Webinar

New Features in LS-OPT® 6.0

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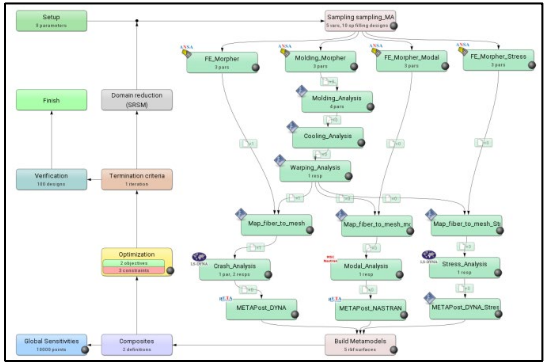
Outline

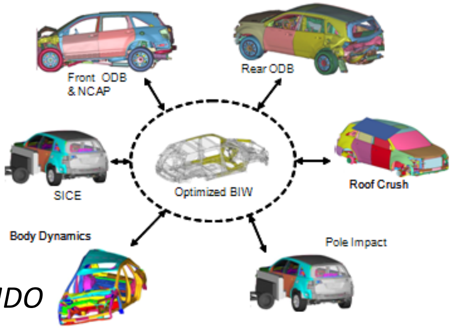
- Overview of LS-OPT
- New features in LS-OPT 6.0
  - DIC-based parameter identification
  - Support Vector Classification
  - Interactive tables
  - Other new features

LS-OPT® - Optimization, Probabilistic Analysis & System Calibration

- Process manager
  - multi-stage
  - multi-case
  - multi-level

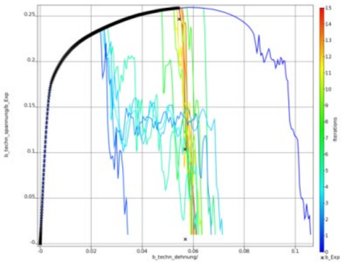


- Optimization
  - MDO
  - MOO
  - Shape Optimization



Multi-case MDO

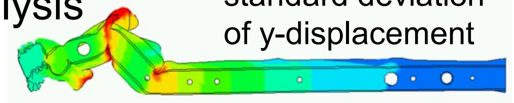
- Material Calibration
  - Curve matching
    - Hysteresis
    - Noise
  - Full-field Calibration



GISSMO

- Statistics and Uncertainty
  - Robust Design
  - Sensitivity Analysis
  - LS-DYNA® Statistics
    - Outlier Analysis

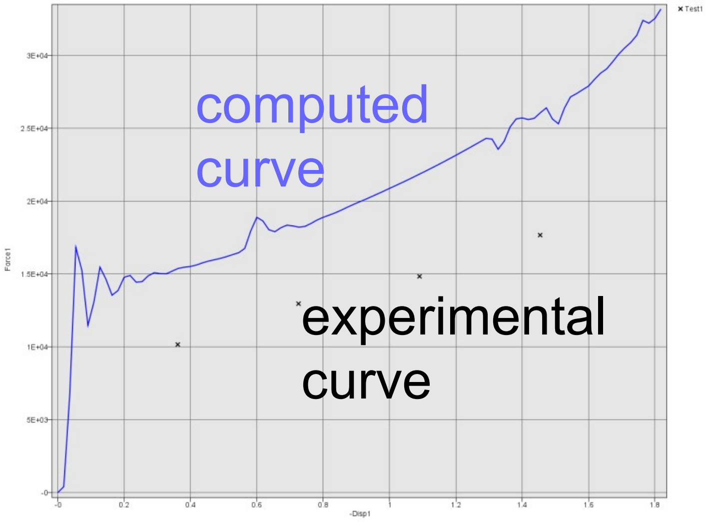
standard deviation of y-displacement



Parameter Identification

Parameter Identification

- Parameter Identification problems are non-linear inverse problems solved using optimization
- Computed curves (from LS-DYNA®), dependent on parameters, are matched to experimental curves
- Optimization provides a calibration of the unknown parameters

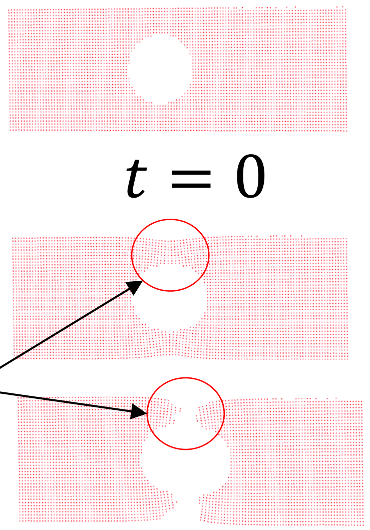


Calibration of material parameters - Standard approach

- Global data from experiment is used
- Problems:
  - Instability typical in calibration problems, especially complex models with many parameters
  - Local phenomena such as coupon necking/barreling missed

→ Use full-field data

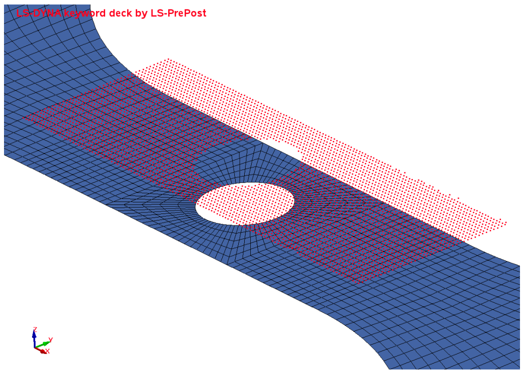
Local deformation



$t = 0$

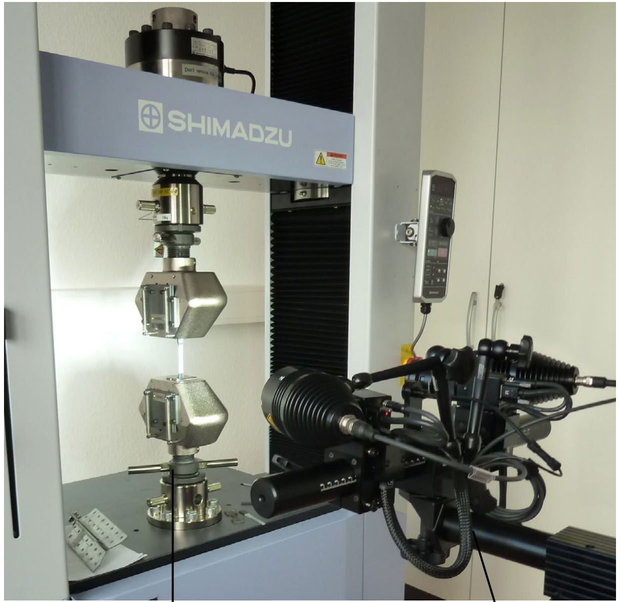
DIC data: deformation states

Full field test result (4557 pts) from optical scan is mapped and tracked



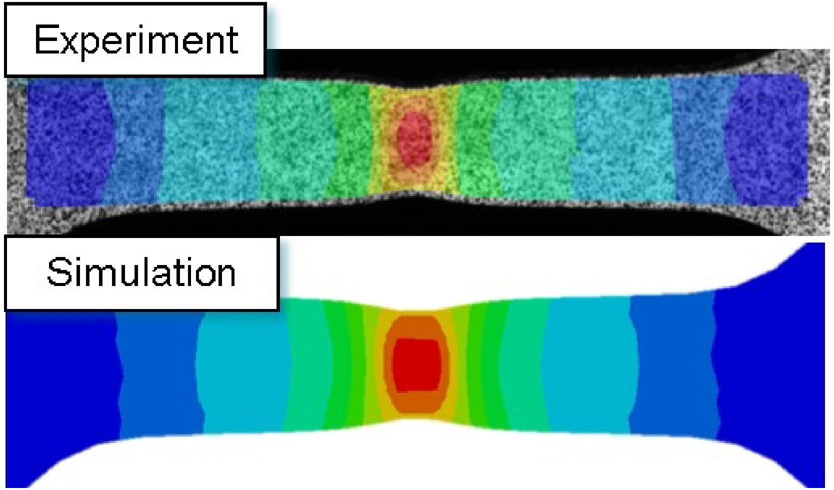
Digital Image Correlation

- Optical method for tracking changes in images



Tensile testing equipment

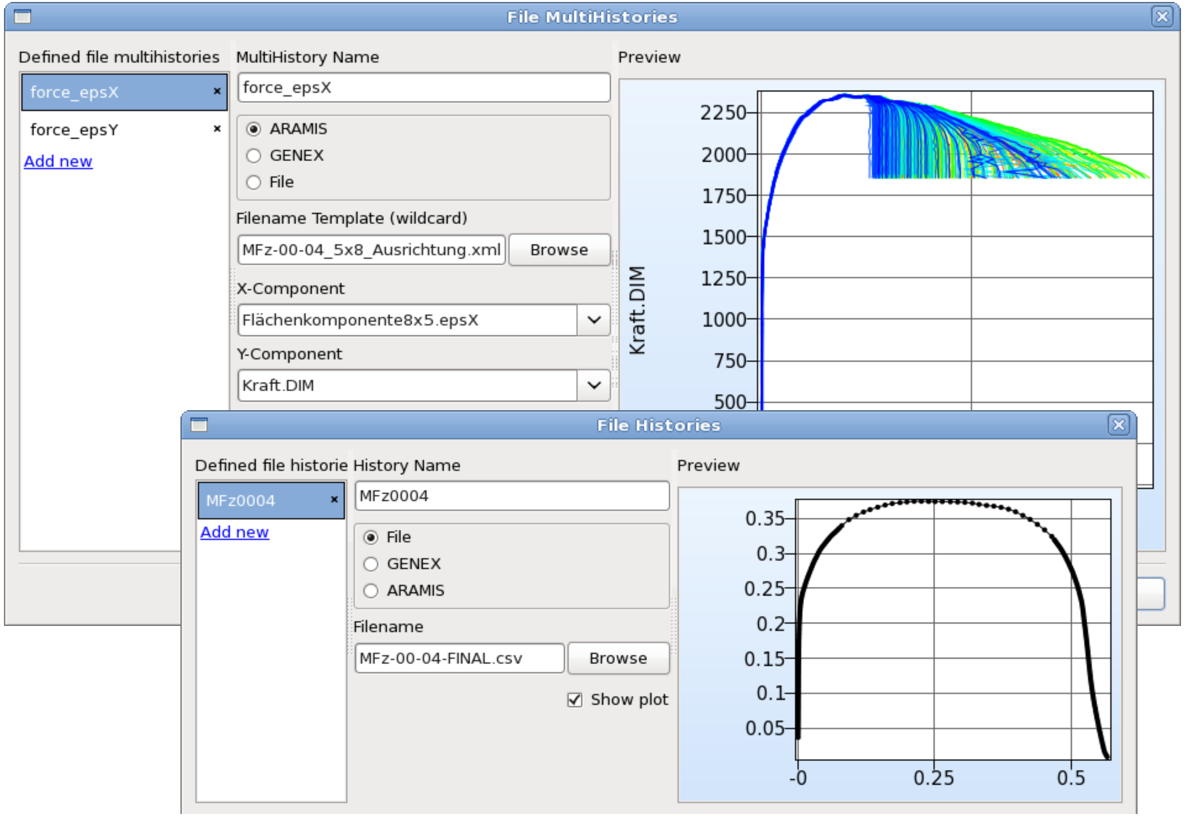
Measurement system



gom/ARAMIS setup at DYNAmore GmbH

Import DIC data into LS-OPT

- Interfaces (LS-OPT 6.0) Multihistories and Histories
  - ARAMIS (gom)
  - GENEX
    - Extraction from ASCII files
    - DIC data may be stored in multiple files
      → One file per time stage

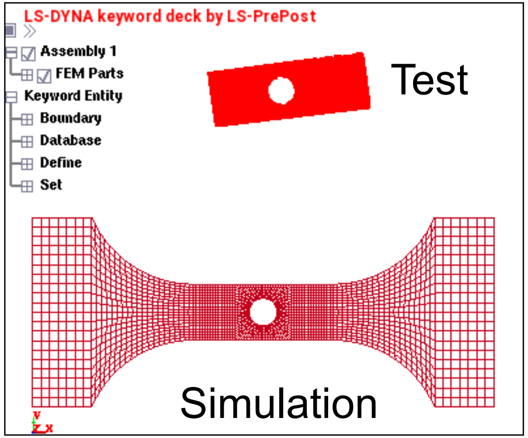


Alignment of test and simulation data

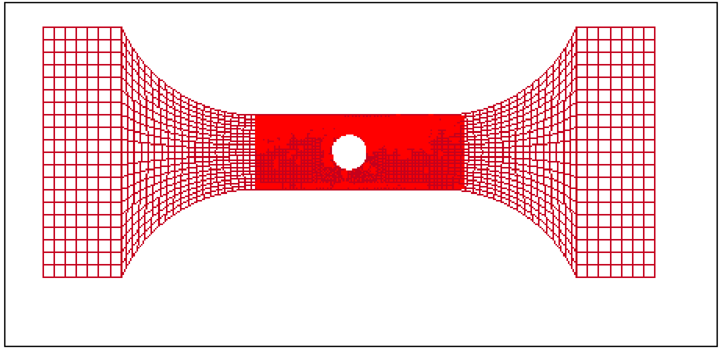
- Test and simulation geometries are typically in different coordinate systems
- Transformation of coordinates using least square formulation

$$\min_{\boldsymbol{T}} \left\| \hat{s} \boldsymbol{X}_{\mathrm{Test}} \boldsymbol{T} - \boldsymbol{X}_{\mathrm{FE}} \right\|$$

  - $\boldsymbol{X}_{\mathrm{Test}}$: Test points (subset), $\boldsymbol{X}_{\mathrm{FE}}$: FE model points, $\boldsymbol{T}$: transform, $\hat{s}$: Isotropic scaling

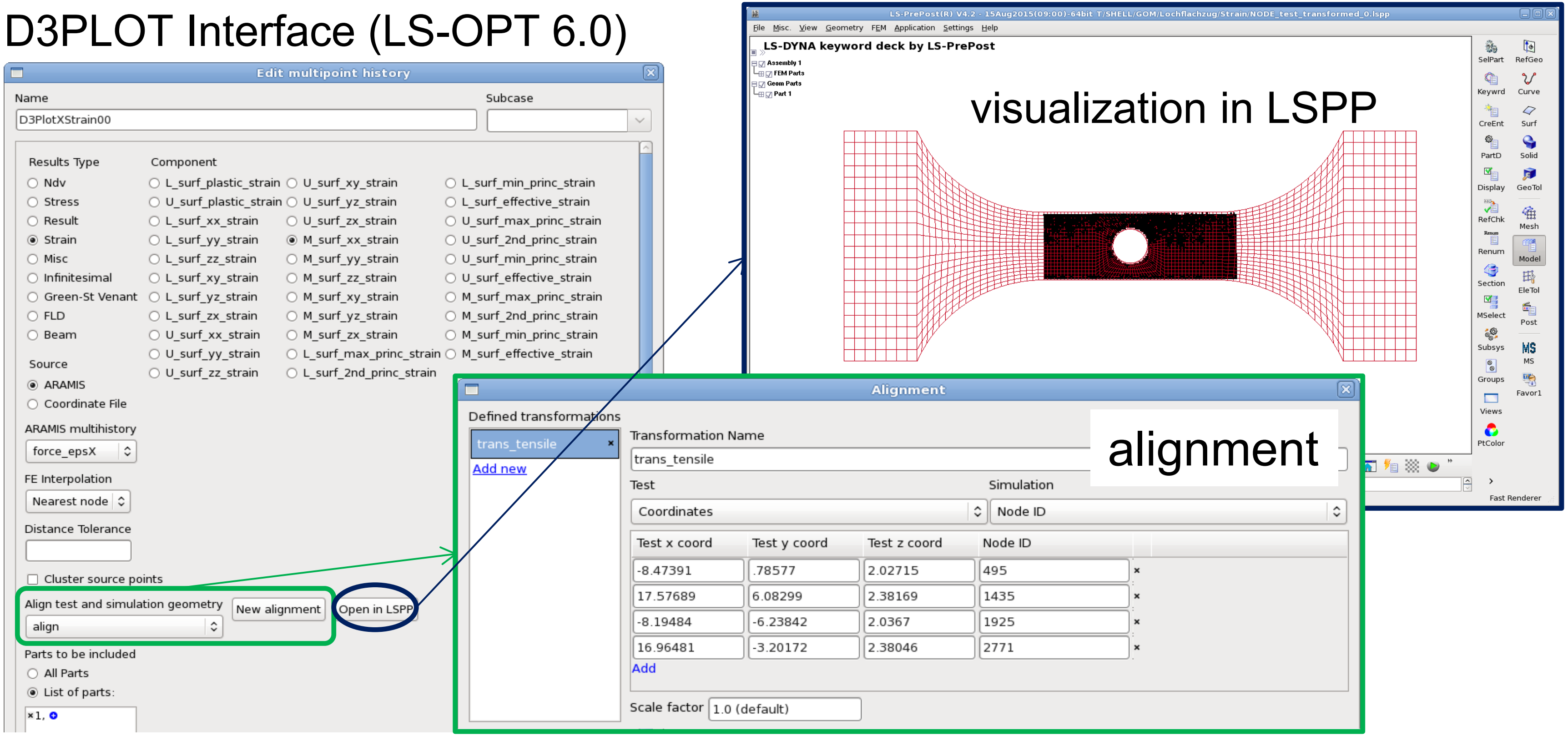


Alignment



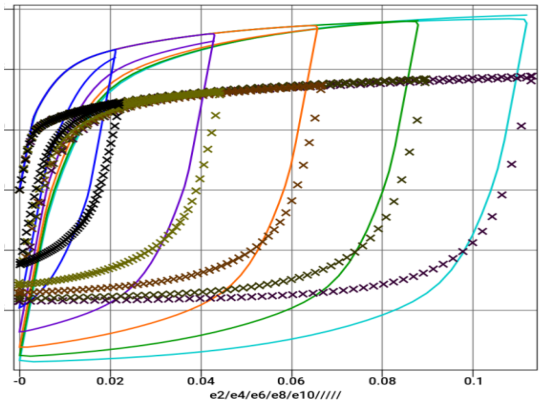
Extraction of Multihistories from simulation

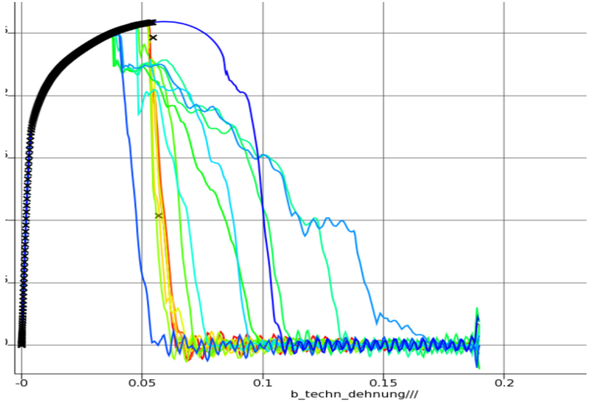
- D3PLOT Interface (LS-OPT 6.0)

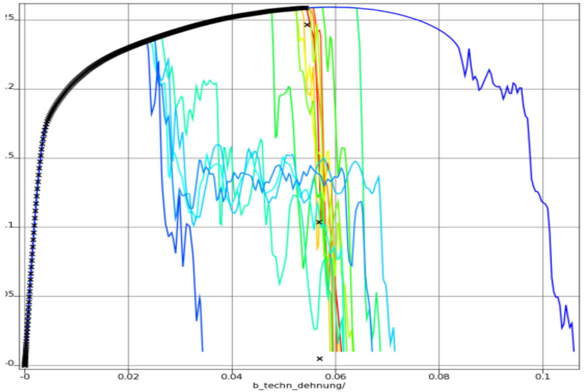


Calibration: Computational challenges

- Experimental and computational results can be difficult to compare







Hysteresis

Material 125 - Loading/Unloading

→ Partial Curve Mapping

Partial Matching

Failure model: GISSMO - post-failure oscillation of coupon

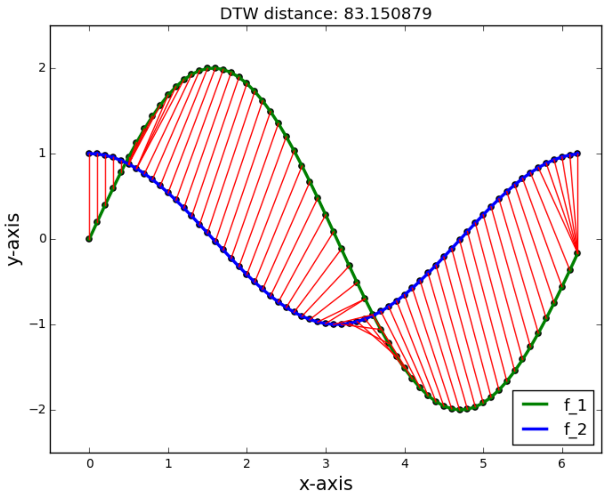
→ Partial Curve Mapping

Noise

Failure model: GISSMO - element erosion a discrete process

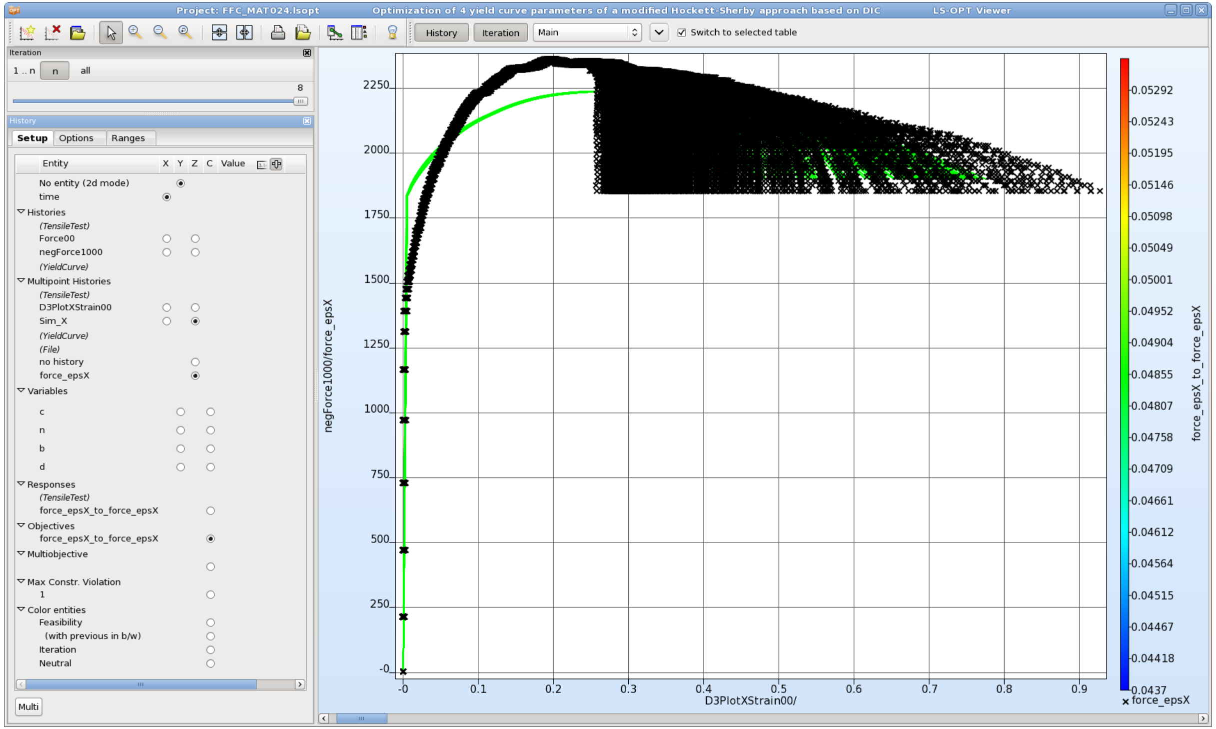
Dynamic Time Warping

- Suitable for noisy curves
- Not suitable for partial mapping
- Warping path: minimum accumulated distance
  which is necessary to traverse all points in the curves

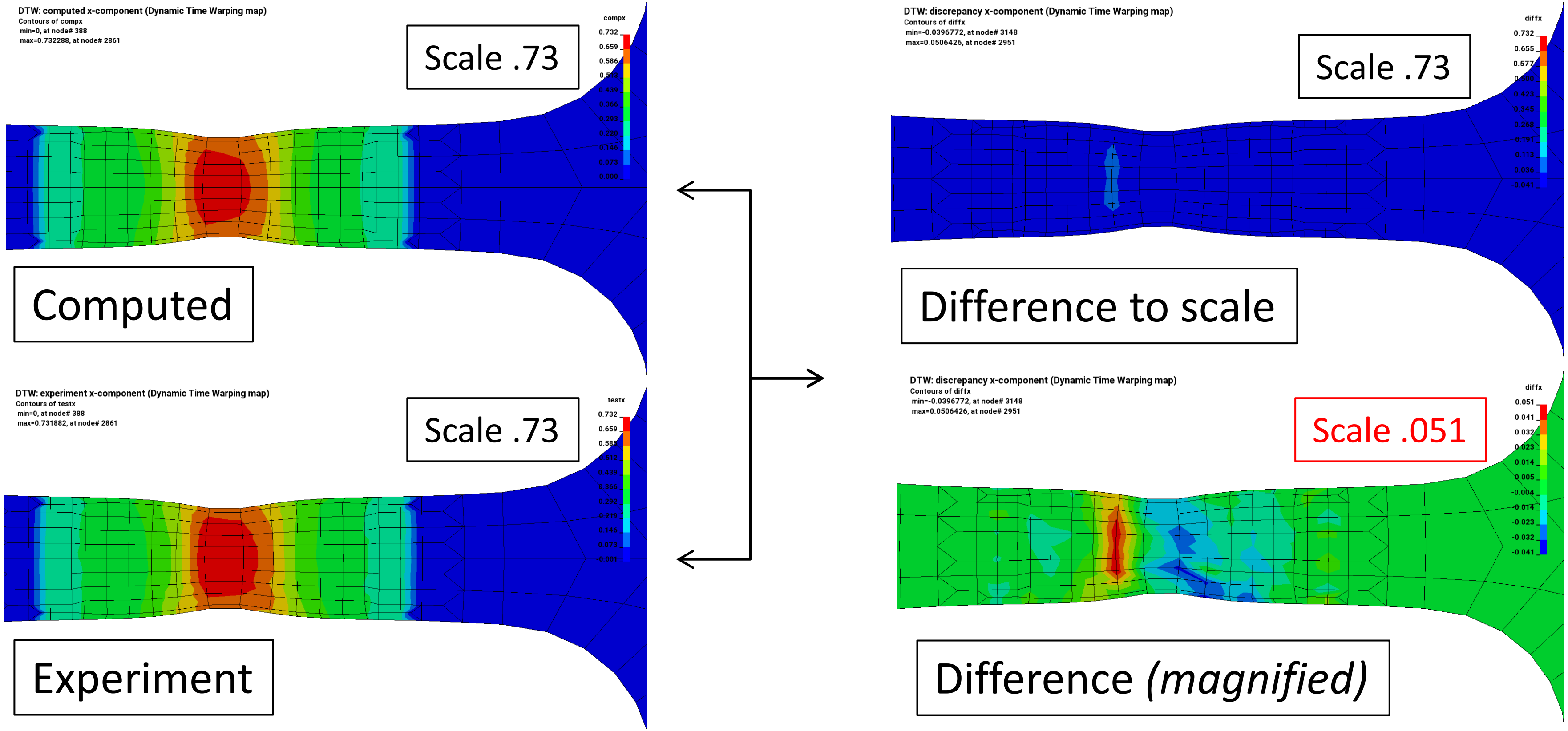


Postprocessing: Multihistory plot

- Visualization of test and simulation curves



Postprocessing: Contour plots in LS-PrePost



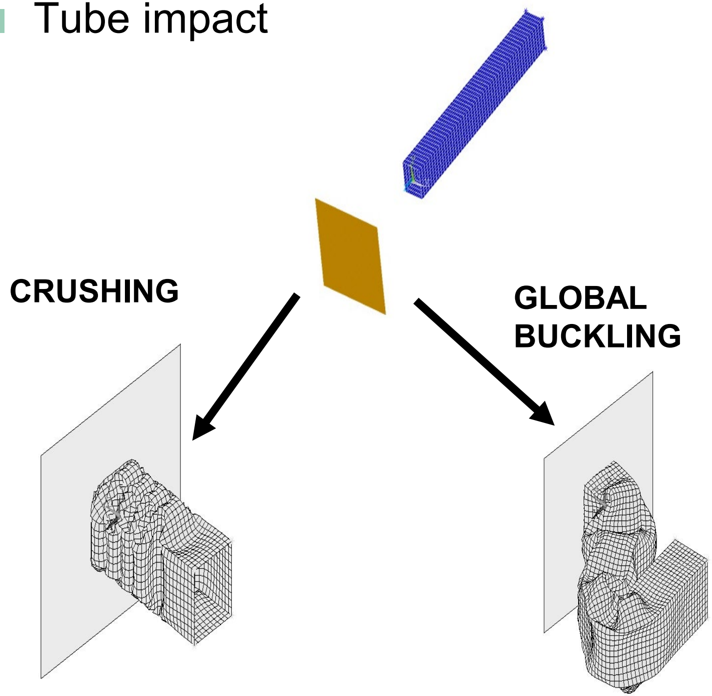
LSTC Livermore Software Technology Corp.

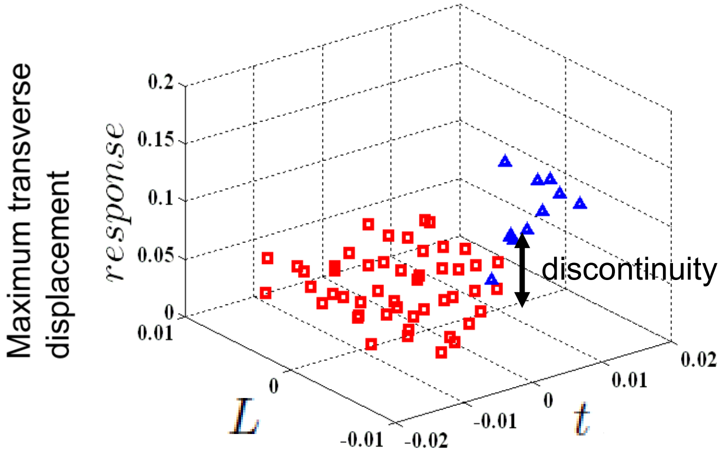
DYNA MORE

Support Vector Machine Classification

Metamodeling Challenges

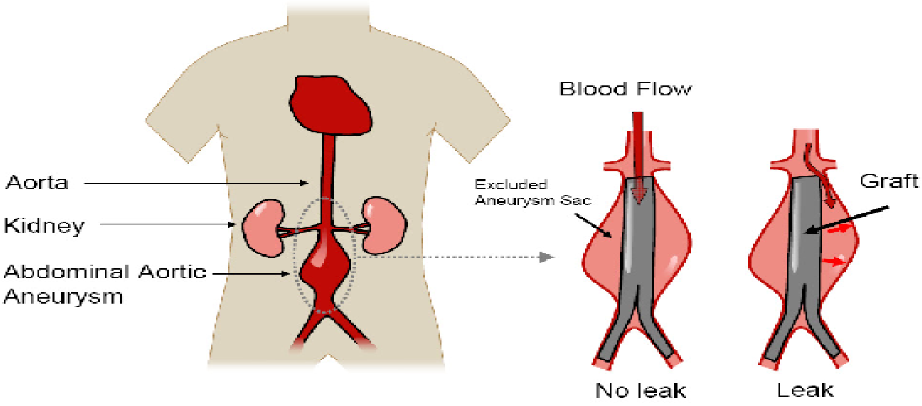
- Discontinuous responses
  - Tube impact

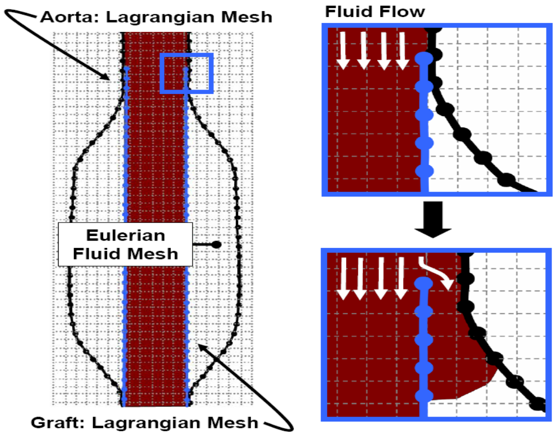




Metamodeling Challenges

- Binary responses
  - Blood leakage from stent





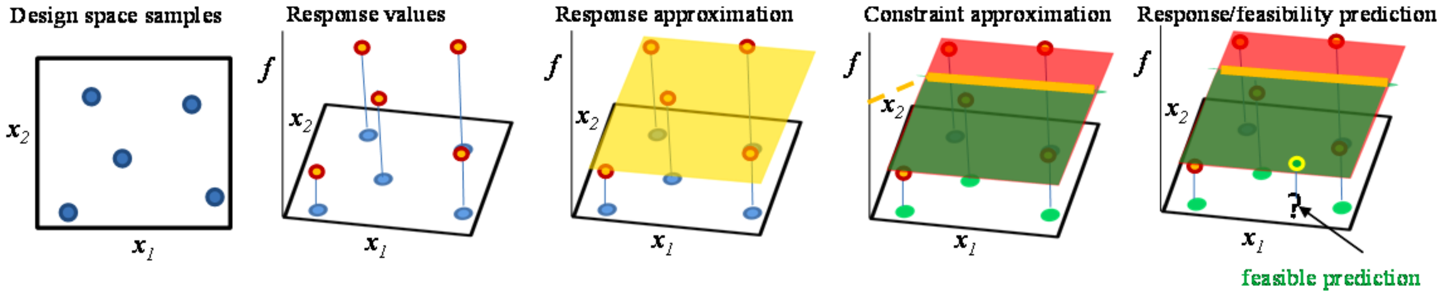
Layman, R. et al. "Simulation and probabilistic failure prediction of grafts for aortic aneurysm."
Engineering Computations 27.1 (2010): 84-105.

Binary information:
Failed (leaked) or not (no leakage)

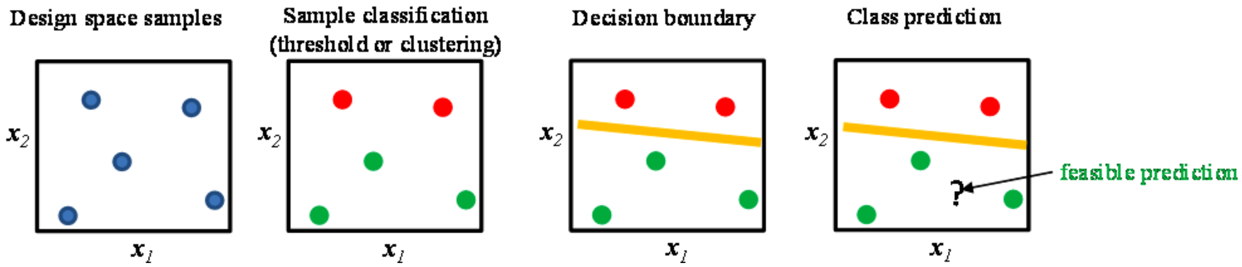
Support Vector Machine Classification

- Discontinuous and binary responses
  - Map input data to category

Metamodeling

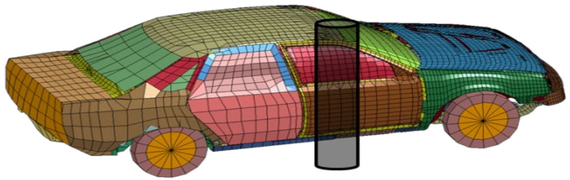


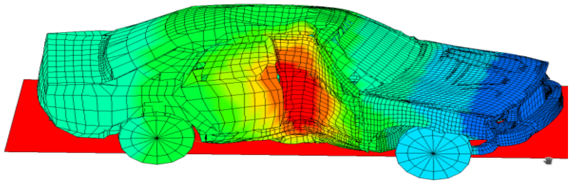
Basic classification method

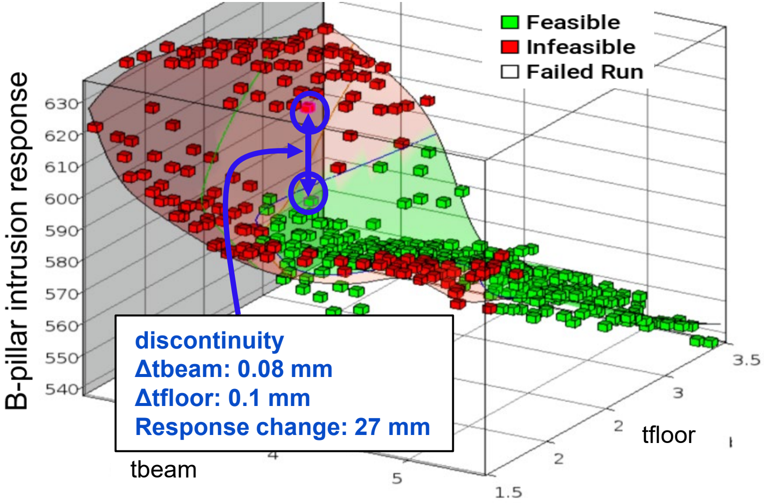


Application 1: Discontinuous Constraint Reliability

- Side Pole Impact
  - Random/Noise Variables (Normal distribution)
    - Beam thickness
    - Floor thickness
  - Reliability assessment
    - B-pillar intrusion < 585 mm
    - Lower beam intrusion < 710 mm
    - Door intrusion < 638.23 mm

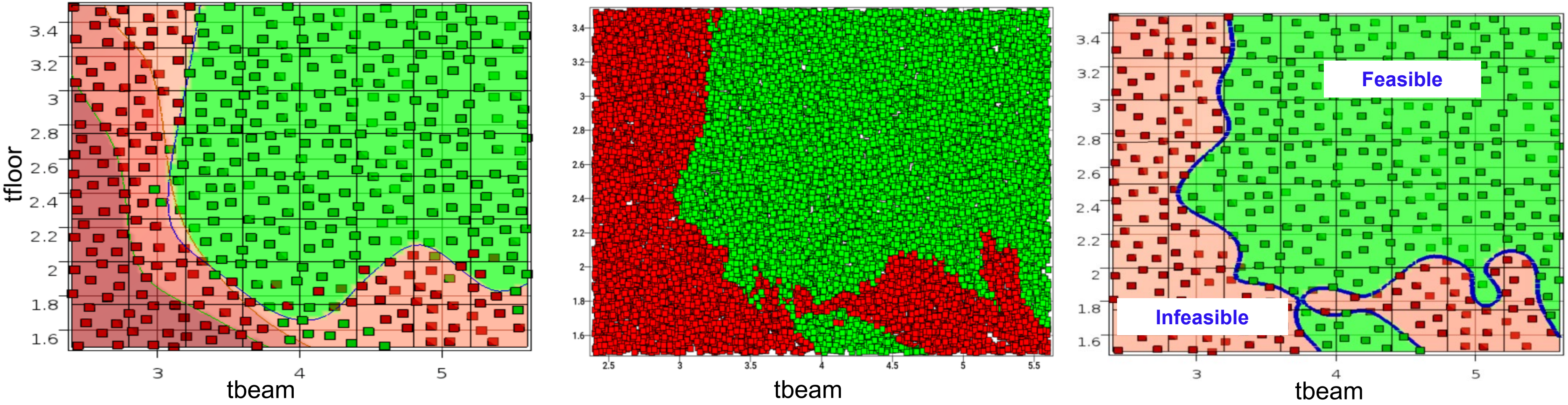






Application 1: Discontinuous Constraint Reliability

- Classifier able to approximate highly nonlinear boundaries accurately
  - Failure probability using Neural Network Metamodel (400 samples): 0.0217
  - Failure probability using SVM Classifier (400 samples): 0.0218
  - Actual Failure probability (20,000 LS-DYNA runs): 0.0219



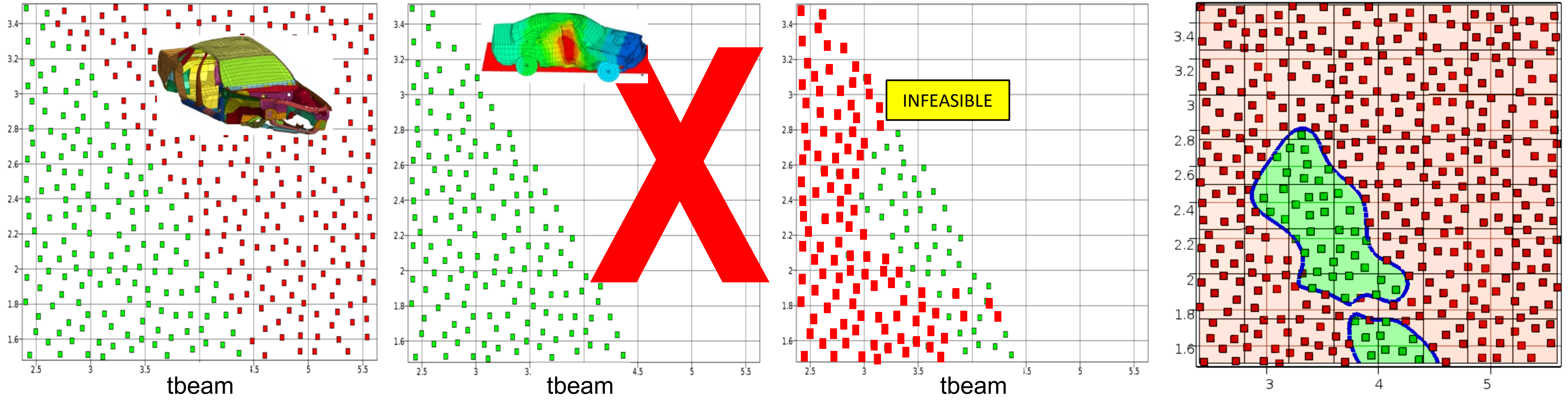
Neural net approximation of constraint (inaccurate) | Actual constraint feasibility (LS-DYNA) | SVM classifier-based constraint (accurate)

Application 2: Multidisciplinary Analysis

- Optimization Cost Savings
  - NVH analysis followed by crash analysis
    - Because classifier is used, *crash analysis needed only at feasible NVH points*
    - Crash simulation savings: 246 out of 400 (61.5 %)

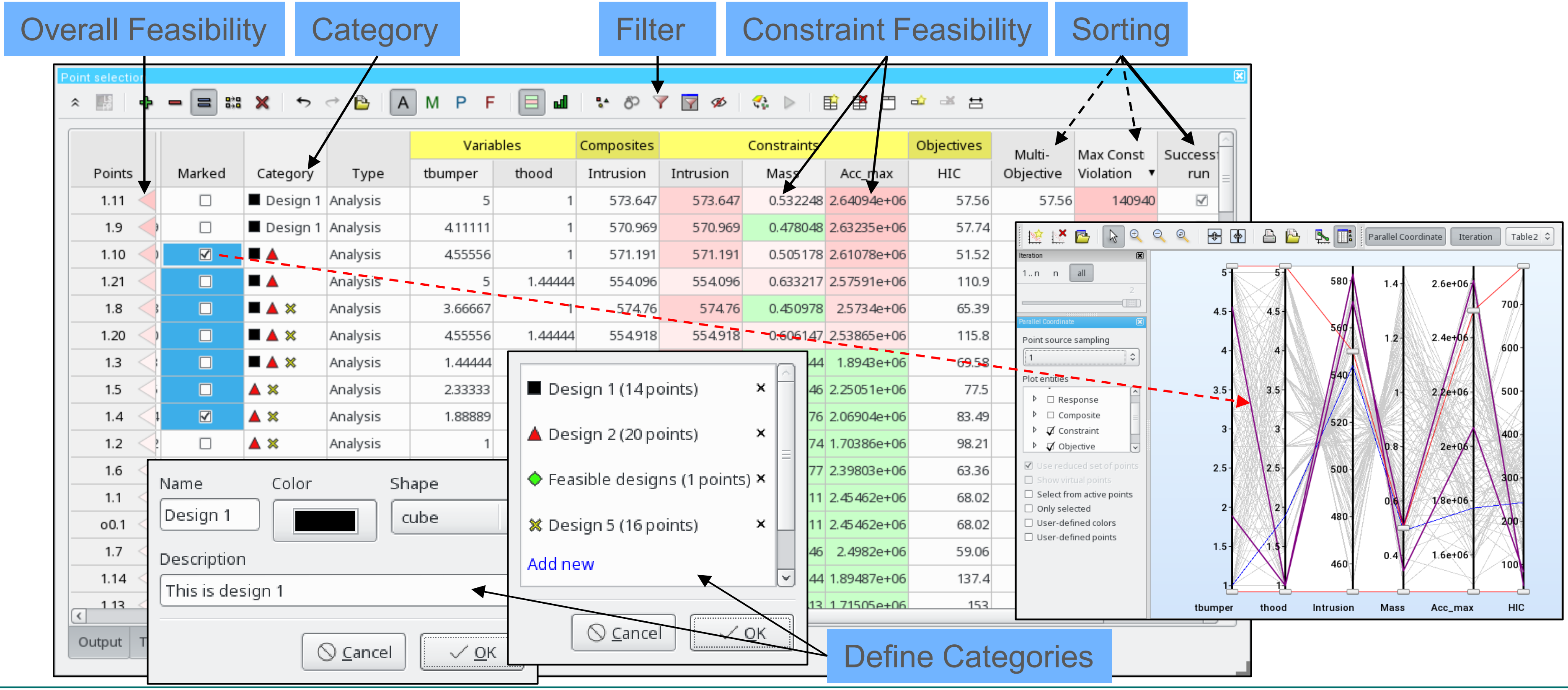
NVH Samples (400)

Crash Samples (154)



Interactive Tables

Interactive Tables



Interactive Tables

- Interactive Constraint management

Constraints are only changed for the active tab

Reset

Constraint	Lower Bound	Strict	Upper Bound	Strict
Intrusion	Set lower bound	×	550	☐
Mass	Set lower bound	×	0.7	☐
Acc_max	Set lower bound	×	2.5e+06	☐

- Statistics of selected point

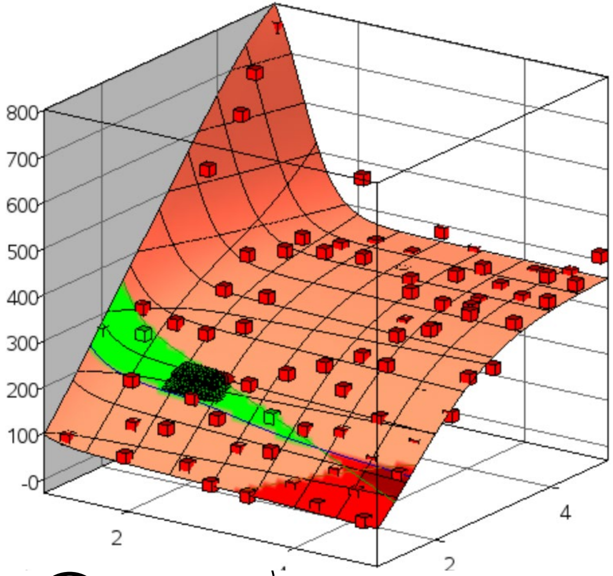
Point selection

	Variables		Composites	Constraints		
Points	tbumper	thood	Intrusion	Intrusion	Mass	Acc_max
Nominal	0	0	0	0	0	0
Mean	2.97523	2.93732	521.056	521.056	0.849357	1.99565e+06
StdDev	1.27034	1.29872	33.3185	33.3185	0.306708	288499
SS	1086.83	1071.02	2.83503e+07	2.83503e+07	84.7155	4.22765e+14
Min	1	1	450.81	450.81	0.288374	1.4871e+06
Max	5	5	583.545	583.545	1.44187	2.64094e+06
Lower Constraint	N/A	N/A	N/A	N/A	N/A	N/A
Lower Exceeded	N/A	N/A	N/A	N/A	N/A	N/A
Prob. Exceed Lower	N/A	N/A	N/A	N/A	N/A	N/A
Upper Constraint	N/A	N/A	N/A	550	0.5	2.5e+06
Upper Exceeded	N/A	N/A	N/A	24	88	6
Prob. Exceed Upper	N/A	N/A	N/A	0.230769	0.846154	0.0576923
Num. Values	104	104	104	104	104	104

Output | Table1 | Table2

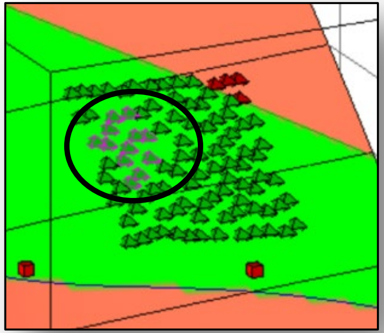
Interactive Tables

- Virtual points



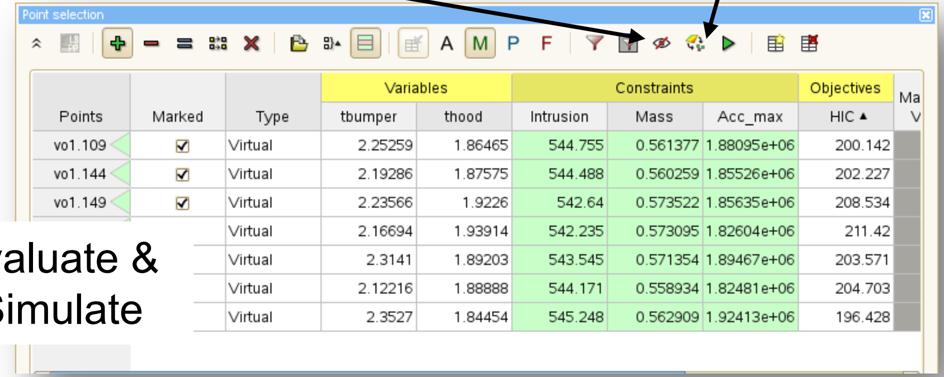
1 Generate in Viewer

2 Select



Virtual points

Run simulations



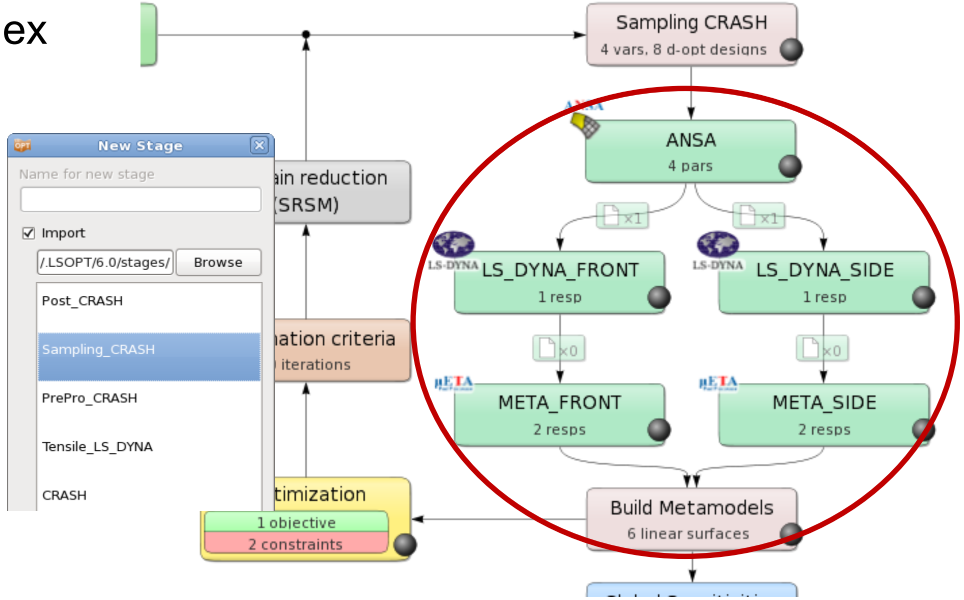
Points	Marked	Type	tbumper	thood	Intrusion	Mass	Acc_max	HIC ▲	Ma V
			Variables		Constraints			Objectives	
vo1.109	☑	Virtual	2.25259	1.86465	544.755	0.561377	1.88095e+06	200.142	
vo1.144	☑	Virtual	2.19286	1.87575	544.488	0.560259	1.85526e+06	202.227	
vo1.149	☑	Virtual	2.23566	1.9226	542.64	0.573522	1.85635e+06	208.534	
		Virtual	2.16694	1.93914	542.235	0.573095	1.82604e+06	211.42	
		Virtual	2.3141	1.89203	543.545	0.571354	1.89467e+06	203.571	
		Virtual	2.12216	1.88888	544.171	0.558934	1.82481e+06	204.703	
		Virtual	2.3527	1.84454	545.248	0.562909	1.92413e+06	196.428	

3 Evaluate & Simulate

Other new Features

Other new Feature

- Taguchi method
  - Classical robust design approach using Orthogonal Arrays
- Interface to LS-TaSC
  - Facilitates LS-TaSC to work with complex design schemes and constraints
- Export and import of stages
  - Individually
  - Full case-based process
    - E.g. Frontal Crash including its pre- and post-processing could be imported/exported as a unit with a given name



More Information on the LSTC Product Suite

- Livermore Software Technology Corp. (LSTC)
  www.lstc.com
- LS-DYNA
  - Support / Tutorials / Examples / FAQ
    www.dynasupport.com
  - More Examples
    www.dynaexamples.com
  - Conference Papers
    www.dynalook.com
  - European Master Distributor
    www.dynamore.de
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- LS-OPT/LS-TaSC
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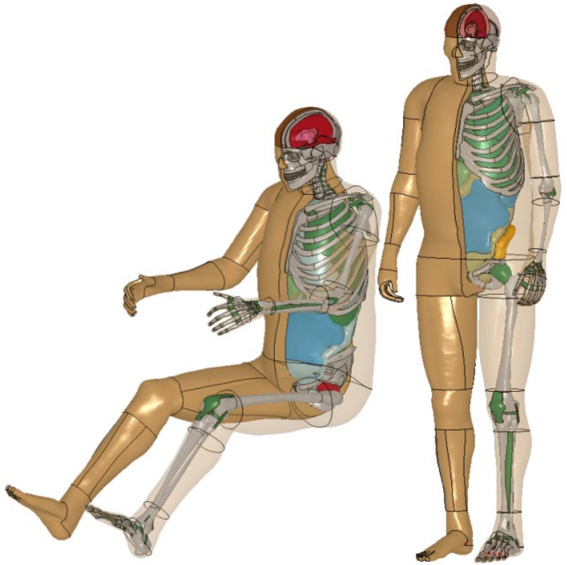
    www.lsoptsupport.com



[THUMS® www.dynamore.de]

Thank you for your attention!

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