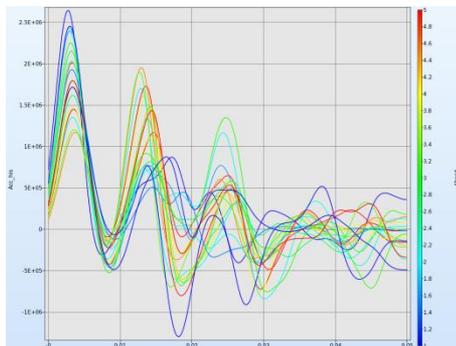
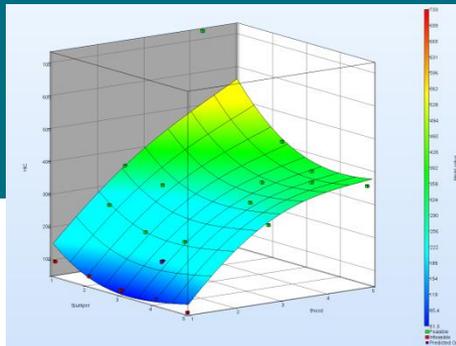




# LS-OPT<sup>®</sup>: Status and Outlook



Nielen Stander<sup>1</sup>, Anirban Basudhar<sup>1</sup>, Imtiaz Gandikota<sup>1</sup>  
Katharina Witowski<sup>2</sup>, Åke Svedin<sup>3</sup>, Christoffer Belestam<sup>3</sup>

<sup>1</sup>Livermore Software Technology Corporation

<sup>2</sup>DYNAmore GmbH

<sup>3</sup>DYNAmore Nordic AB

Bamberg, 12.10.2016



# Outline

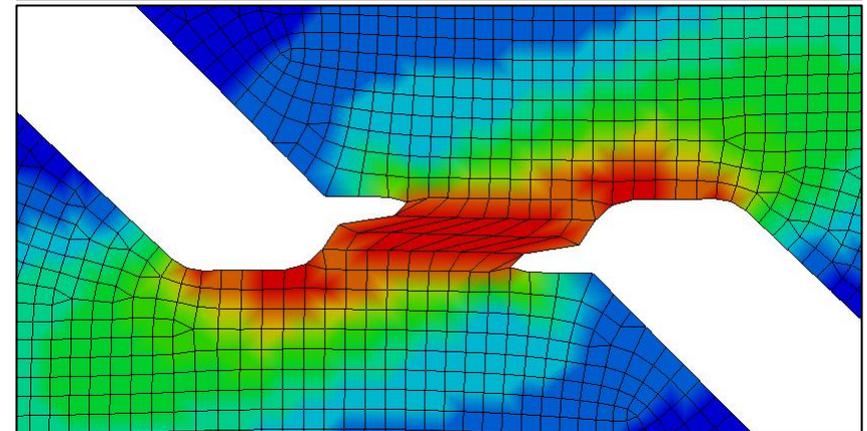
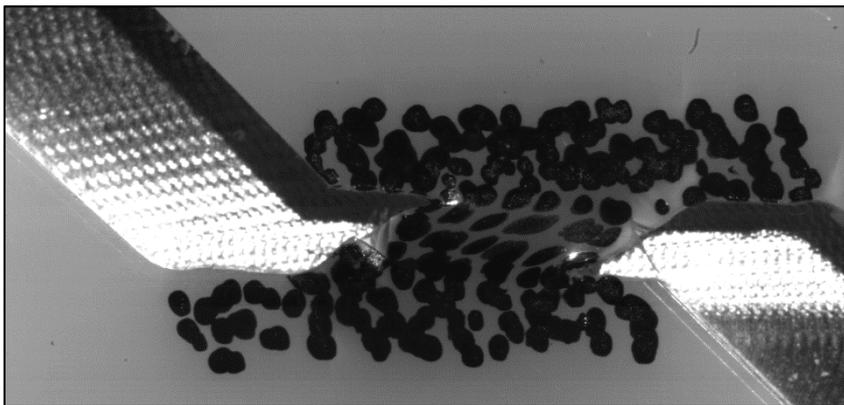
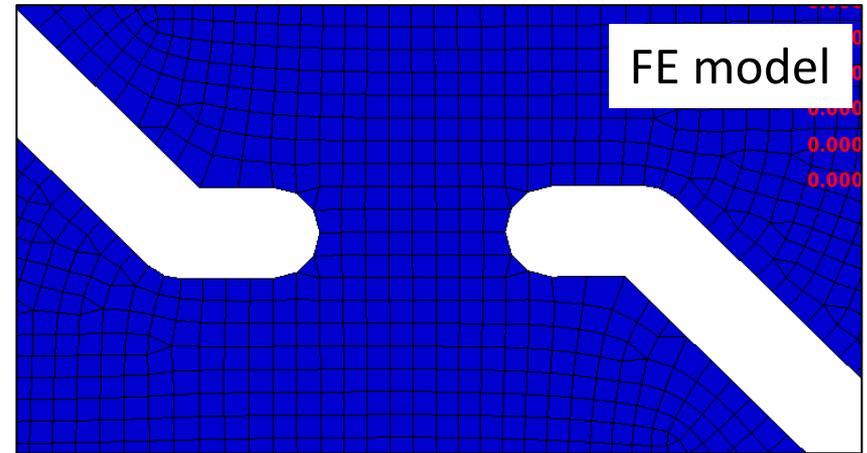
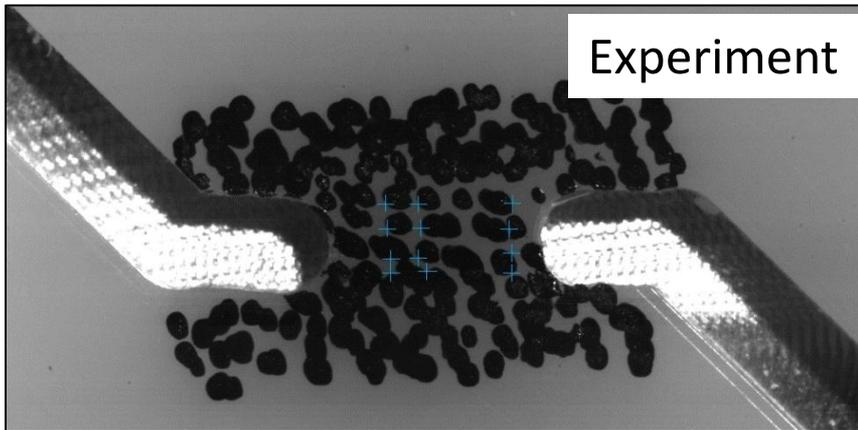
- Current Development
  - Digital Image Correlation based Parameter Identification
  - Interactive Tables
  - Support Vector Classification
- Summary

# Digital Image Correlation (DIC) based System Identification



# Digital Image Correlation

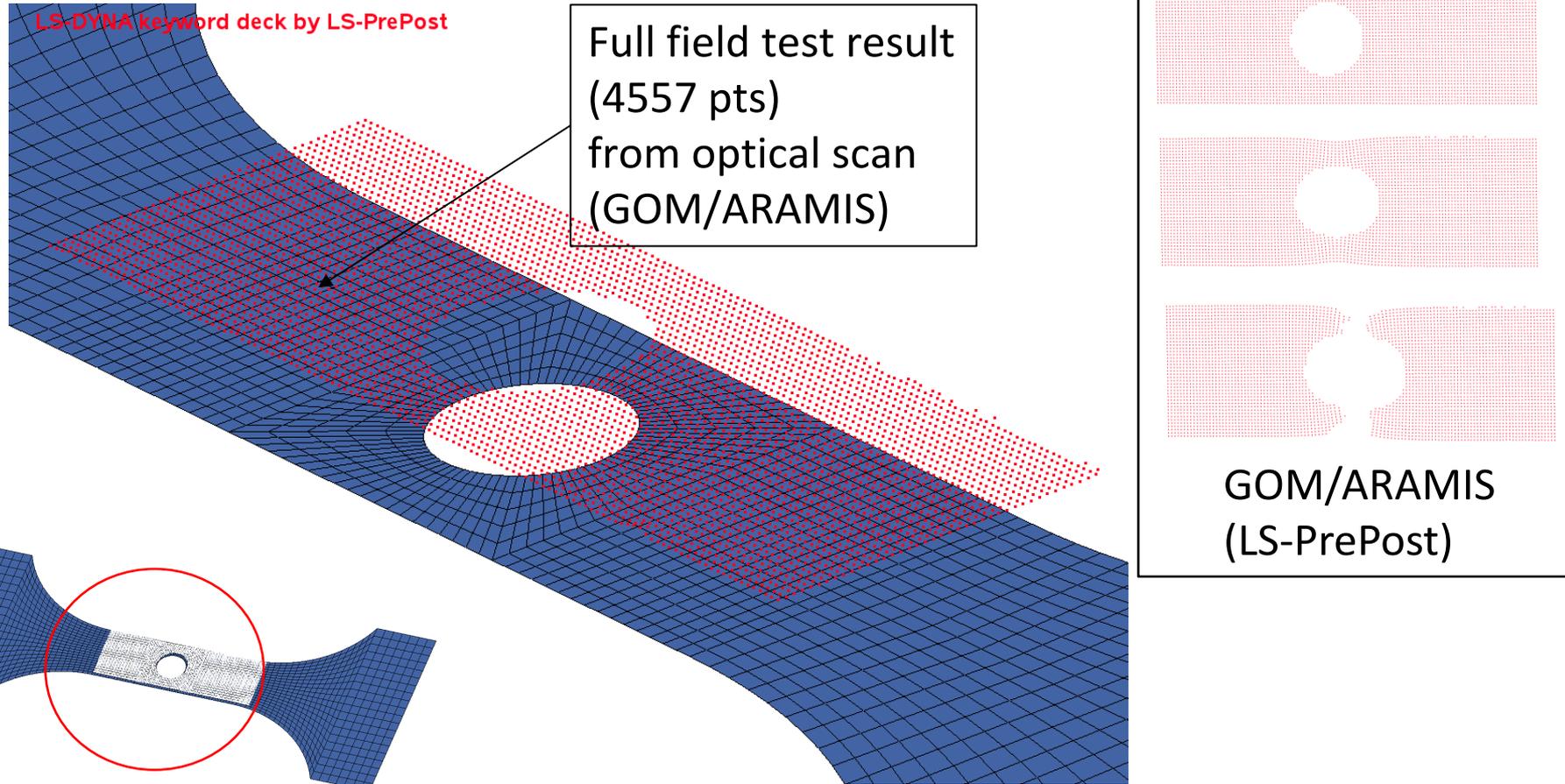
- Example: Shear



Courtesy: Veronika Effinger, DYNAmore GmbH; Andreas Hirth, Daimler AG

# DIC-based Calibration

- Matching in time and space: Example (tensile)



Courtesy: Martin Helbig, Andre Haufe, DYNAmore GmbH

# LS-OPT: Multipoint Histories

## Simulation results

- D3PLOT interface
- Expression
- Crossplot

The image shows two overlapping windows from the LS-OPT software interface. The background window is titled "Stage 1" and has tabs for "Setup", "Parameters", "Histories", "Multihistories", "Responses", "Multiresponses", and "File Operations". The "Multihistories" tab is active, showing a list of "Multipoint History definitions":

- mh\_first\_principal\_strain** (x): D3PLOT: 1st principal strain of part 1
- cp\_mh\_first\_principal\_strain** (x): Crossplot: X: disp, Y: mh\_first\_principal\_strain

On the right side of the "Stage 1" window, there is an "Add new" section with a list of categories: **Generic**, **EXPRESSION**, **Derived**, **Crossplot**, **LS-DYNA**, and **D3PLOT**. A "File Multihistories" button is located below this list.

The foreground window is titled "Edit multipoint history" and contains the following fields and options:

- Name:** mh\_first\_principal\_strain
- Subcase:** (dropdown menu)
- Location:** gom/ARAMIS history
  - gom/ARAMIS: test\_Lochflachzug\_s1
  - Coordinate File
  - Set ID
- Parts to be included:**
  - All Parts
  - List of parts: \*1, 1
- Results Type:**
  - Ndv
  - Stress
  - Result
  - Strain
  - Misc
  - Infin
  - FLD
  - Beam
- Component:**
  - x-strain
  - y-strain
  - z-strain
  - xy-strain
  - yz-strain
  - zx-strain
  - mean strain
  - effective strain(v-m)
- Other options:**
  - 1st-prin. deviatoric
  - 2nd-prin. deviatoric
  - 3rd-prin. deviatoric
  - max shear strain
  - 1st-principal strain
  - 2nd-principal strain
  - 3rd-principal strain

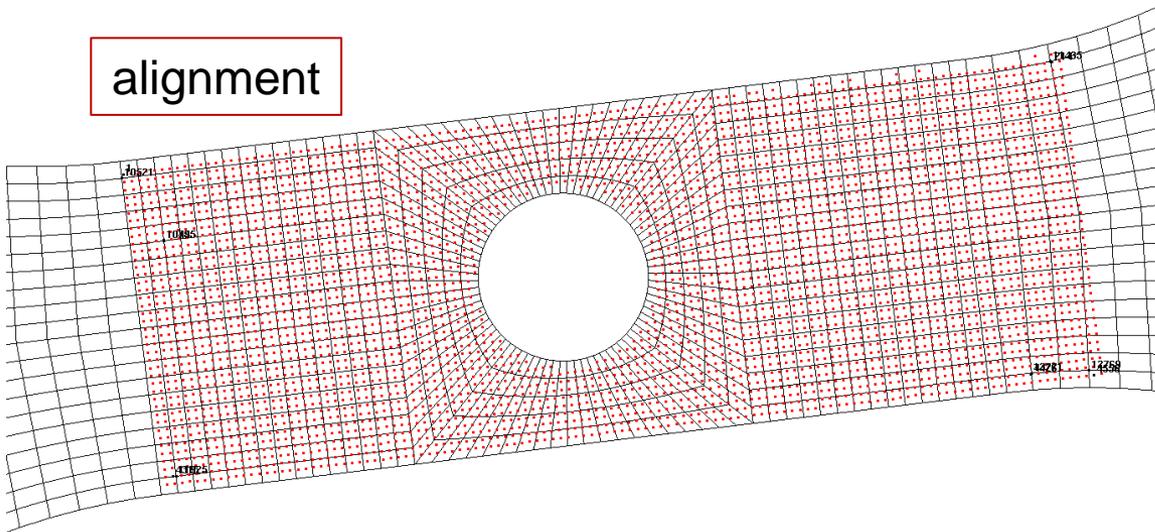
Buttons for "Cancel" and "OK" are at the bottom of the dialog.

# LS-OPT: File Multihistories

## Test data

- GOM/Aramis interface
- GenEx
- File

alignment



File MultiHistories

Defined file multihistories

- test\_Lochflachzug\_s1

[Add new](#)

MultiHistory Name  
test\_Lochflachzug\_s1

gom/ARAMIS  
 GENEX  
 File

Filename Template (wildcard)  
INPUT/example\_data-Stufe-0-\*.csv [Browse](#)

X-Component  
AD-1

Y-Component  
Major Strain

Align test and simulation geometry

Test	Simulation
GOM point	Node ID
4-9	495
120-1	1435
1-39	1925
112-39	2771

[Add](#)

OK

# LS-OPT: Multipoint MSE

Curve matching metric

- Multipoint Mean Square Error

**New response**

Name	Subcase	Multiplier	Offset
MSE		n/a	n/a

Target multihistory:  
test\_Lochflachzug\_s1 [add new file multihistory](#)

Computed multihistory:  
cp\_mh\_first\_principal\_strain

Regression Points

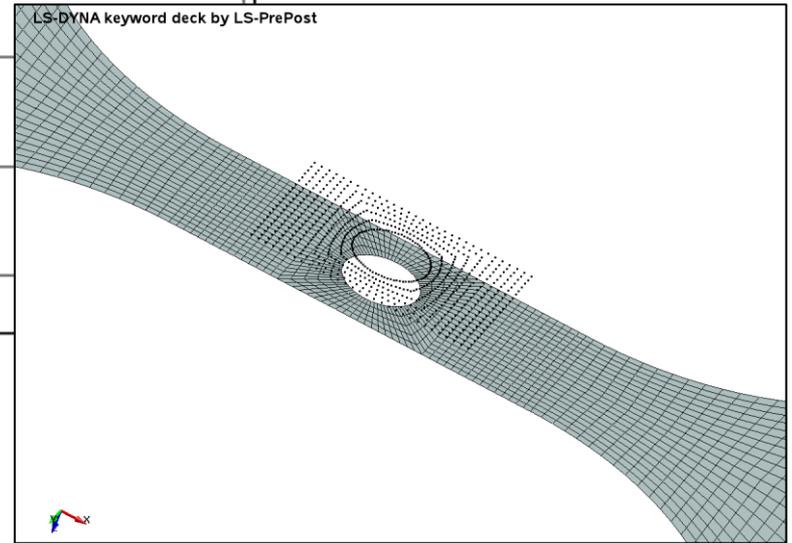
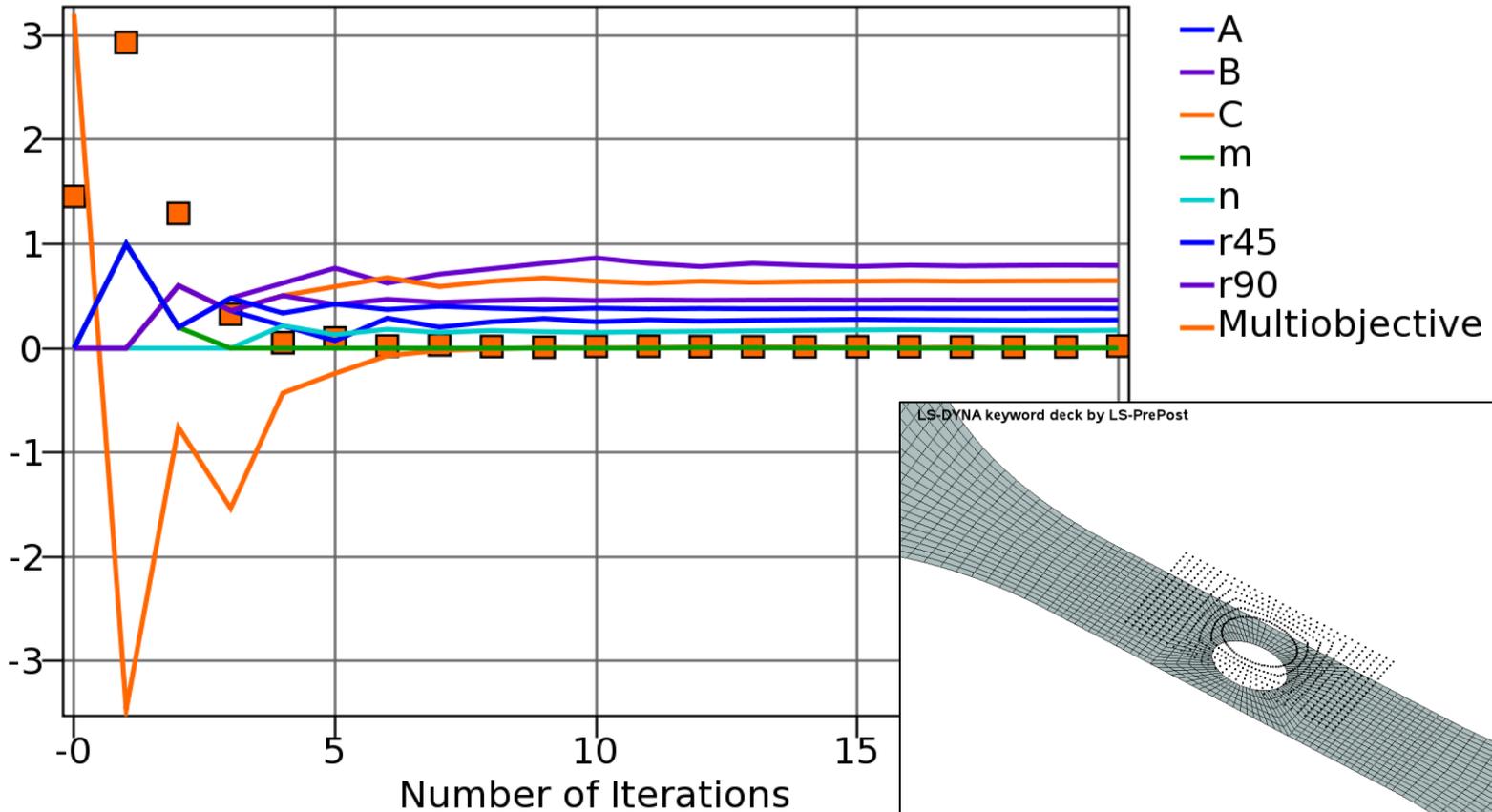
From target curve

Fixed number (equidistant, interpolated)

Cancel OK

# Coordinate-based re-identification

- GISSMO model using displacement field



# Interactive Tables

# Interactive Tables

Enhanced visualization and interactive features

- Create multiple tables by filtering, sorting, ...
- Calculate Statistics
- Generate large sets of virtual results from Viewer
- Select and run new simulations from Viewer

Point selection

Points	Experiment	Marked	Category	Type	Variables		Constraints			Objectives	Max Constr. Violation	Successful run
					tbumper	thood	Intrusion	Mass	Acc_max	HIC		
1.51	51	<input type="checkbox"/>		Analysis	4.41623	1.05401	570.009	0.508923	2.64006e+06	57.36	140065	<input checked="" type="checkbox"/>
1.25	25	<input type="checkbox"/>		Analysis	4.76061	1.03942	569.455	0.526546	2.61048e+06	56.73	110483	<input checked="" type="checkbox"/>
1.79	79	<input type="checkbox"/>	▲ Design 3	Analysis	4.99101	1.29889	558.96	0.599694	2.60226e+06	85.85	102261	<input checked="" type="checkbox"/>
1.32	32	<input type="checkbox"/>	▲ Design 3	Analysis	4.12964	1.28967	562.32	0.545154	2.53807e+06	92.41	38065.8	<input checked="" type="checkbox"/>
1.15	15	<input type="checkbox"/>	▲ Design 3	Analysis	4.99811	1.6433	547.256	0.678349	2.53325e+06	131.3	33252	<input checked="" type="checkbox"/>
1.18	18	<input type="checkbox"/>	▲ Design 3	Analysis	3.56832	1.12579	570.282	0.473595	2.51647e+06	74.02	16466	<input checked="" type="checkbox"/>
1.3	3	<input type="checkbox"/>	▲ Design 3	Analysis	1.76757	1.0101	581.923	0.337472	2.02331e+06	83.9	31.9233	<input checked="" type="checkbox"/>
1.33	33	<input type="checkbox"/>		Analysis	1.08194	1.02178	581.203	0.298377	1.74097e+06	98.16	31.2033	<input checked="" type="checkbox"/>
1.4	4	<input type="checkbox"/>		Analysis	2.42597	1.09409	577.067	0.396692	2.23334e+06	88.65	27.0667	<input checked="" type="checkbox"/>
1.1	1	<input checked="" type="checkbox"/>	■ Baseline 1	Analysis	3	1	575.683	0.410311	2.45462e+06	68.02	25.6834	<input checked="" type="checkbox"/>
1.60	60	<input type="checkbox"/>		Analysis	1.44671	1.17056	573.893	0.354514	1.81918e+06	98.65	23.8927	<input checked="" type="checkbox"/>
1.55	55	<input type="checkbox"/>		Analysis	1.80753	1.35316	566.856	0.417911	1.8971e+06	124.7	16.856	<input checked="" type="checkbox"/>

# Interactive Tables

**Category**

**Filter**

**Feasibility**

**Sorting**

**Generate virtual points**

**Over-all Feasibility**

**Define Categories**

Points	Experiment	Marked	Category	Type	Variables		Constraints			Objectives	Max Constr. Violation	Successful run
					tbumper	thood	Intrusion	Mass	Acc_max	HIC		
1.51	51	<input type="checkbox"/>		Analysis	1.41623	1.05401	570.009	0.508923	2.64006e+06	57.36	140065	<input checked="" type="checkbox"/>
1.25	25	<input type="checkbox"/>		Analysis	1.41623	1.05401	569.455	0.526546	2.61048e+06	56.73	110483	<input checked="" type="checkbox"/>
1.79	79	<input type="checkbox"/>	▲ Design 3	Analysis	1.41623	1.05401	558.96	0.599694	2.60226e+06	85.85	102261	<input checked="" type="checkbox"/>
1.32	32	<input type="checkbox"/>	▲ Design 3	Analysis	1.41623	1.05401	562.32	0.545154	2.53807e+06	92.41	38065.8	<input checked="" type="checkbox"/>
1.15	15	<input type="checkbox"/>	▲ Design 3	Analysis	1.41623	1.05401	547.256	0.678349	2.53325e+06	131.3	33252	<input checked="" type="checkbox"/>
1.15	15	<input type="checkbox"/>	▲ Design 3	Analysis	1.41623	1.05401	570.282	0.473595	2.51647e+06	74.00	16466	<input checked="" type="checkbox"/>
1.60	60	<input type="checkbox"/>	▲ Design 3	Analysis	1.76757	1.0101	581.923	0.337472	2.02			<input type="checkbox"/>
1.55	55	<input type="checkbox"/>	▲ Design 3	Analysis	1.08194	1.02178	581.203	0.298377	1.74			<input type="checkbox"/>
1.91	91	<input type="checkbox"/>	▲ Design 3	Analysis	2.42597	1.09409	577.067	0.396692	2.23			<input type="checkbox"/>
1.98	98	<input checked="" type="checkbox"/>	■ Baseline 1	Analysis	3	1	575.683	0.410311	2.45			<input type="checkbox"/>
1.26	26	<input type="checkbox"/>	▲ Design 3	Analysis	1.44671	1.17056	573.893	0.354514	1.81			<input type="checkbox"/>
1.62	62	<input type="checkbox"/>	▲ Design 3	Analysis	1.80753	1.35316	566.856	0.417911	1.8			<input type="checkbox"/>
1.83	83	<input type="checkbox"/>	▲ Design 3	Analysis	2.95623	1.3441	562.558	0.485857	2.28			<input type="checkbox"/>
1.21	21	<input type="checkbox"/>	◆ Design 2	Analysis	2.42165	1.45185	561.479	0.47859	2.05			<input type="checkbox"/>
1.10	10	<input type="checkbox"/>	◆ Design 2	Analysis	2.08532	1.5656	558.233	0.483237	1.92			<input type="checkbox"/>

**Define Categories**

- Baseline 1 (2 points)
- ◆ Design 2 (4 points)
- ▲ Design 3 (5 points)
- + Most feasible (5 points)

Name: Baseline 1  
Color: [Blue Box]  
Shape: cube

Description:

Add selected points

Save Cancel

Parallel Coordinate

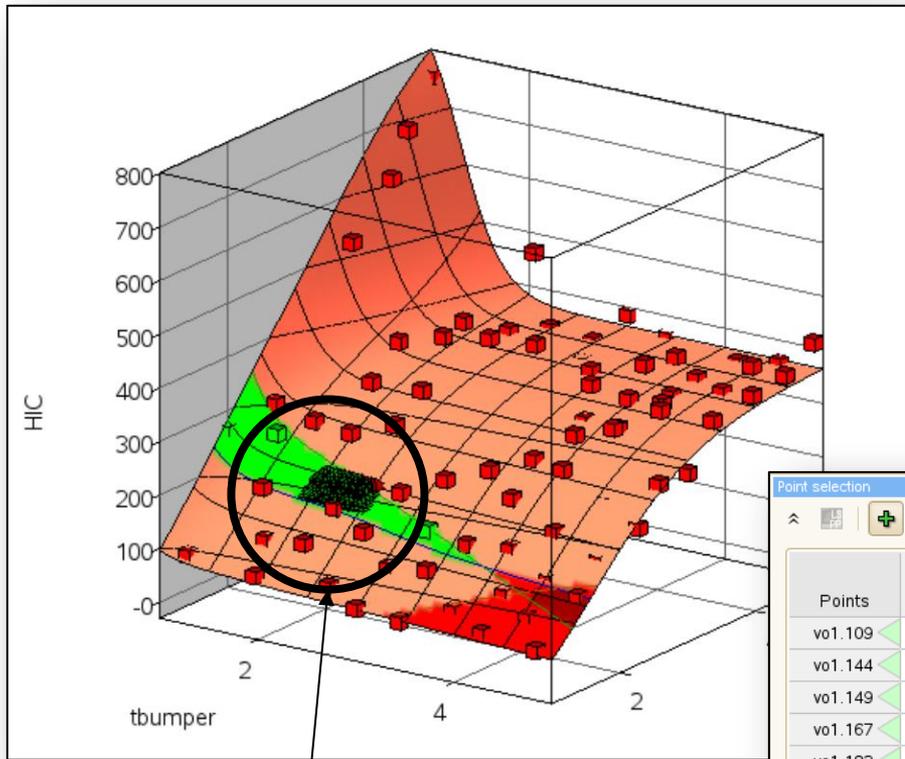
Point source sampling: 1

Plot entities:

- Variable
- Response
- Composite
- Constraint
- Objective

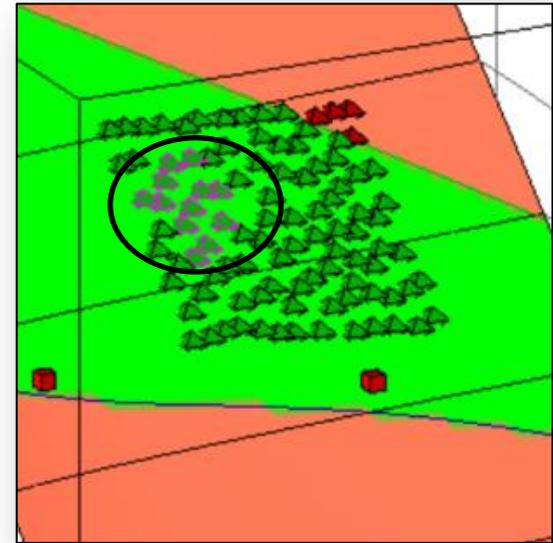
# Interactive Tables

- Generate virtual points → new simulations



Generate in Viewer

Select



Virtual points      Run simulations

Point selection

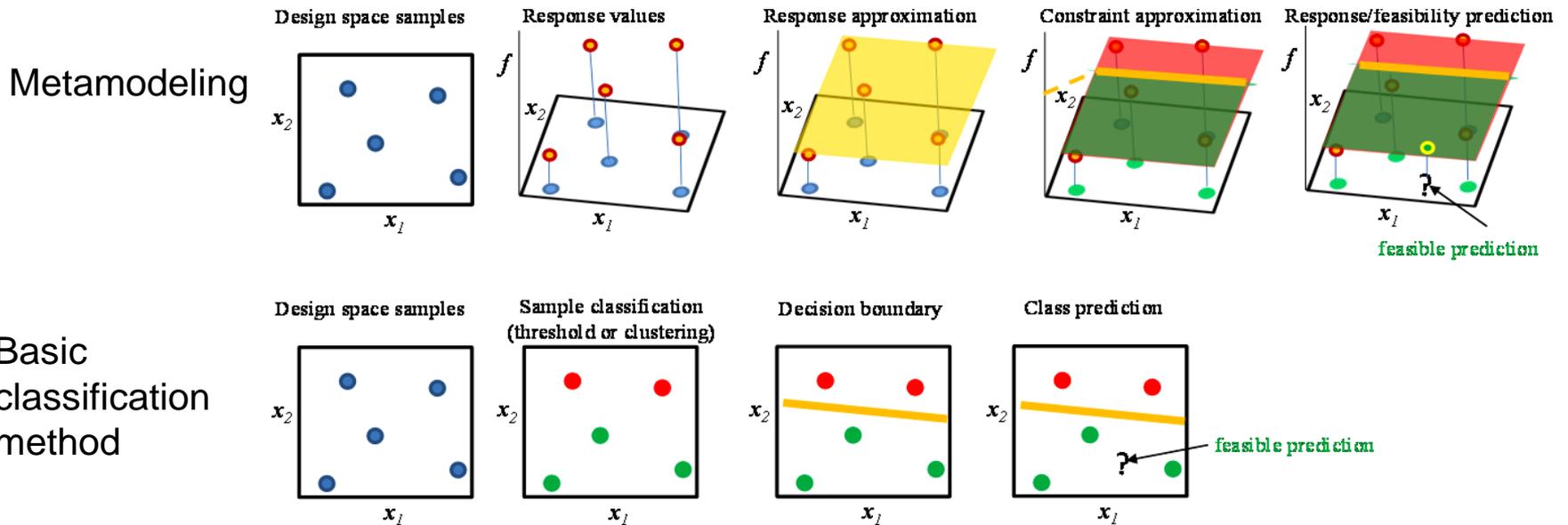
Points	Marked	Type	Variables		Constraints		Objectives		Ma	V
			tbumper	thood	Intrusion	Mass	Acc_max	HIC ▲		
vo1.109	<input checked="" type="checkbox"/>	Virtual	2.25259	1.86465	544.755	0.561377	1.88095e+06	200.142		
vo1.144	<input checked="" type="checkbox"/>	Virtual	2.19286	1.87575	544.488	0.560259	1.85526e+06	202.227		
vo1.149	<input checked="" type="checkbox"/>	Virtual	2.23566	1.9226	542.64	0.573522	1.85635e+06	208.534		
vo1.167	<input checked="" type="checkbox"/>	Virtual	2.16694	1.93914	542.235	0.573095	1.82604e+06	211.42		
vo1.182	<input checked="" type="checkbox"/>	Virtual	2.3141	1.89203	543.545	0.571354	1.89467e+06	203.571		
vo1.196	<input checked="" type="checkbox"/>	Virtual	2.12216	1.88888	544.171	0.558934	1.82481e+06	204.703		
vo1.200	<input checked="" type="checkbox"/>	Virtual	2.3527	1.84454	545.248	0.562909	1.92413e+06	196.428		

Output Table1

# Support Vector Classification

# Support Vector Classification

- Discontinuous and binary responses
  - Map input data to category

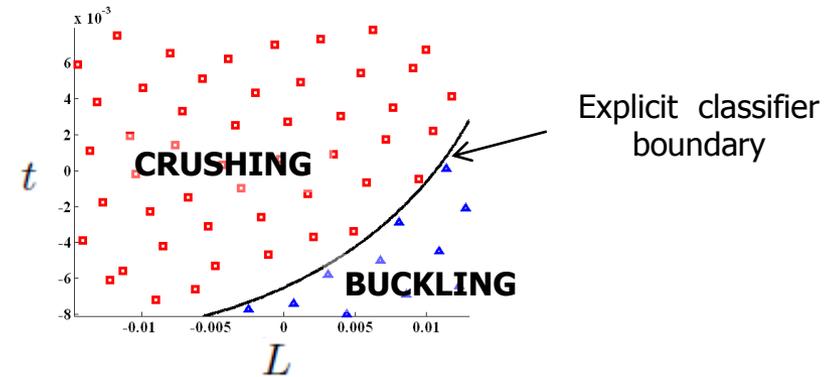
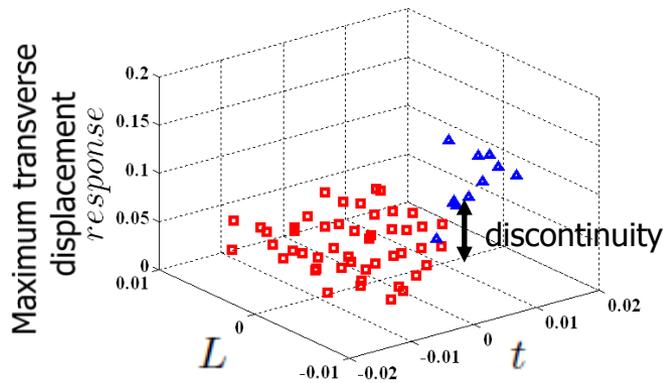
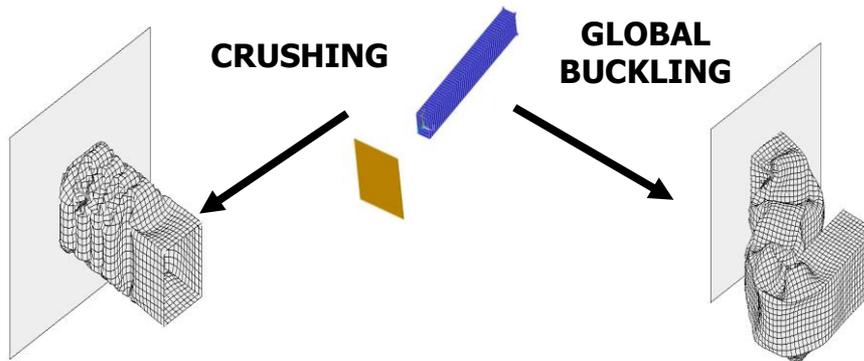


- Adaptive multi-objective optimization
  - classifier defines the boundary of the Pareto optimal designs

*Basudhar, A. (2015). Multi-objective Optimization Using Adaptive Explicit Non-Dominated Region Sampling. In 11th World Congress on Structural and Multidisciplinary Optimization.*

# Support Vector Classification

- Example: Tube impact

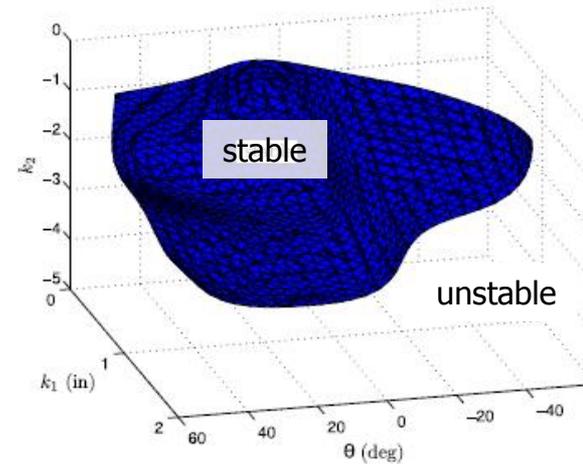
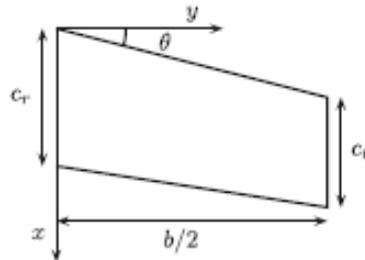


**Design Space (length and thickness)**

# Support Vector Classification

- Example: Wing Aeroelasticity
- Binary constraints
  - **Divergence instability**
    - Zero vs Non-zero Modal Frequency
  - **Flutter instability**
    - Positive vs Negative damping coefficient

*Basudhar, Anirban, et al. "Constrained efficient global optimization with support vector machines." Structural and Multidisciplinary Optimization 46.2 (2012): 201-221.*



**Decision Surface  
in Design Space**

# Summary

## Current Development

- DIC-based parameter identification
  - Multihistories
  - GOM interface
  - Multi MeanSqErr
- Interactive tables
  - Sorting, filtering ...
  - Generation of virtual points
  - Run new simulations from Viewer
- Support Vector Classification
  - Discontinuous/binary responses

→ Will be available in Version 6.0



**Thank you!**