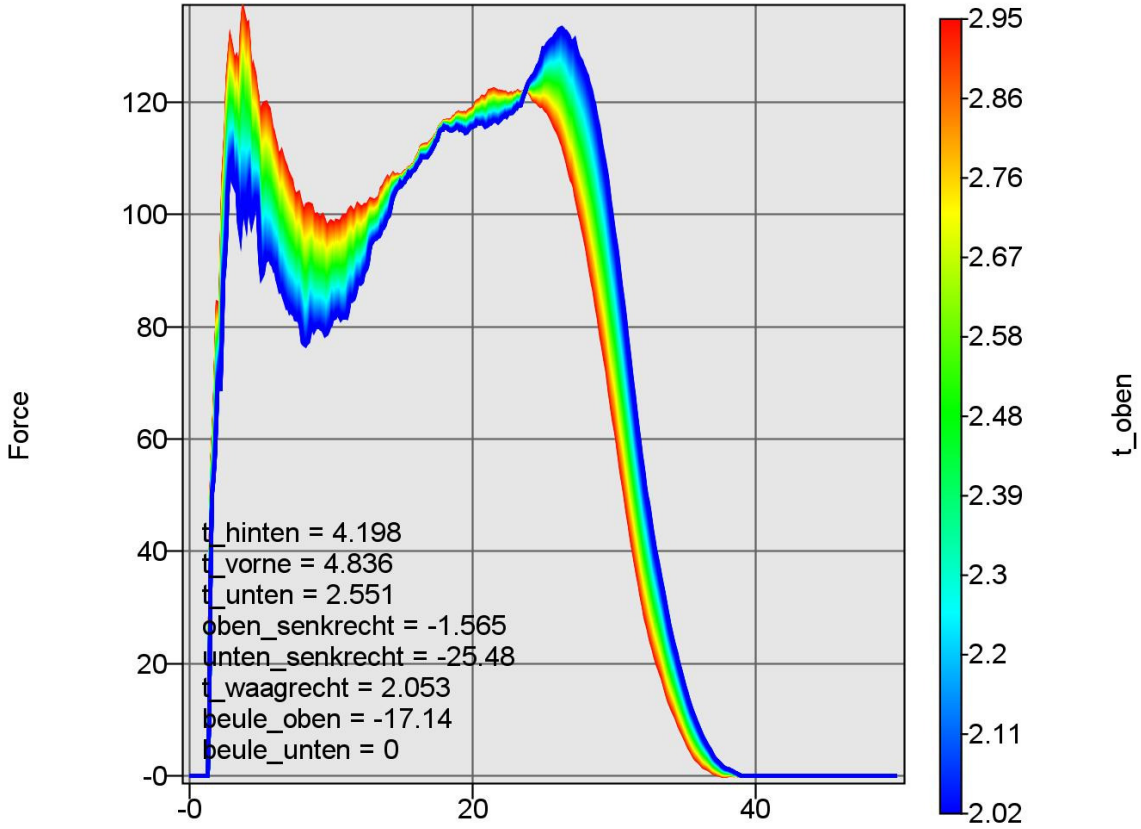
Visualization

- Predicted Histories – extension of metamodel concept to curve data



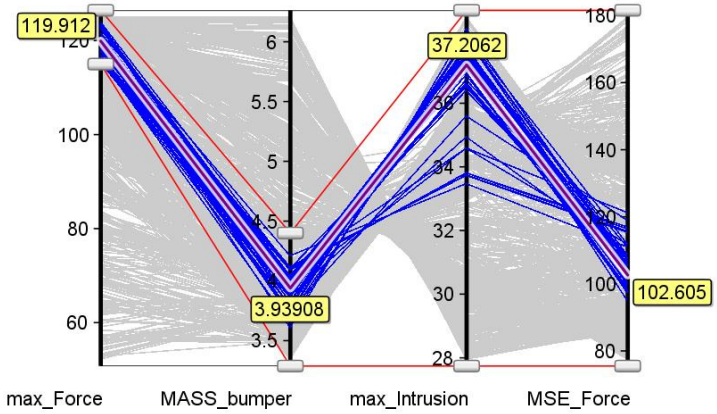
Visualization

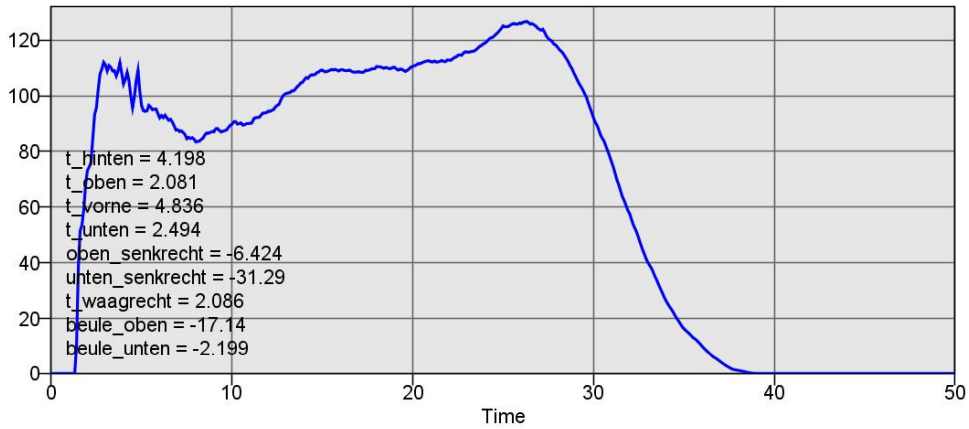
- Predicted History colored by variable
  → curves for the whole range of the selected variable are displayed
  → visualizes the effect of a single parameter on the curve



Visualization

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

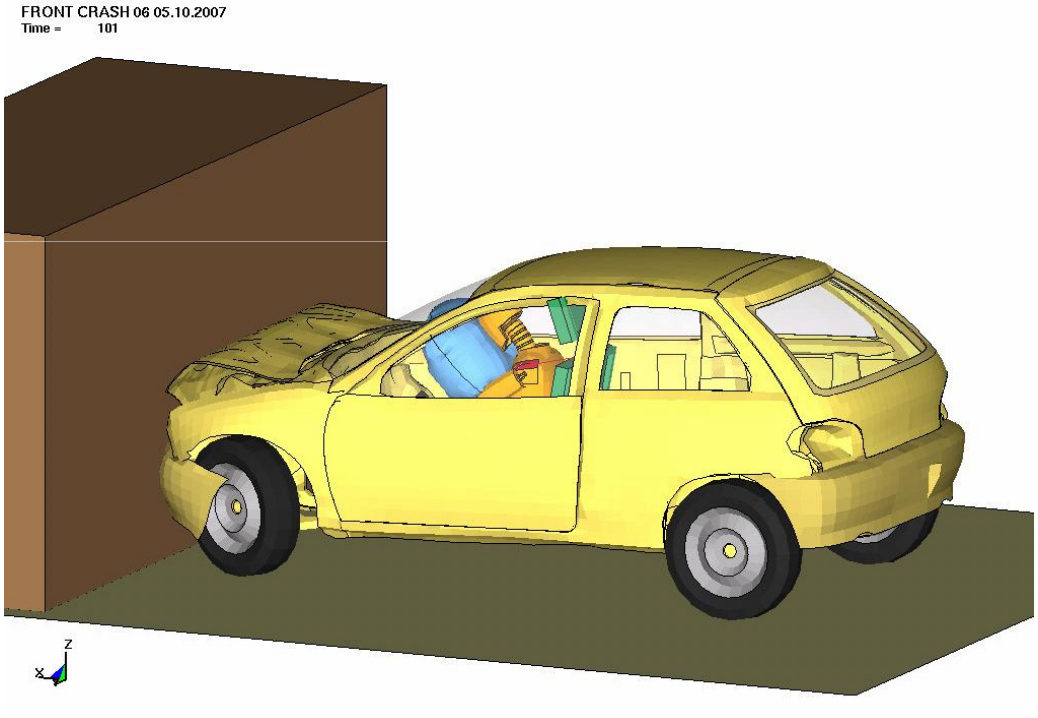




- Selection of suitable points out of the set of Pareto optimal solutions
  - → Store variable values in a .csv file
  - → user-defined sampling in LS-OPT
  - → verification runs for the predicted results can be performed

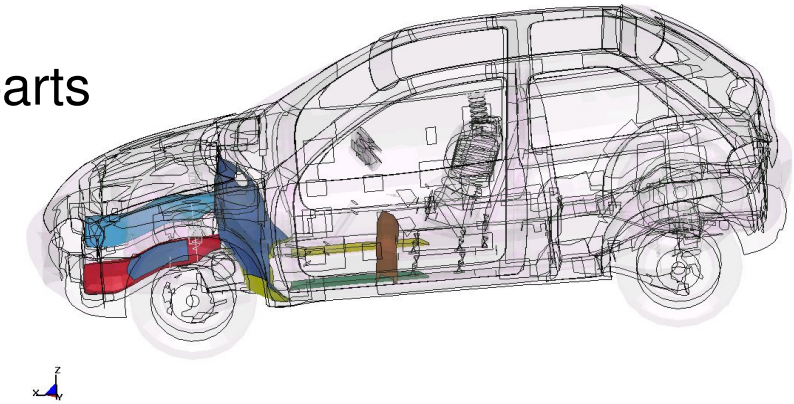
DOE Study of a Front Crash

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

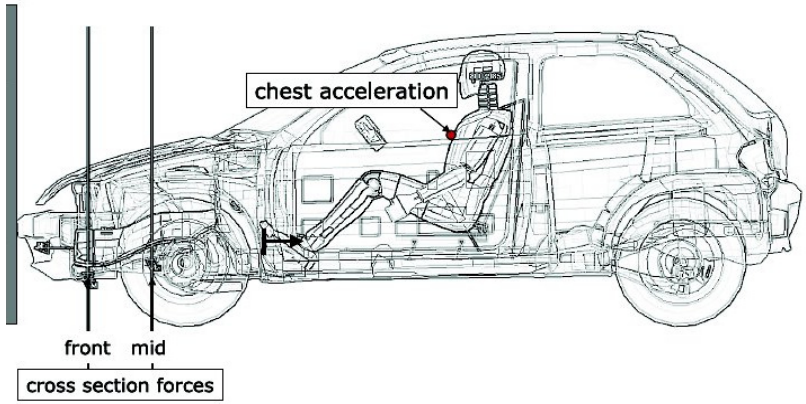


Problem description

- 6 design variables
  - sheet thicknesses of highlighted parts



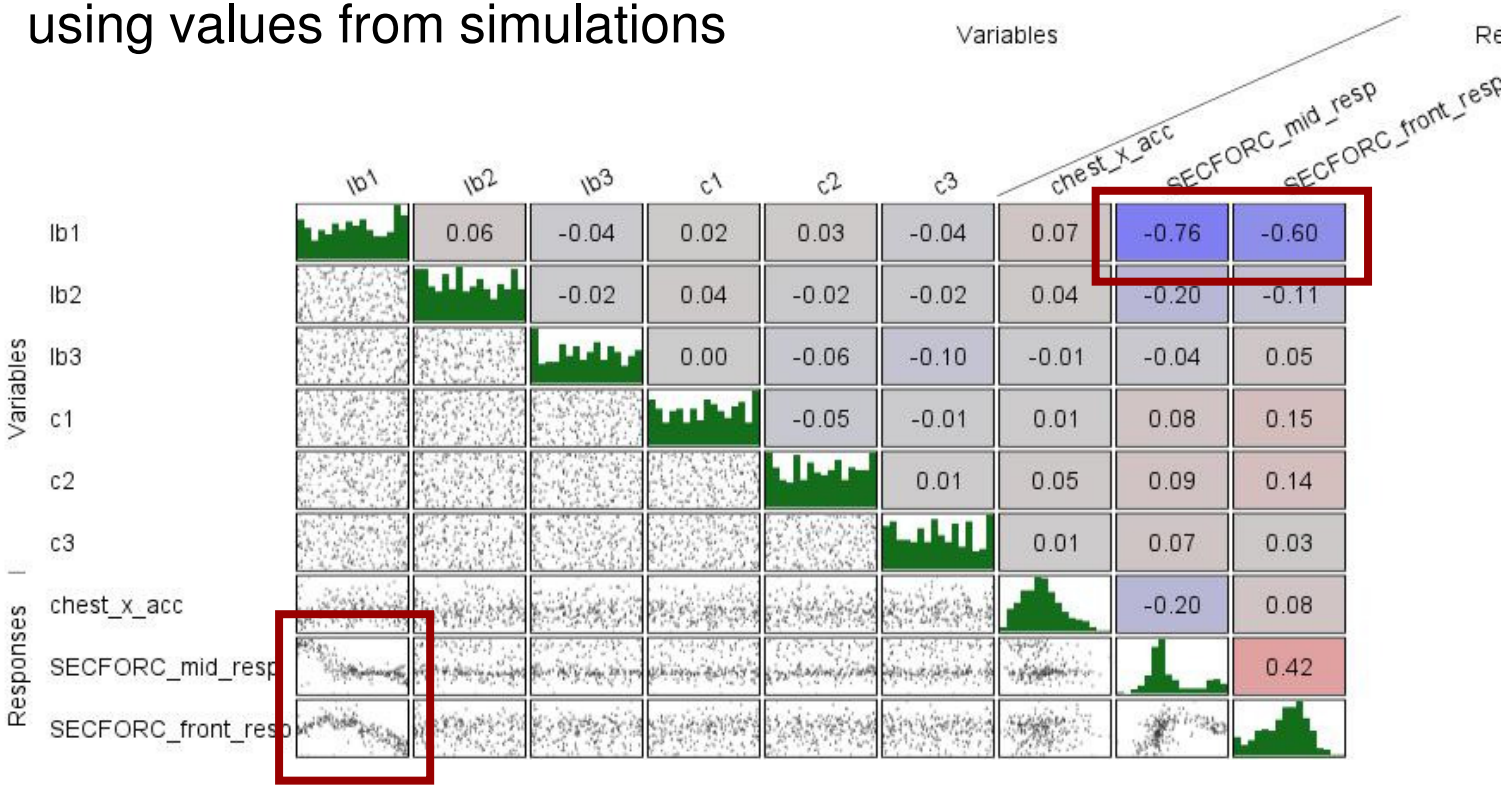
- Responses
  - Chest acceleration of dummy
  - Forces evaluated at 2 cross sections
  - Constraint on mass of vehicle



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

Visualization

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

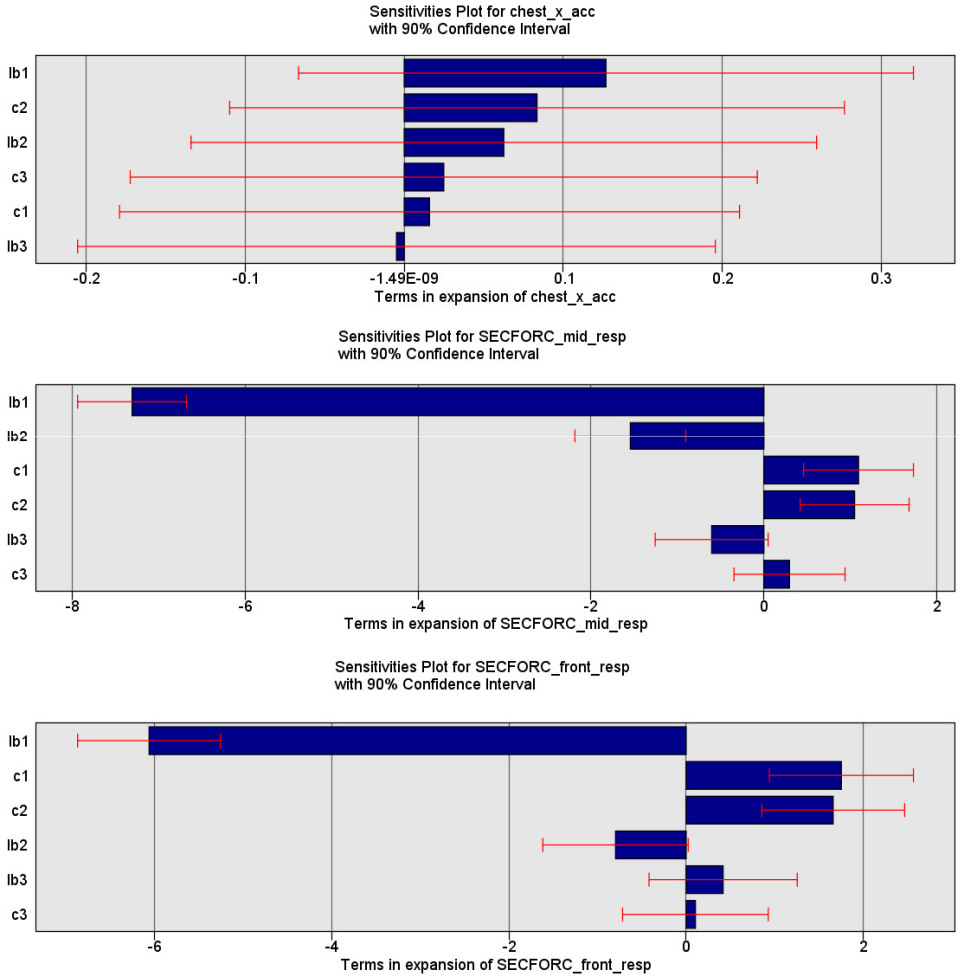


→ *lb1* has a strong effect onto the section forces

→ all variables are insignificant on the chest acceleration

Visualization

- ANOVA (Analysis of Variance) calculated on metamodel



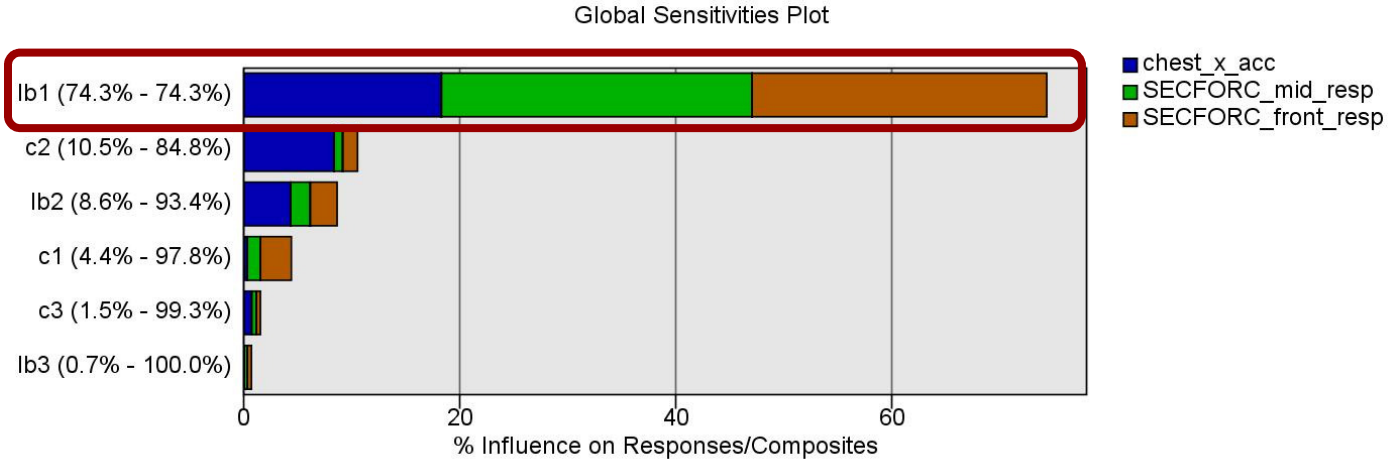
Not meaningful
→ large red error bars

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

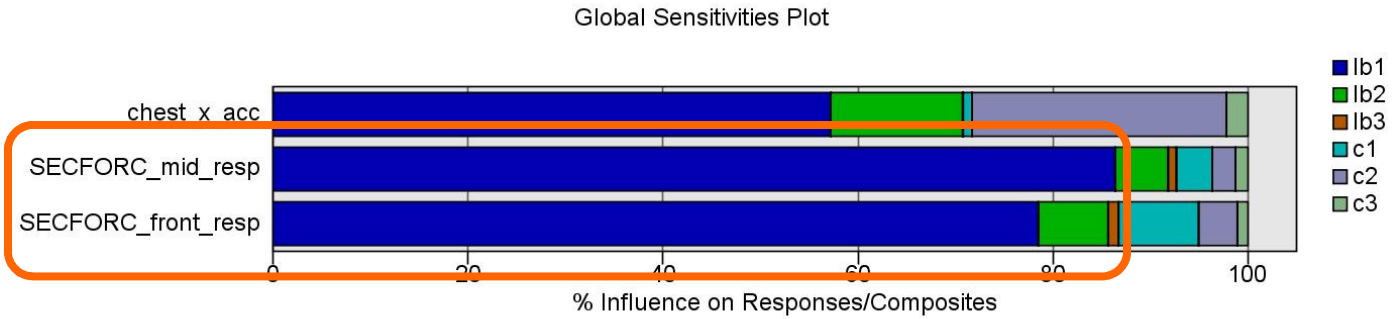
Visualization

- 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

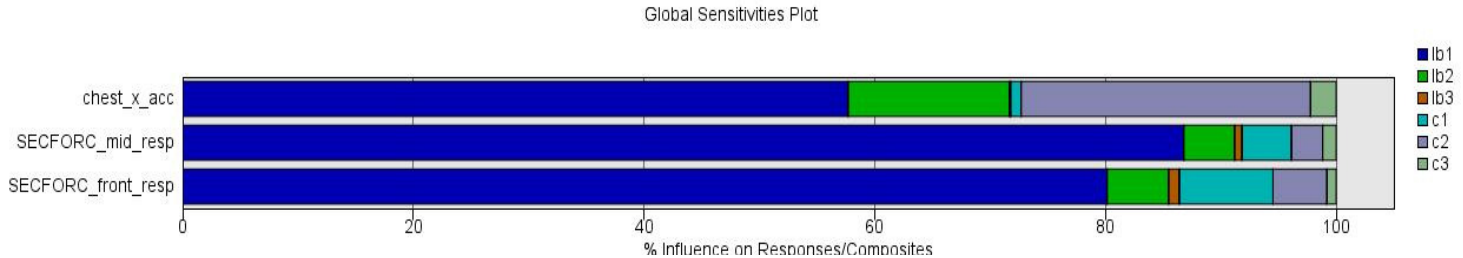


lb1
strongest effect
on section forces



Visualization

- Nonlinear sensitivities
- *lb1* also has a strong effect on the chest acceleration



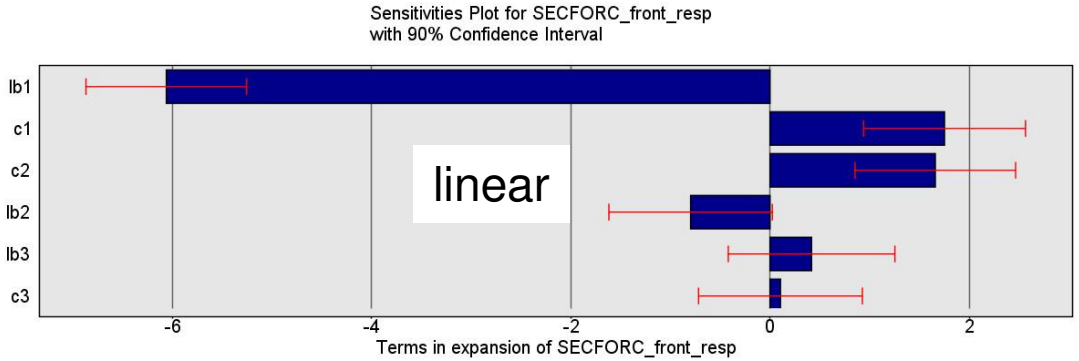
Variables	chest_x_acc	SECFORC_mid_resp	SECFORC_front_resp
lb1	0.07	-0.76	-0.60
lb2	0.04	-0.20	-0.11
lb3	-0.01	-0.04	0.05
c1	0.01	0.08	0.15
c2	0.05	0.09	0.14
c3	0.01	0.07	0.03

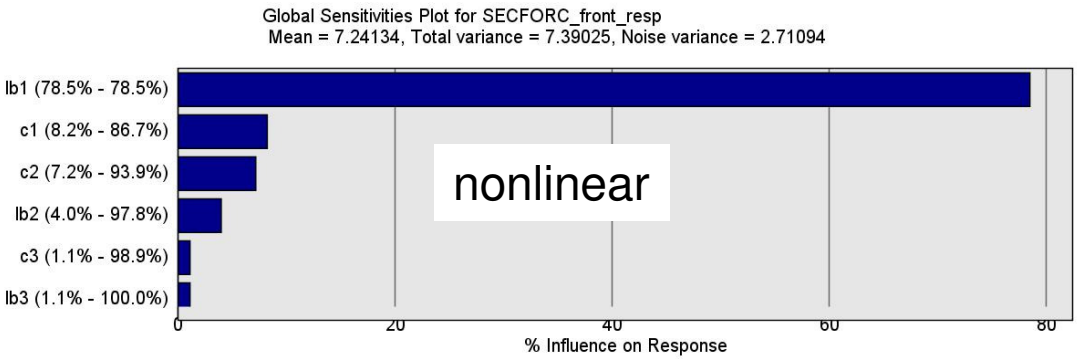
	Total variance
chest_x_accel	0.0013
SECFORC_mid_resp	5.16
SECFORC_front_resp	4.73

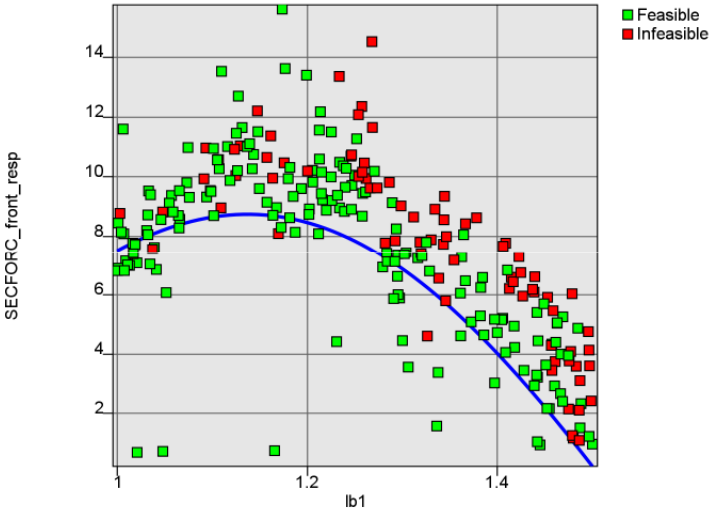
- Total variance of chest acceleration small → correlation coefficient small

Visualization

- 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



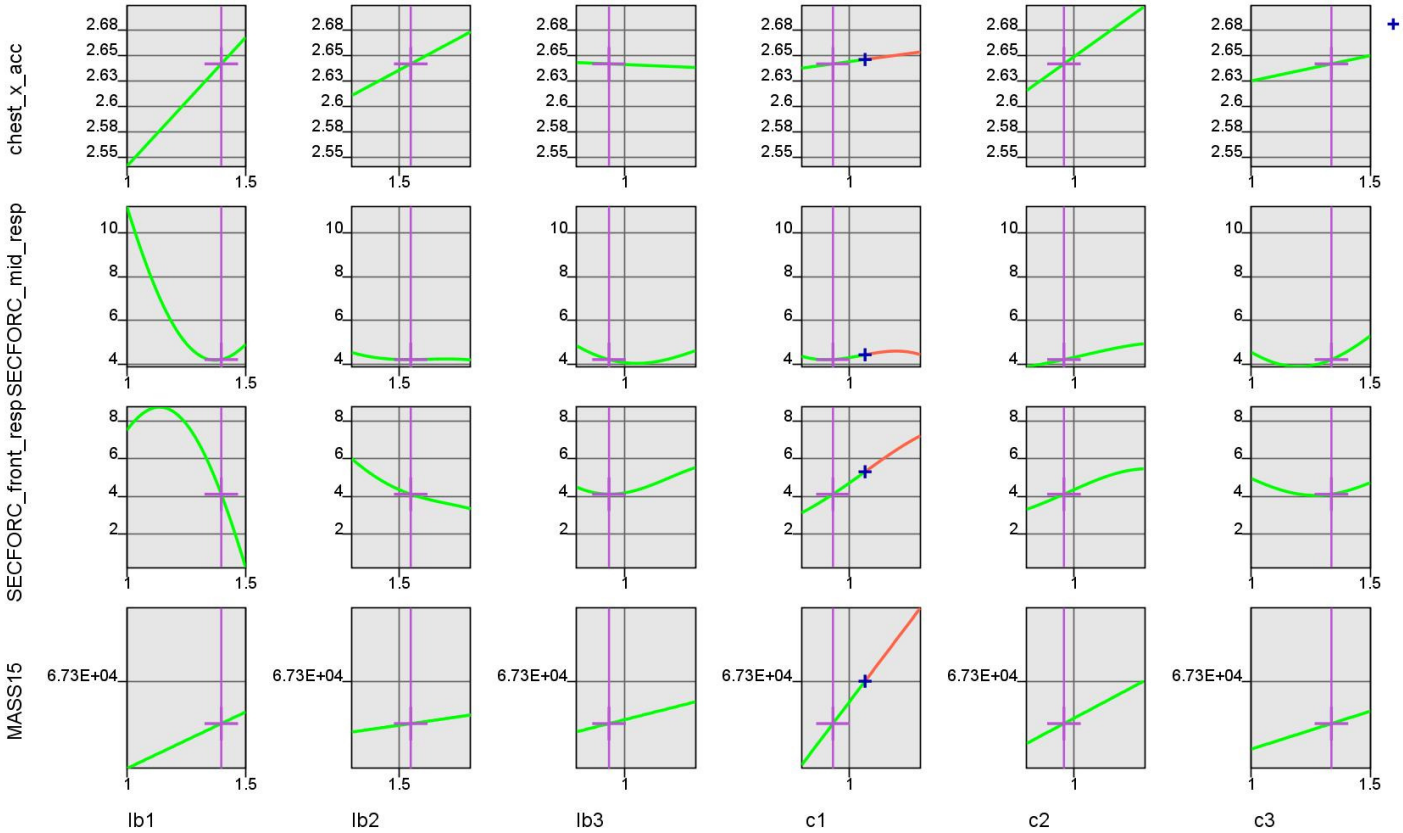




→ quadratic correlation is not detected completely by linear correlation

Visualization

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



Summary

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)