Machine Learning im CAE

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MSC Software / Hexagon

Bayreuther 3D-Konstrukteurstag
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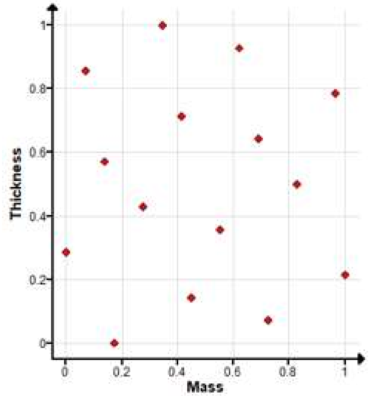
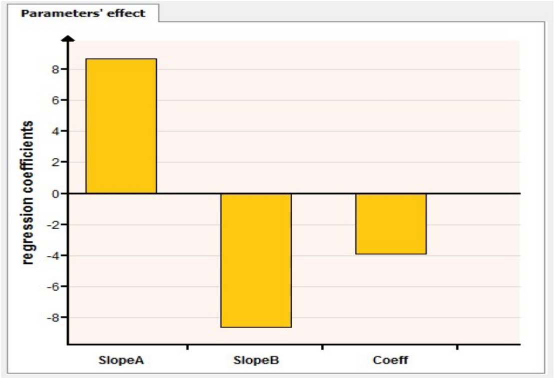
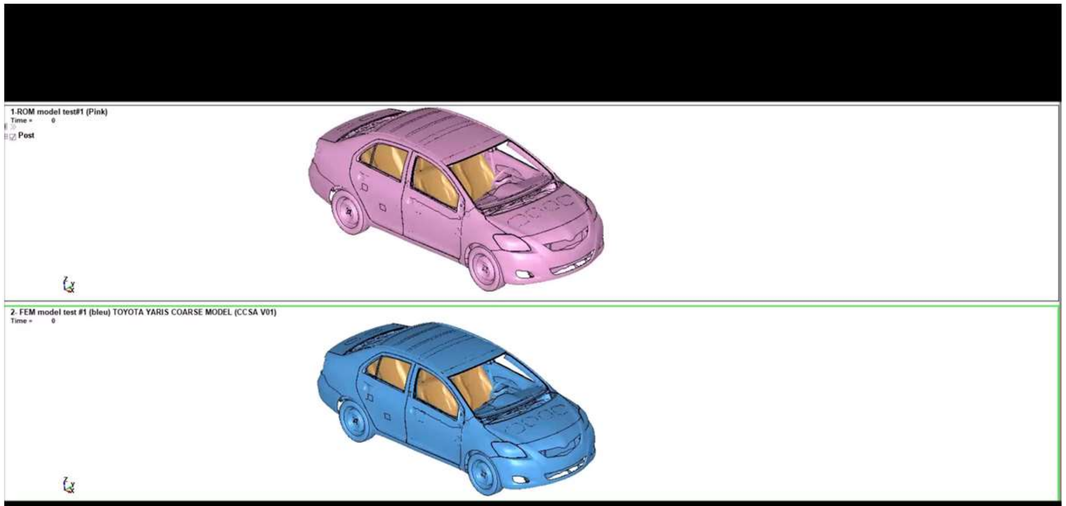
ODYSSEE Overview

- Machine learning for FEM, CFD and other data
- From available analysis or test results, predict responses for further parameter combinations
- Interesting e.g. for highly nonlinear analyses which take long time
- Predict and view time-histories
- Predict and view animations (write and view hdf5, d3plot etc.)
- Image handling
- Generate, improve, reduce DOE
- Understand the influence of model parameters
- Optimization, e.g. adapt analysis model to test result curve

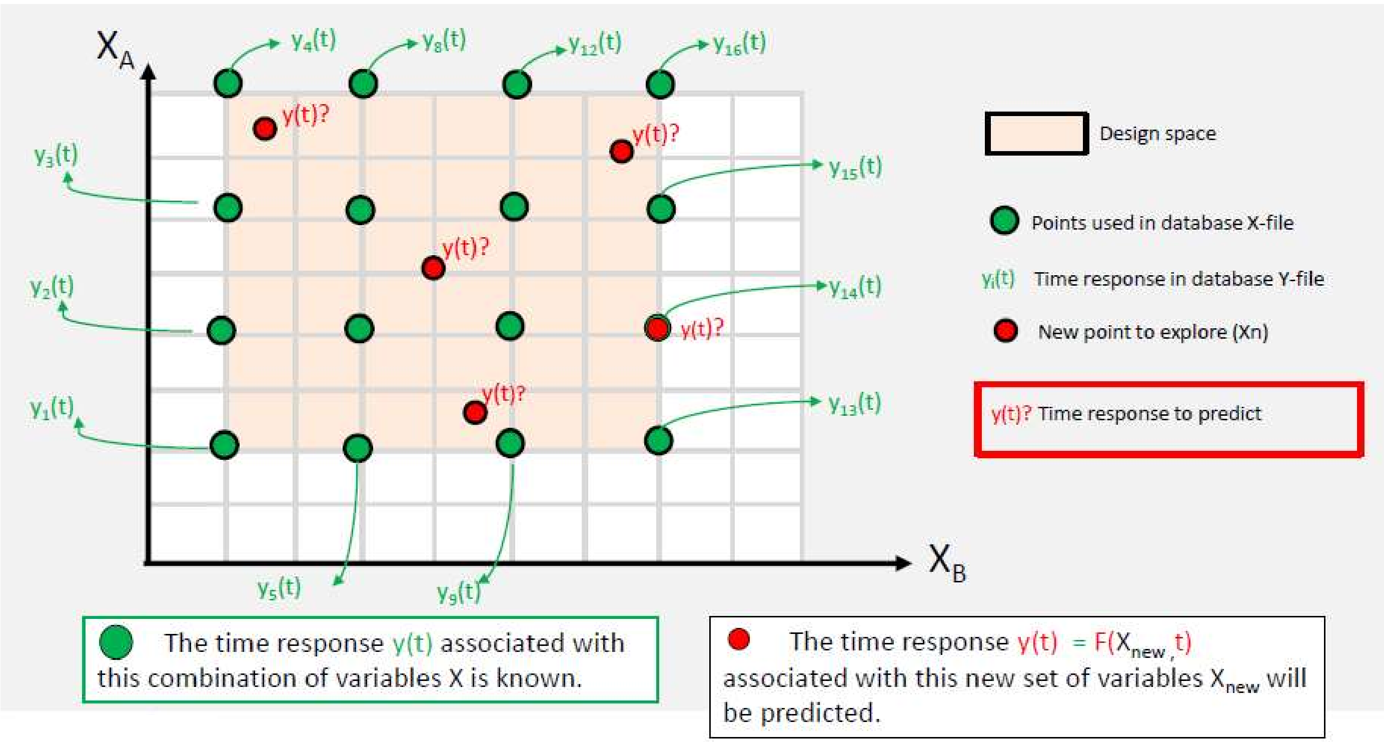






Pink car : Lunar simulation (few seconds) / Blue car : FEM simulation (3h)

Formulation of the Problem

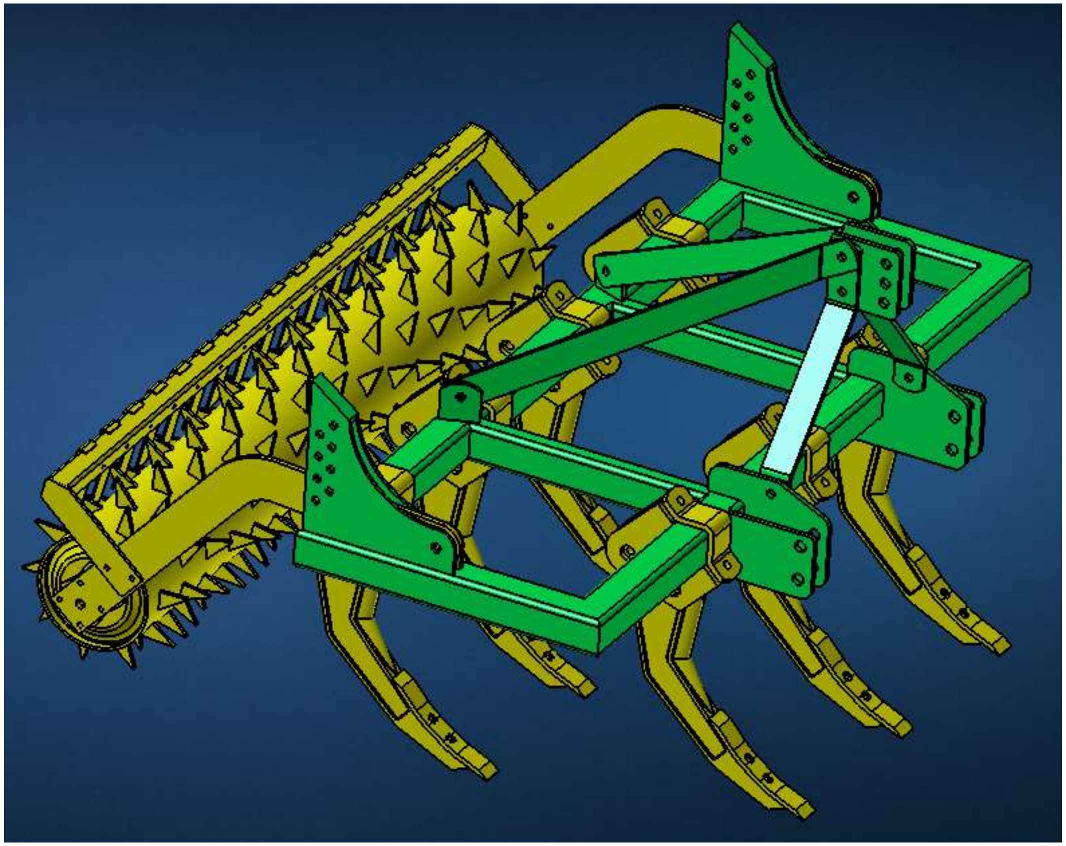


Input: Learning base F(x) = Y
(Existing analysis or test data)

Output: $F(x_{new})$ = ?

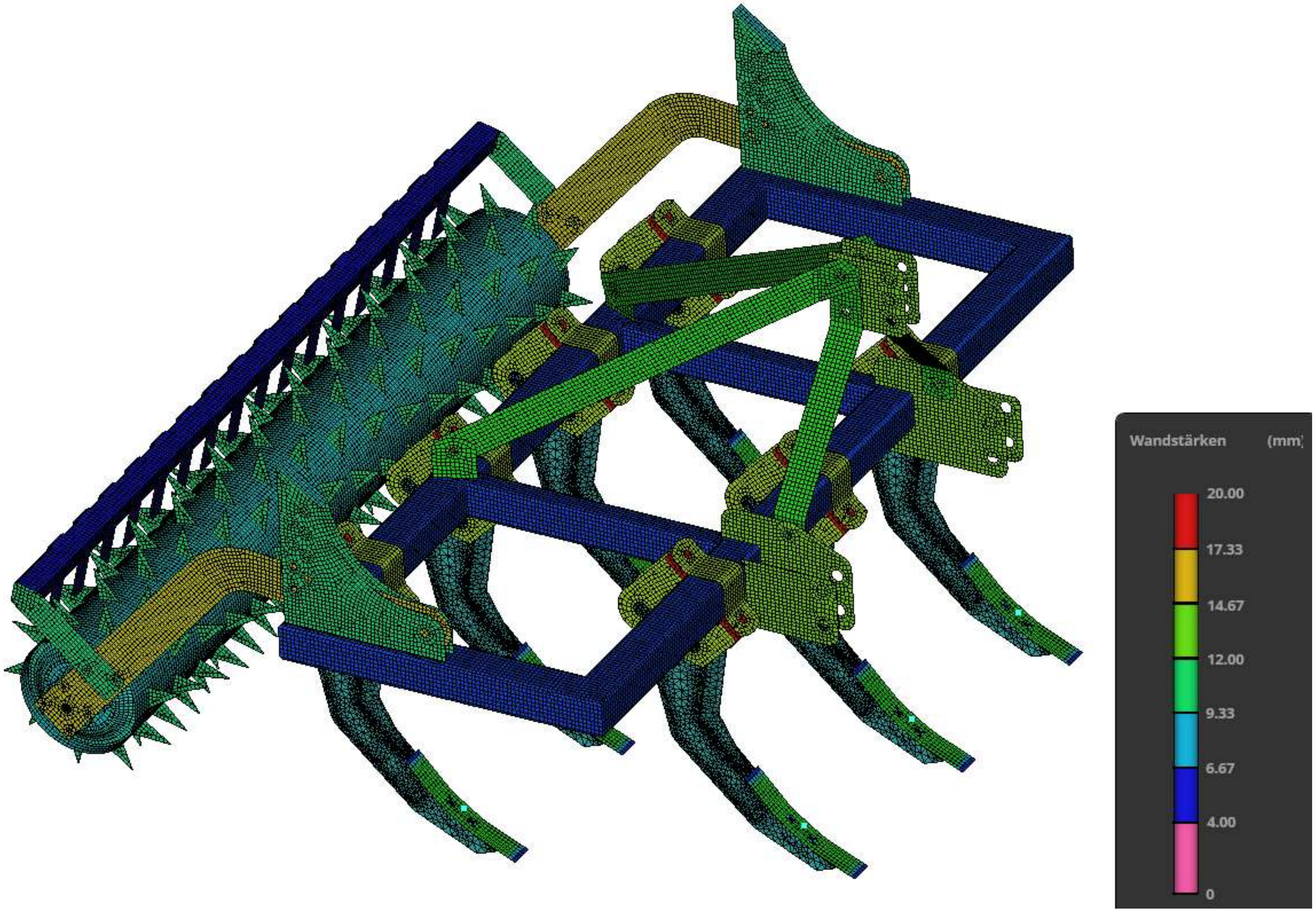
Y can be a curve Y(t)

Example Model: Geometry

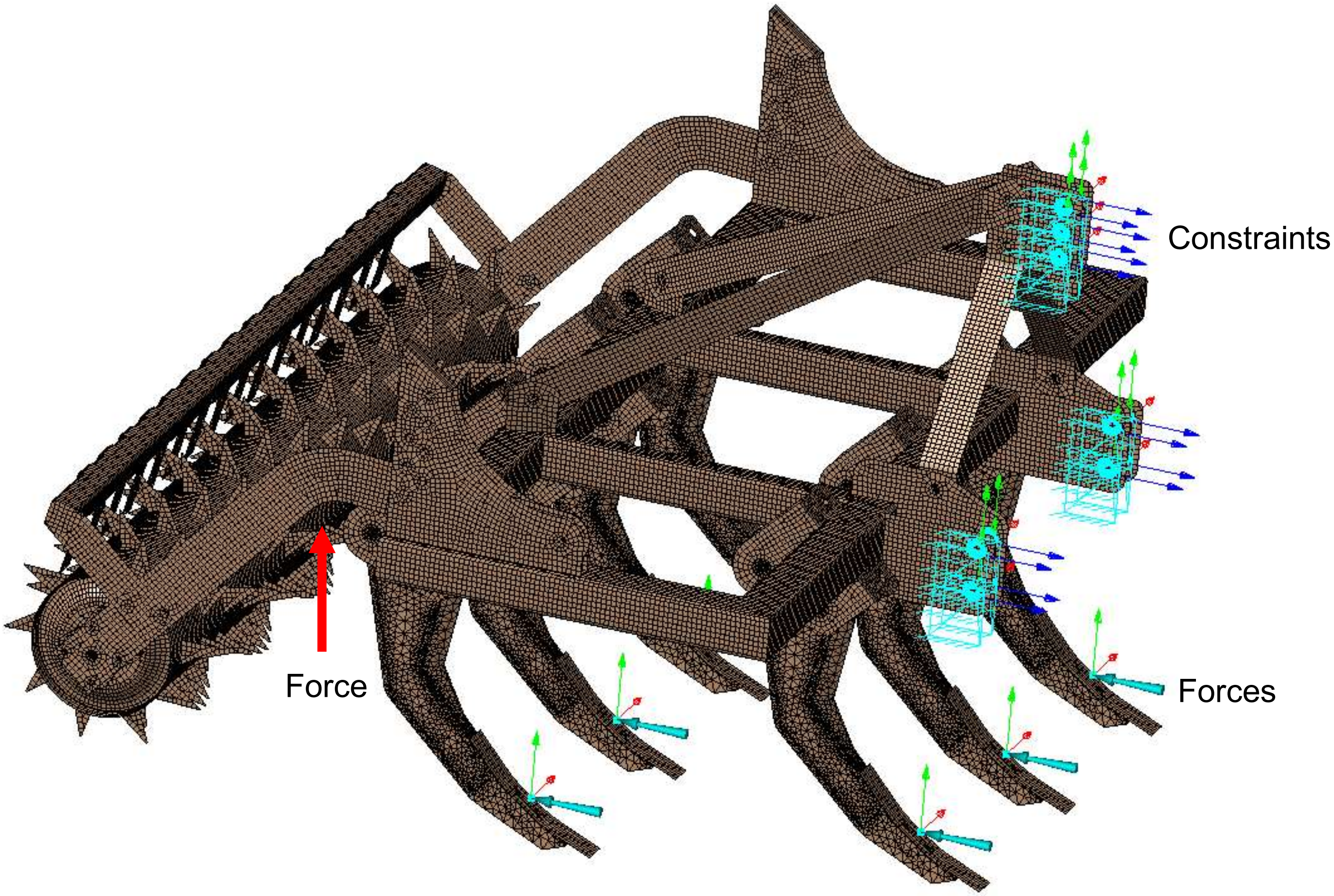


CAD model from Javad Valaei (Grabcad)

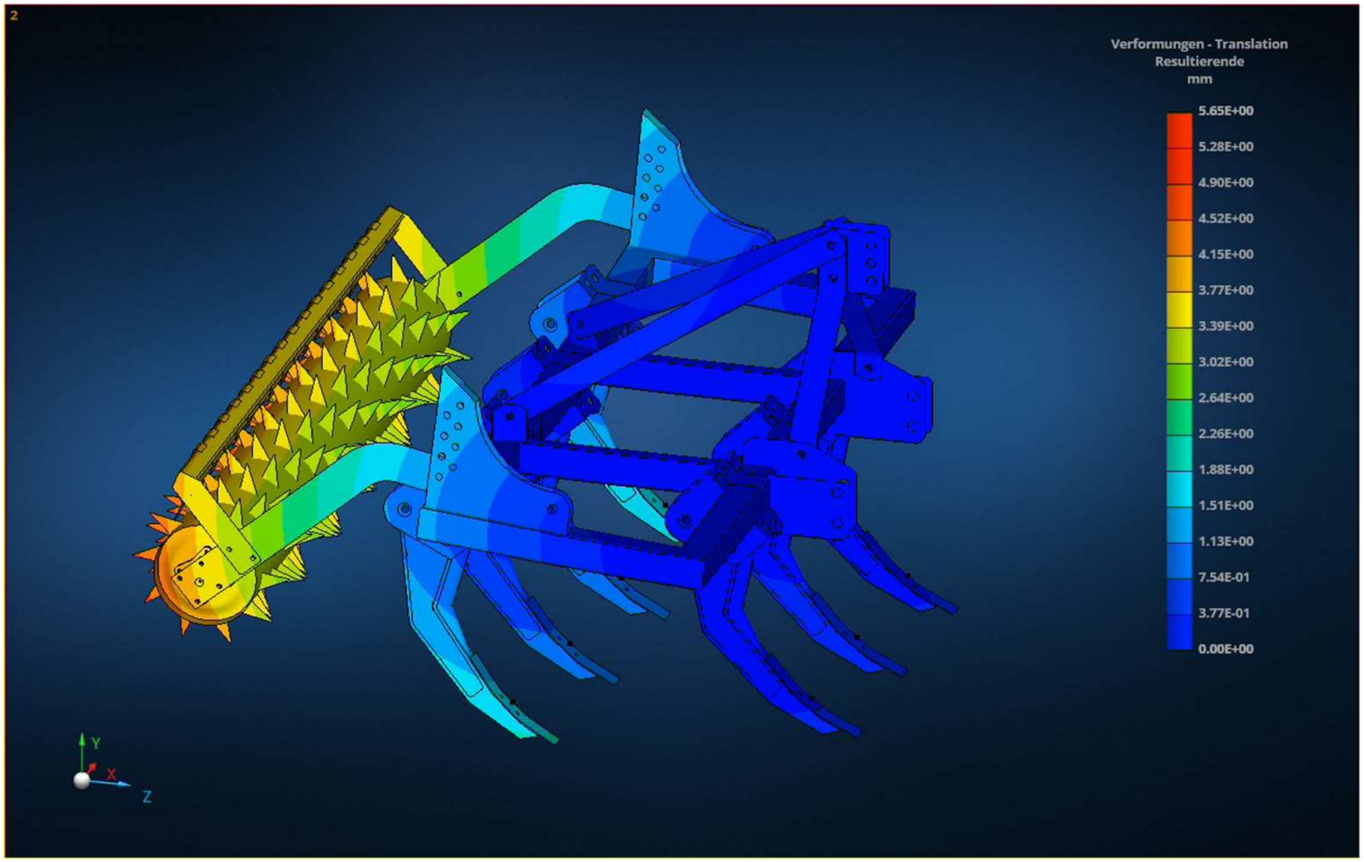
Example Model: FEM Model with Wall Thicknesses



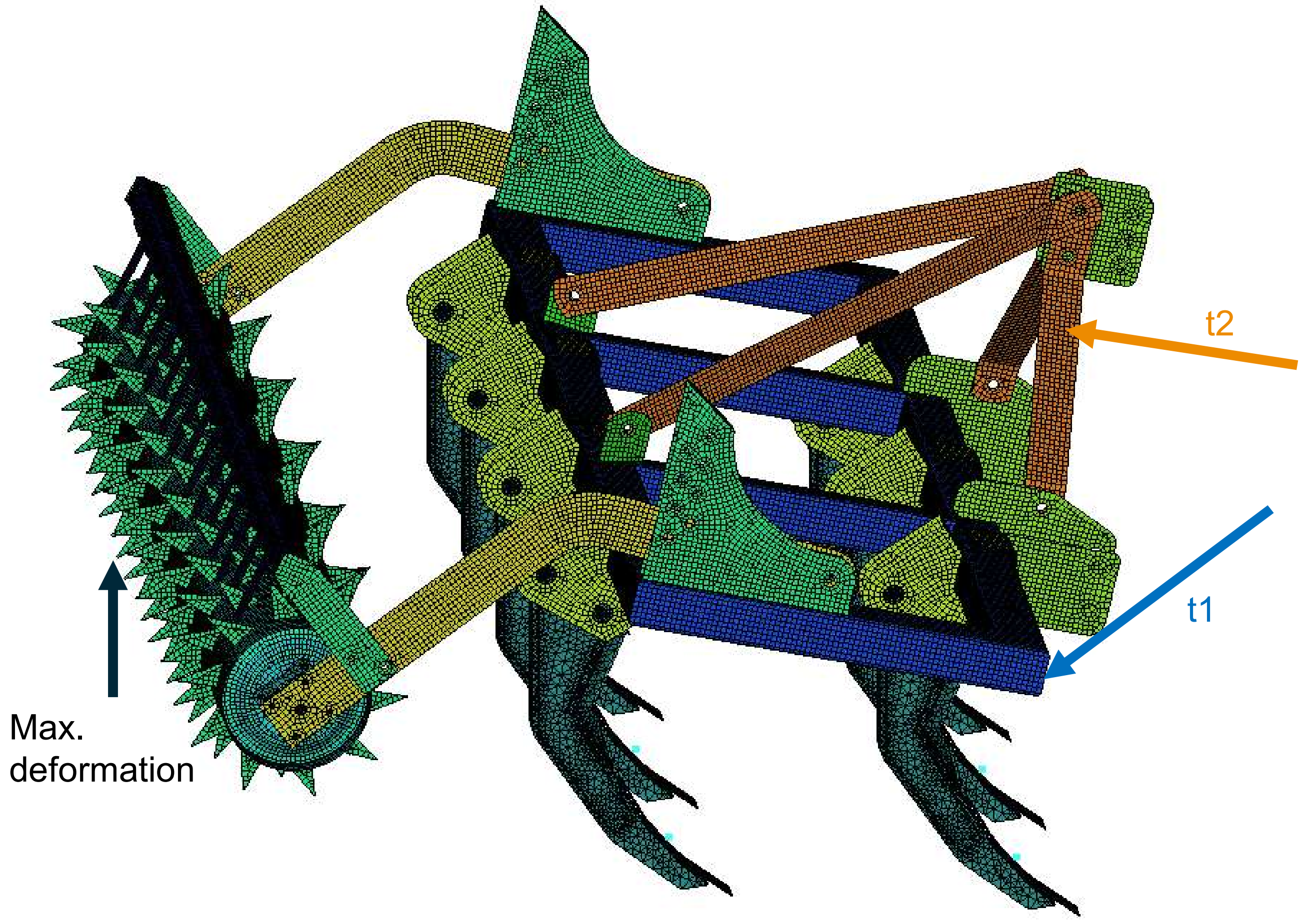
Example Model: FEM Model with Loads and Boundary Conditions



Example Model: Deformation Results



Formulation of the Problem



From these two wall thicknesses predict the max. deformation (and the complete result file)

Learning Base

X

t1	t2
3	16.7692
3.45455	10.6154
3.90909	15.5385
4.36364	13.0769
4.81818	18
5.27273	10
5.72727	14.9231
6.18182	12.4615
6.63636	17.3846
7.09091	11.2308
7.54545	16.1538
8	13.6923

12 combinations of the 2 wall thicknesses

Y

1.77565	3.55814	5.34747	7.1403	8.90885
1.55555	3.11633	4.67978	6.23097	7.80816
1.33615	2.67394	4.00489	5.35077	6.69965
1.203	2.40726	3.60741	4.81806	6.03117
1.07084	2.13906	3.2144	4.29146	5.37043
1.01514	2.02857	3.0481	4.06947	5.09287
0.917384	1.8336	2.75421	3.6761	4.59934
0.866509	1.73224	2.60171	3.47238	4.34432
0.798641	1.59672	2.3977	3.19963	4.00252
0.777377	1.55444	2.33428	3.11514	3.89708
0.721435	1.44262	2.16601	2.89019	3.61518
0.697431	1.39473	2.09408	2.79421	3.49514

Result for the 12 FEM analyses (5 steps in nonlinear analysis)

Requested Output

Xn

t1	t2
7	15

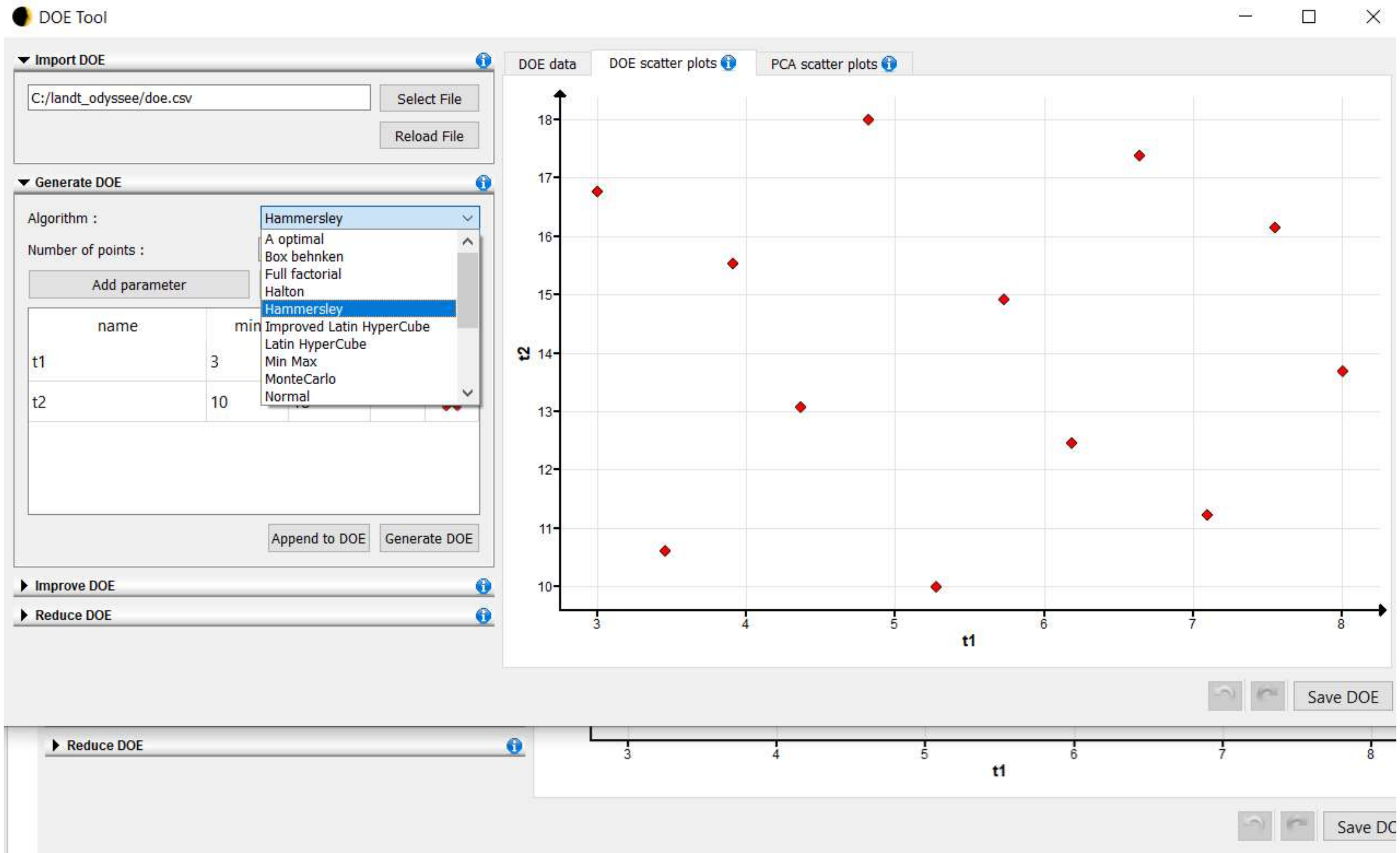
Yn

?

Predict displacements for a new combination of the 2 wall thicknesses

HEXAGON MSC Software

How to Create the DOE (Design of Experiments)



In the DOE Tool, enter the parameters with desired range and number of points.

ODYSSEE will create the DOE

Can also import an existing DOE file and improve it

Export DOE as csv file

Input X-Files: Minimum number of sampling points

The number of sample is depending of the budget available to run simulations. Usually we propose to use a polynomial formula to estimate the number of sampling point. But if **n** is high, we suggest a full factorial formula.

n = variables
d = order

$$(d+1)^n \quad >> \quad C_d^{n+d} = (n+d)!/(d!\,n!)$$

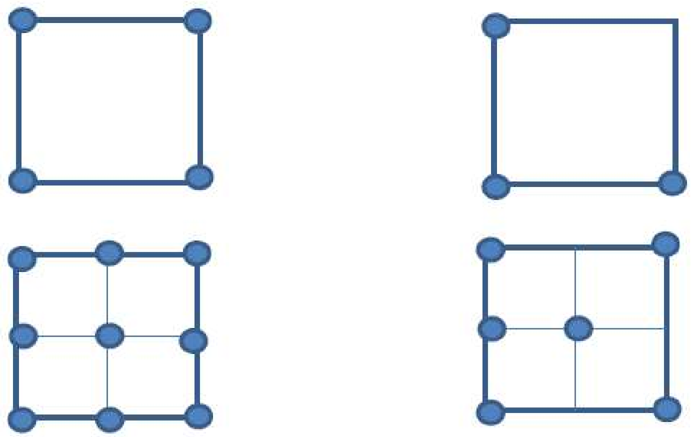
Full factorial formula — *Polynomial formula*

d=1 (linear)
n=2

(2+1)! / (1! 2!) = 3

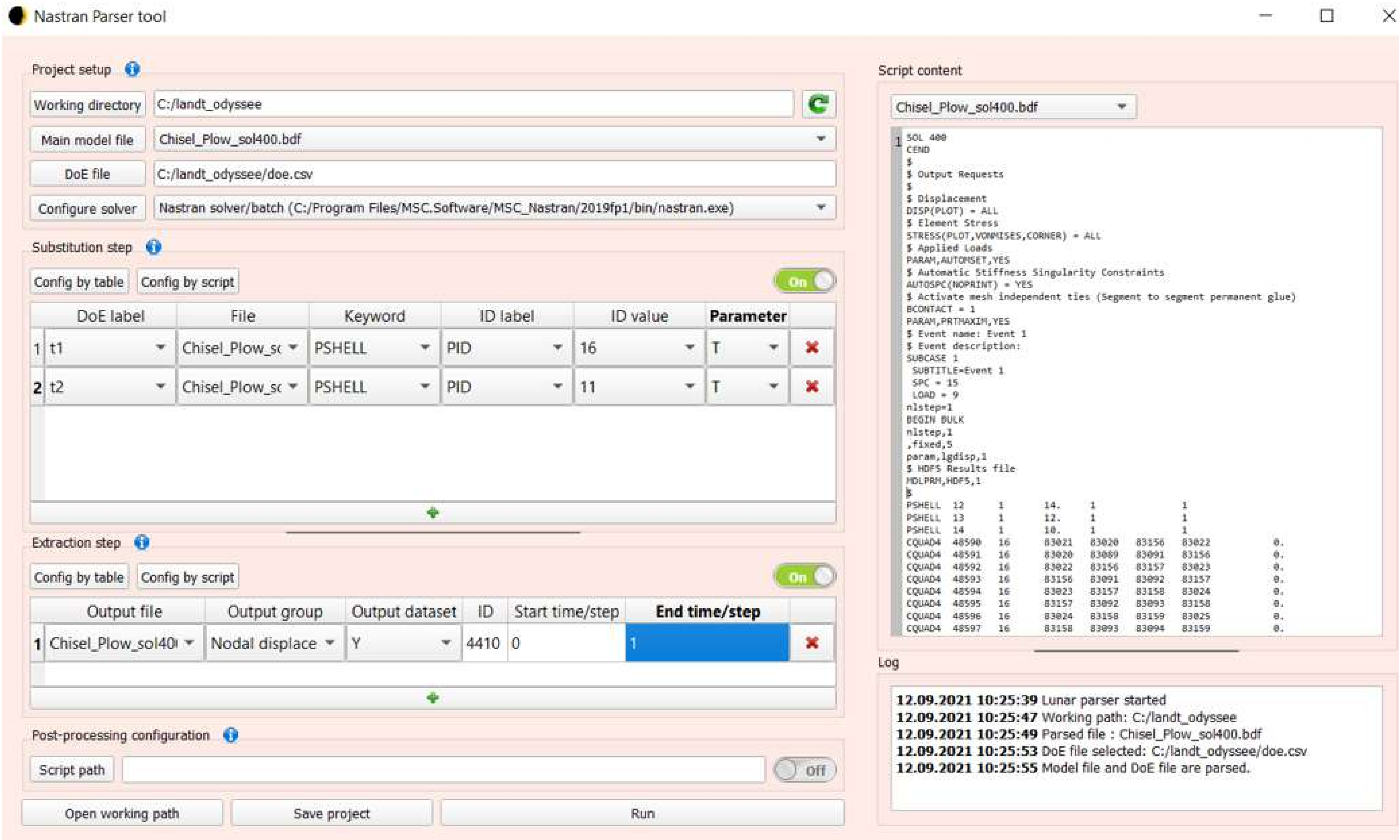
d=2 (parabolic)
n=2

(2+2)! / (2! 2!) = 6



... e.g. with d=2, n=3 variables we suggest 10 points
(2+3)!/(2!*3!) = 5!/(3!*2)

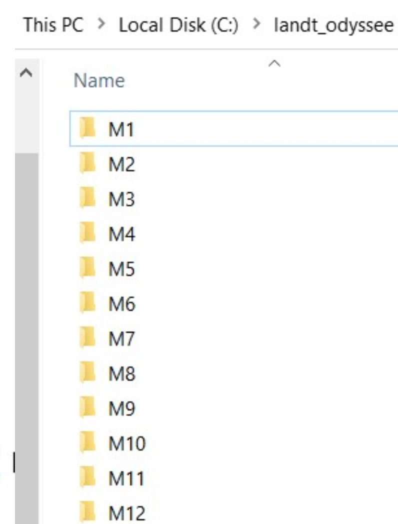
Create the Learning Base (Run the FEM Analyses for all Combinations in the DOE)



Parsers exist for different solver input / output formats or generic txt files

Select the DOE file and one solver input file

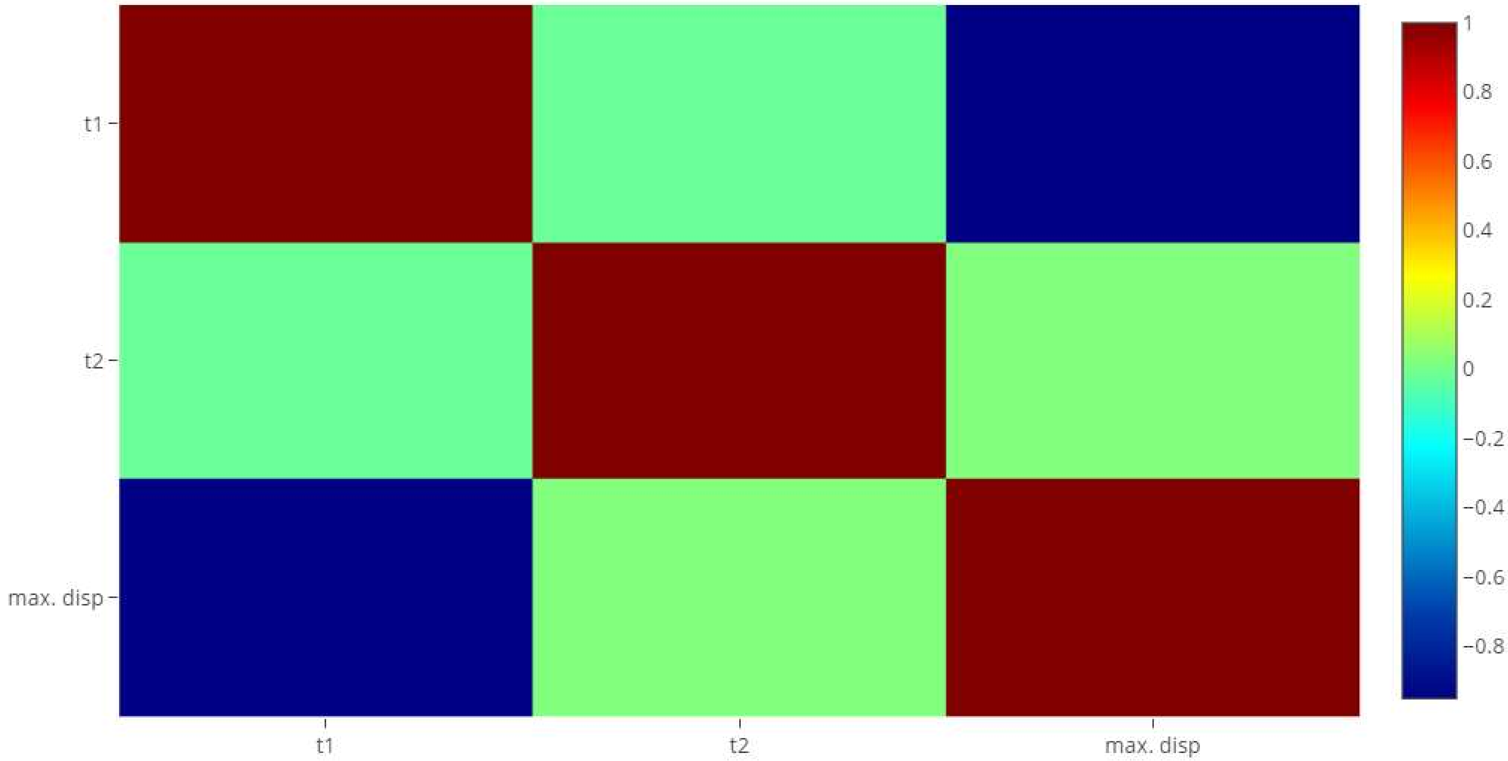
ODYSSEE creates the different variants, starts the solver jobs and extracts the results

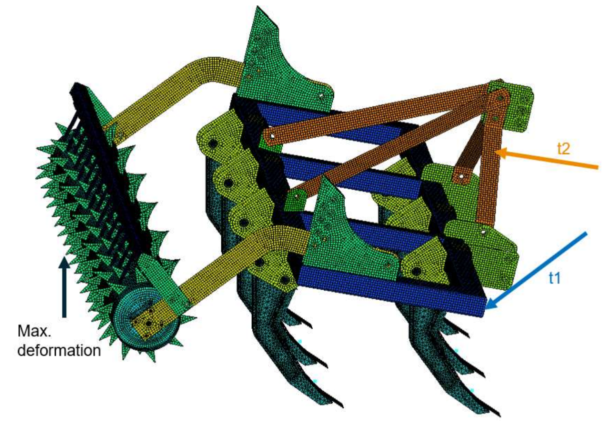


Correlation Plot

Get a first overview of the correlations: which parameters have high influence on the results?

1: 100% correlation; 0: no correlation; -1: 100% negative correlation

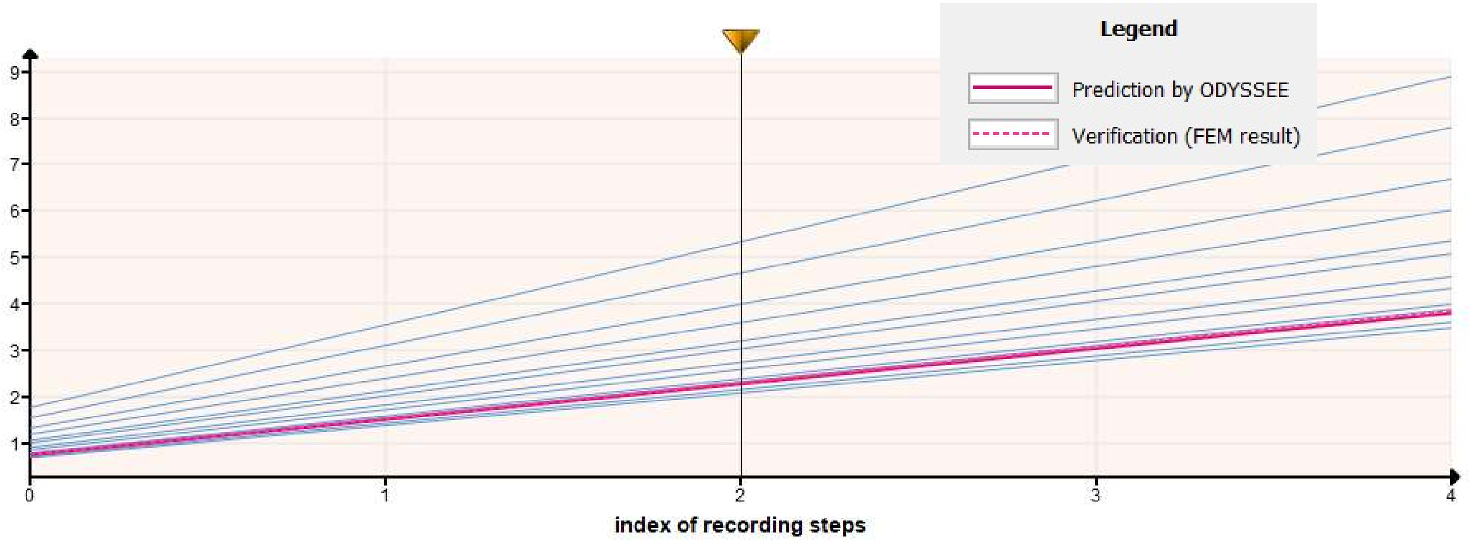


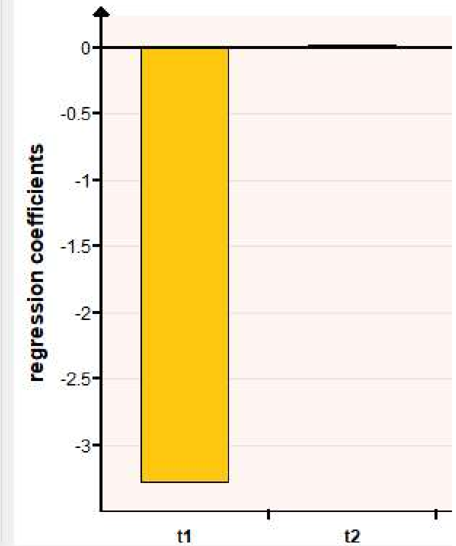


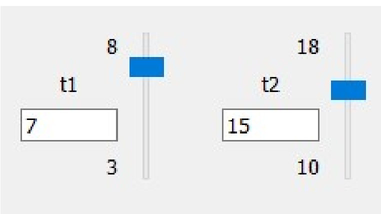
Interpretation:

- t1-t2 very low correlation: good DOE
- t1 – max disp: very high negative correlation
- t2 – max disp: very low correlation
- to influence max disp, t1 is the suitable parameter

Prediction of Max. Displacement for New Parameter Combination





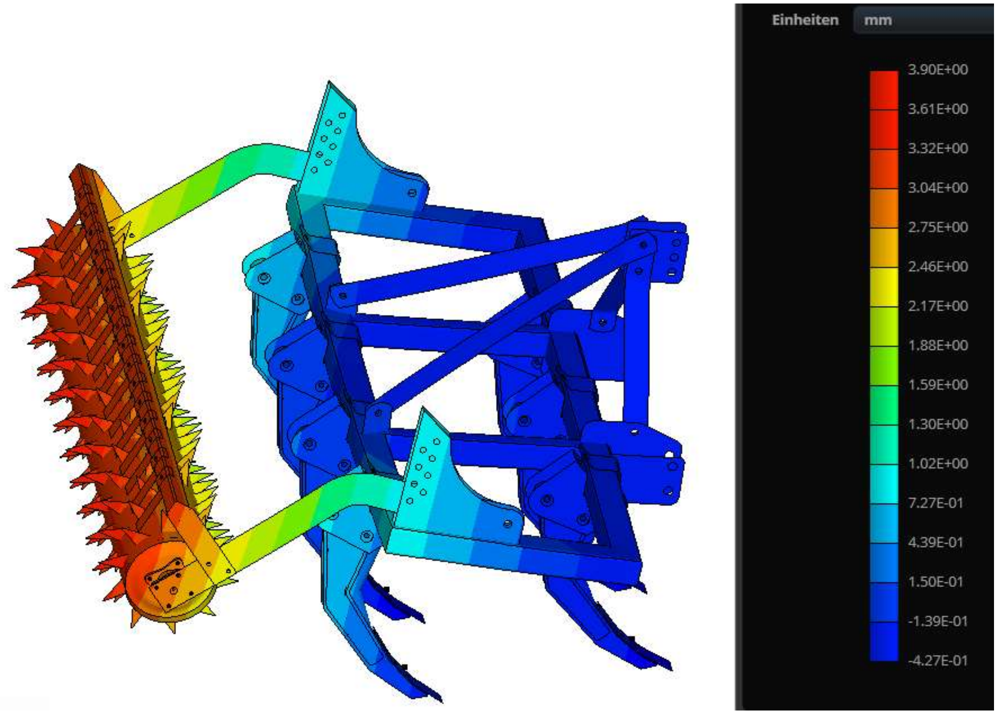


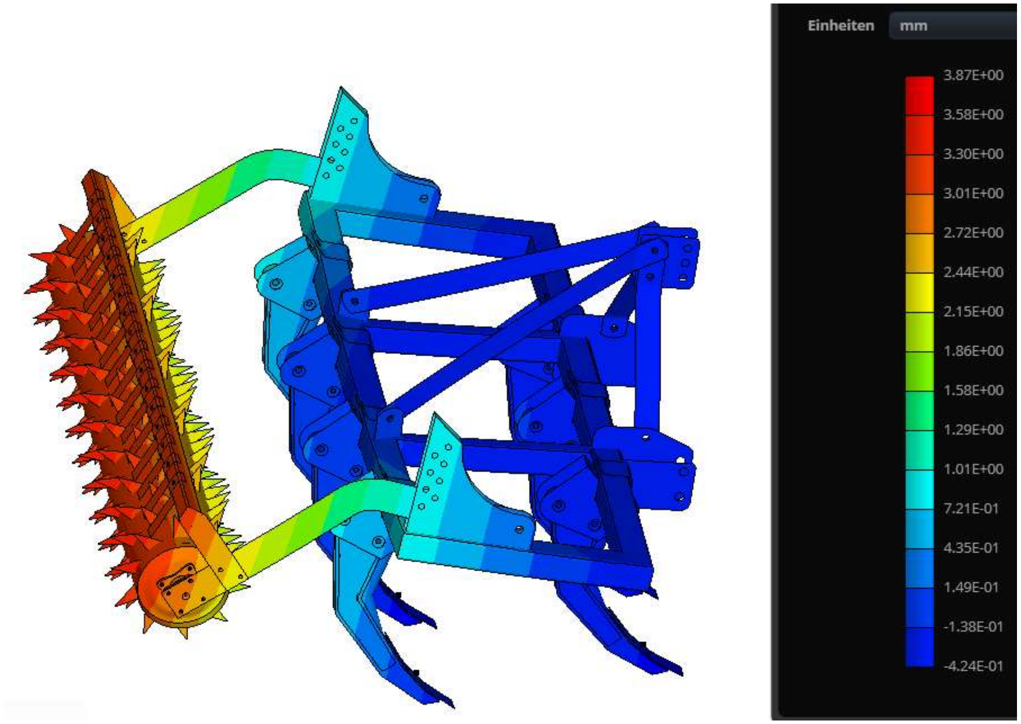
Blue curves: learning base, the results of the 12 Nastran runs

From this learning base, predict the results for a new parameter combination (thicknesses t1 = 7, t2 = 15)

The regression coefficients show again the high influence of t1

Displacements for Full Model

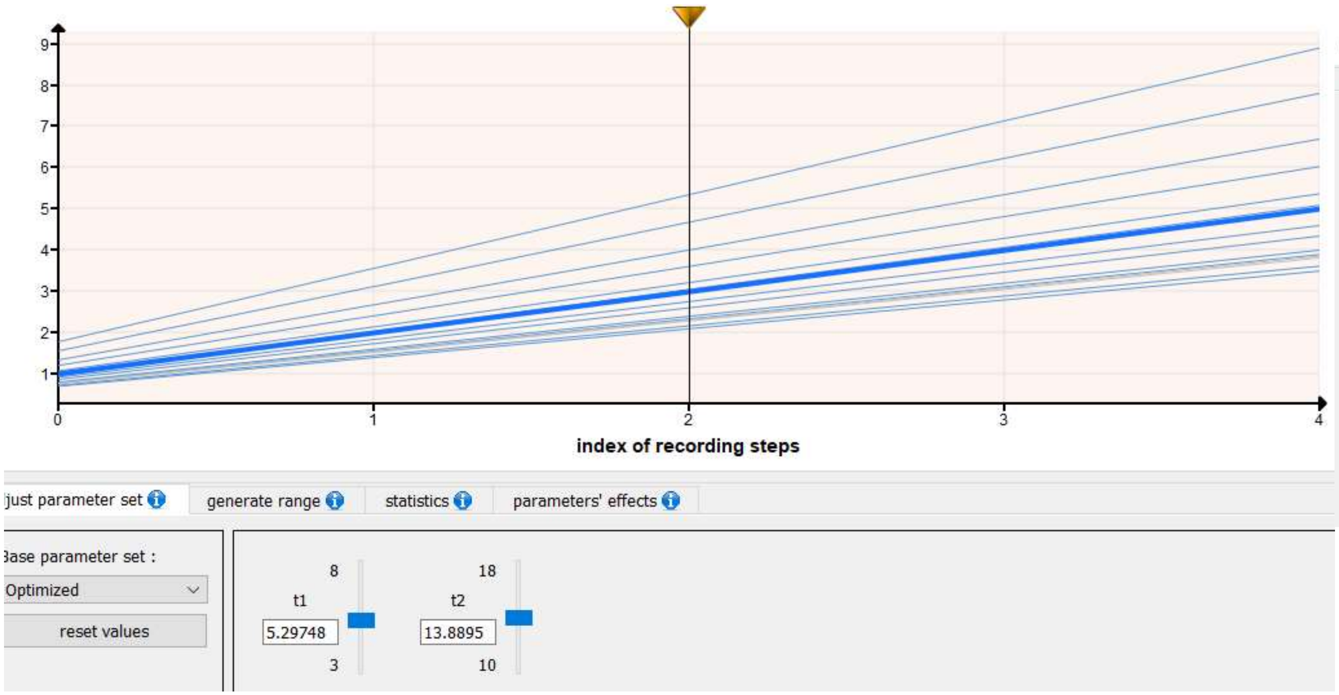


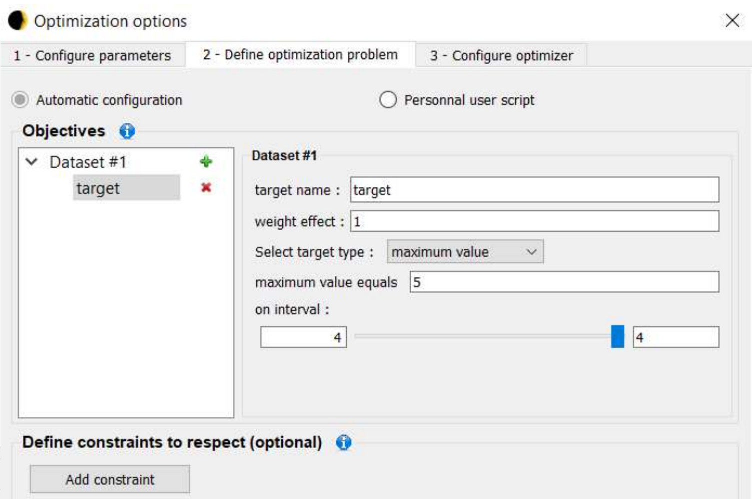


Prediction by ODYSSEE

Verification by FEM

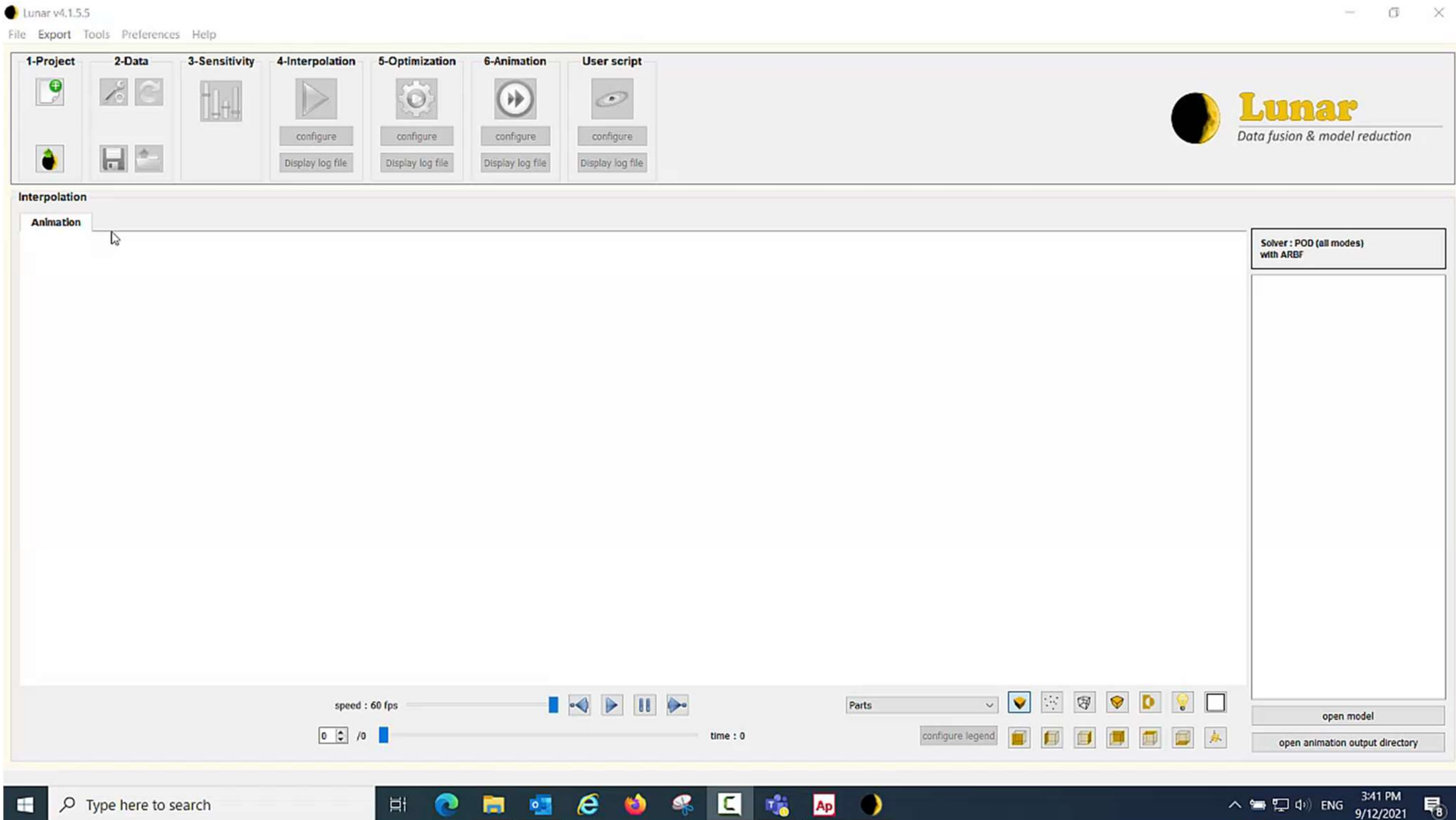
Optimization





Which thicknesses should be used to reach a displacement of max. 5mm?

Video



Software

Other Examples

ODYSSEE
Explore new industrial horizons

Identification of origins of defects
- Casting & Health monitoring

Understanding origin of defects in casting process

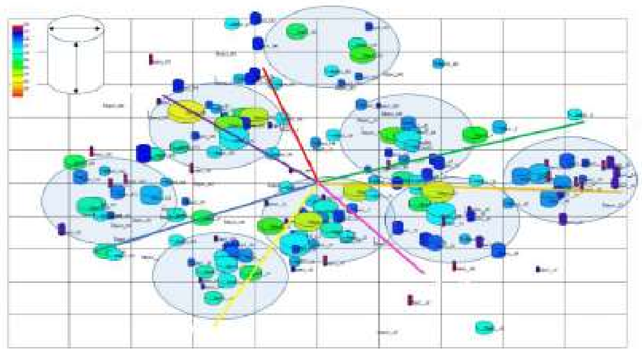
CADLM

Analysis of acquired on-board data

Cost saving by finding links between process parameters and defects

- **Data Analysis using physical sensor data**
- **Correlation table and multi-plots using ODYSSEE.**

dedicated application to prevent defects before they appear!



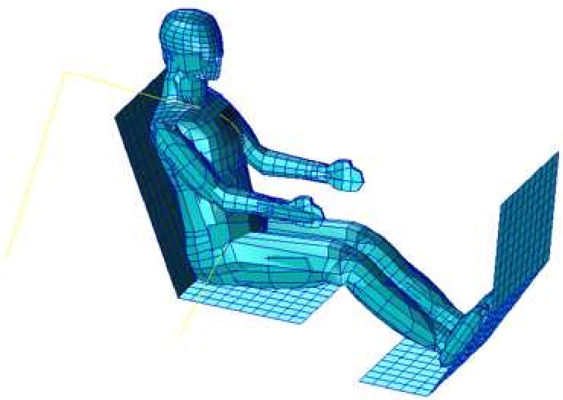
Input:a table of process parameter settings over a time period (X) and all reports of system failure of product deficiency (Y). ODYSSEE identifies source of problem (this is a probability function) by relating Y to X.

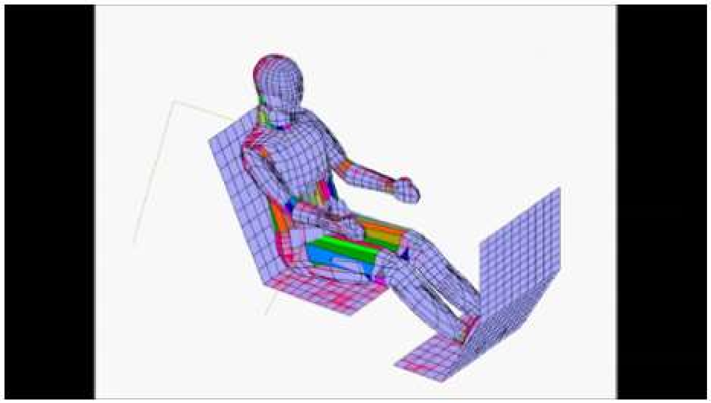
ODYSSEE

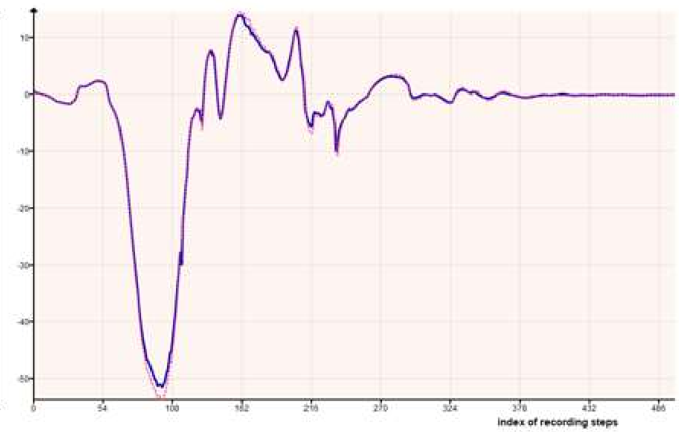
Explore new industrial horizons

Nastran Sol 700 – sled test

Courtesy of Raoul Spote (MSC)







Saved to this PC

10 runs, 2 parameters

Sled acceleration => X1

Pretension force => X2

Output Channel

X-acceleration of

Dummy Head => Y1

Elapsed Time

LUNAR = 8 sec

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Pump membrane optimization with multi-physics interaction

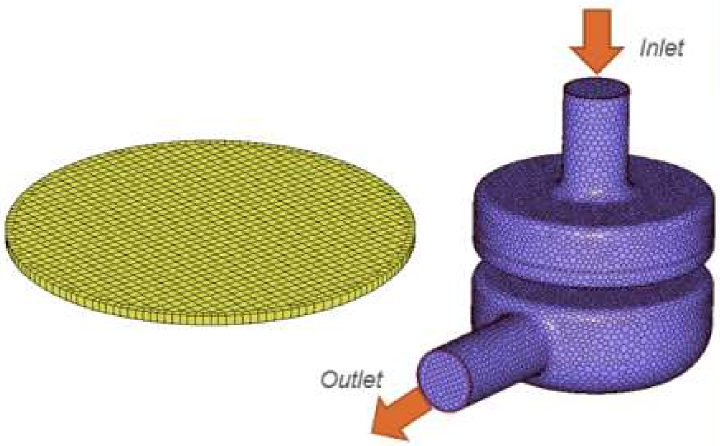
ODYSSEE

Explore new industrial horizons

Design of experiments

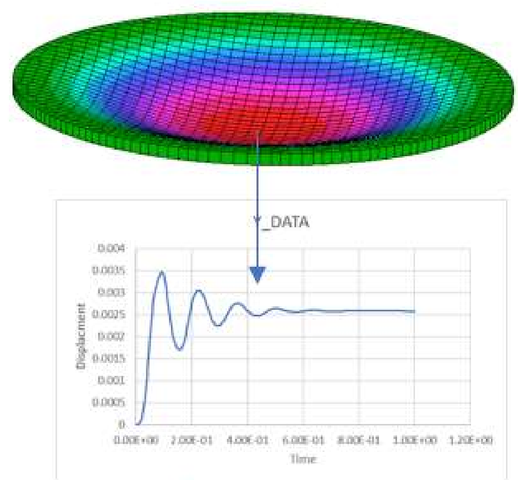
X: (2 variables)

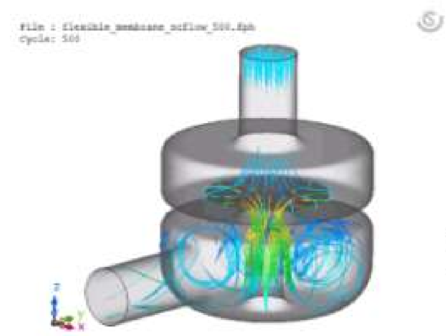
1. Inlet Fluid Speed
2. Membrane Stiffness



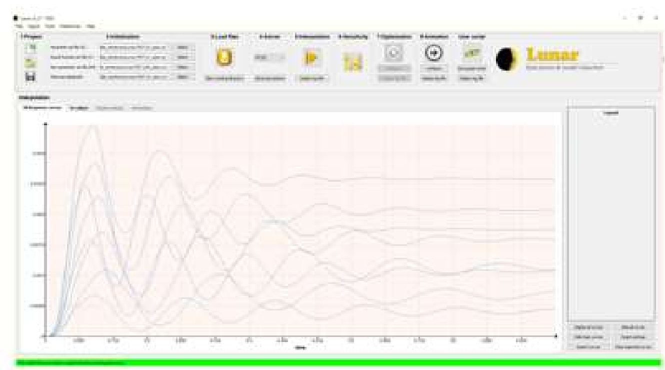
Y:

1. Displacement center of membrane





x 8



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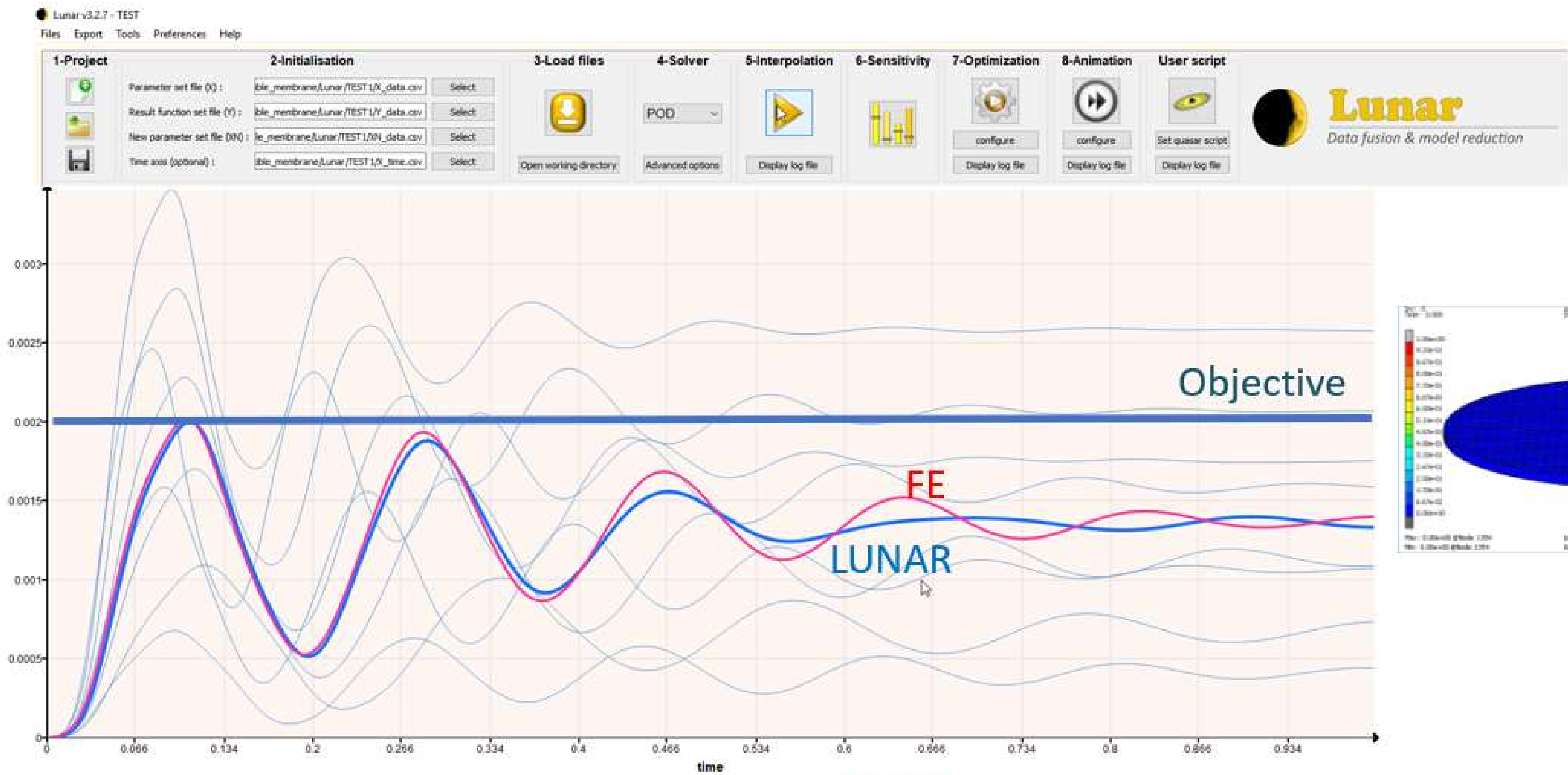
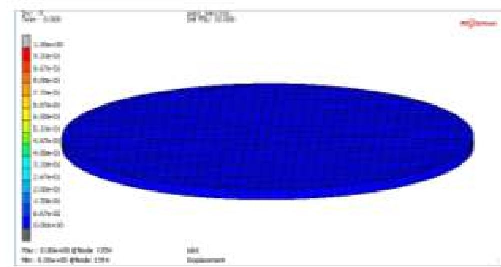
ODYSSEE

Explore new industrial horizons

LUNAR versus Co-simulation (Marc/scFlow)

Result Verification





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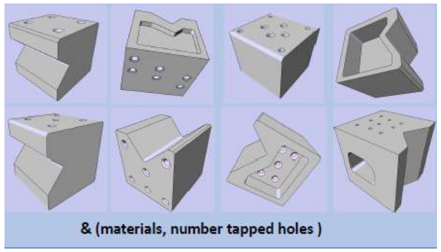
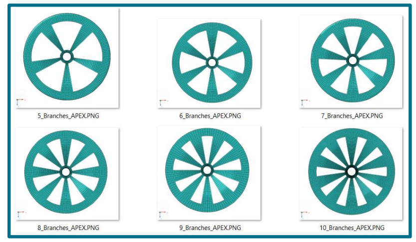
Machine Learning for Images and Production





Database Parameters

Database Results

Learning

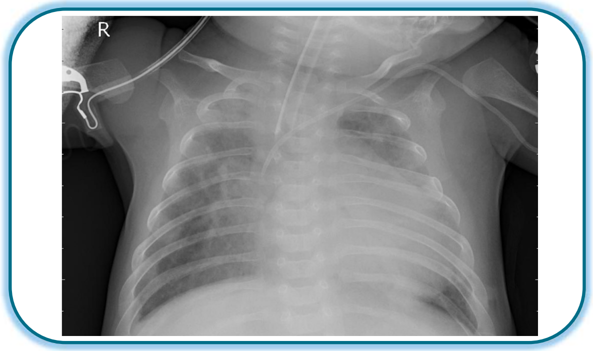
A-eye

New parameters

Predict results in real time

Prediction

Prediction Based on CT Scan

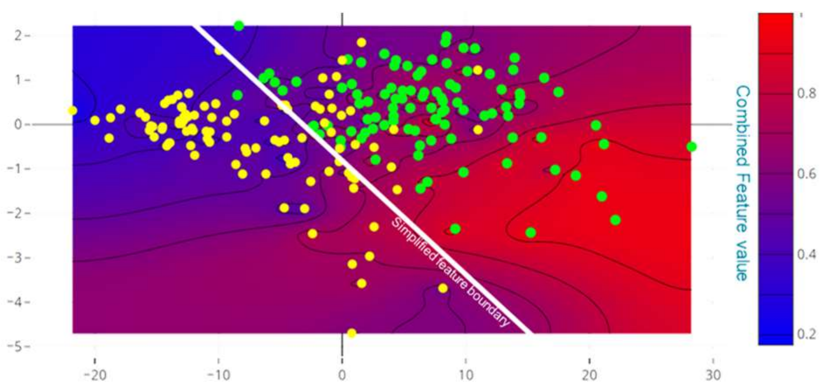


Learning

Prediction

based on 200 cases

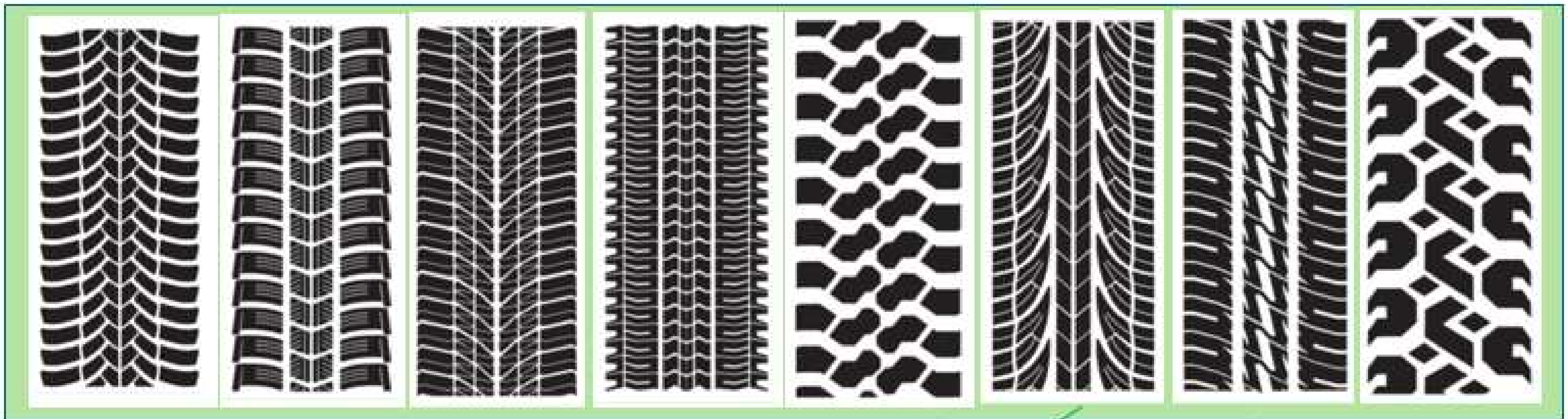
(Error 12%)



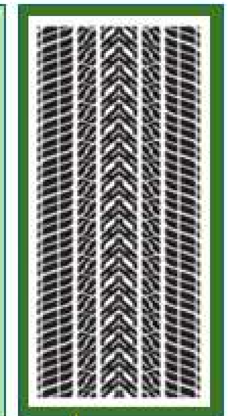
- Pneumonia
- Normal

Predict Sound Spectrum Curves from Tire Pattern Images

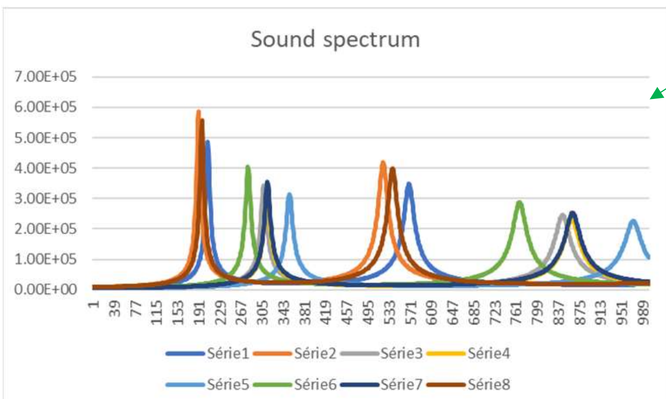
Known database: Parameters (Images)



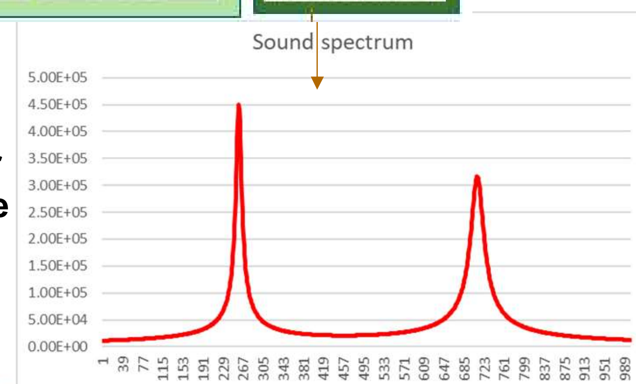
New parameters (new image)



Known database: Results



Predicted results for new image



Vielen Dank fürs Zuhören!

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