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CONFERENCE

Recent Developments in Metamodeling, Optimization, and Uncertainty Quantification in the optiSLang product line

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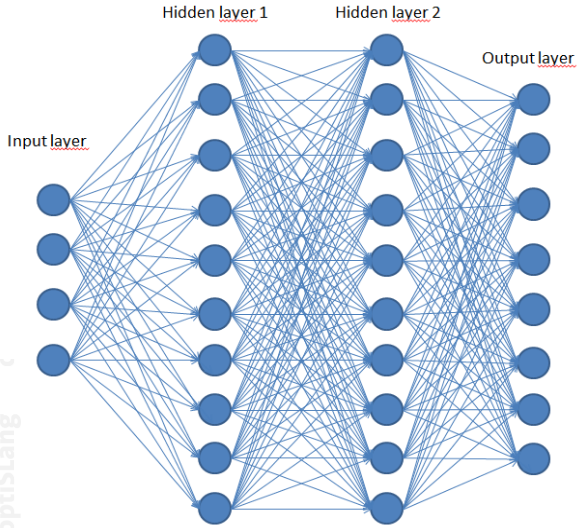
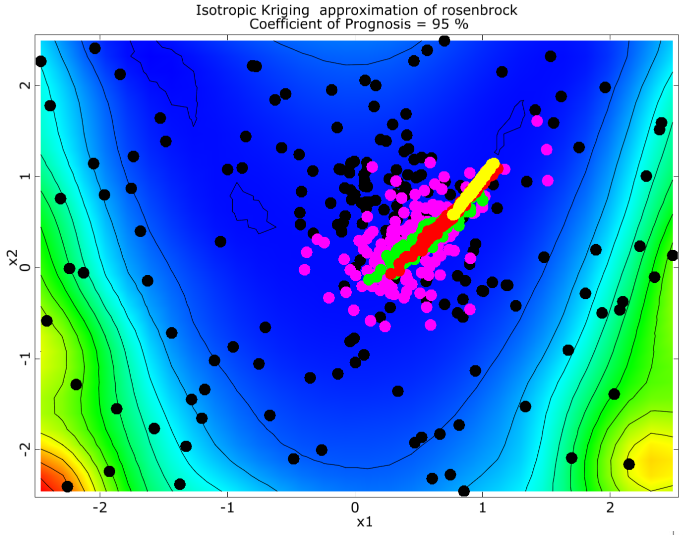
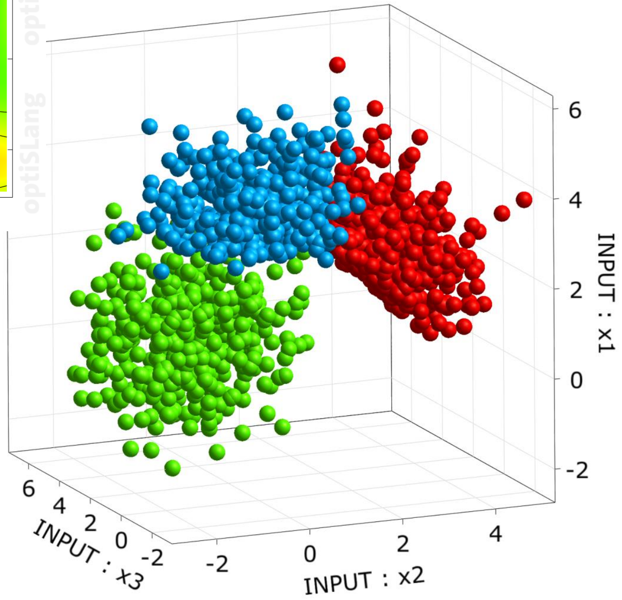
Outline







Meta-Modeling & Data Mining

- Meta-model availability
- Deep feed-forward networks
- Residual plot
- Cluster analysis

Single & Multi-Objective Optimization

- Optimization Wizard Update
- New Nature Inspired Optimization
- Multi-objective AMOP
- Derivative-based optimizer for HFSS

Reliability Analysis

- Multiple FORM and ISPUD
- Reliability Importance Measures

Meta-modeling & Data mining

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MOP- Approximation Models

Premium license

- Polynomials
- Moving Least Squares
- Kriging
- Genetic Aggregation Response Surface (DX)
- Support Vector Regression (DX)

Enterprise license

- Deep Feed-Forward Network
- Signal MOP

DX models, Signal MOP and DFFN are included in optiSLang and ANSYS installers

Property	Value
Models	
Polynomials	
Use	True
Order	2
Coefficient factor	2.00
Moving least squares	
Use	True
Order	2
Coefficient factor	8.00
Kriging	
Use	True
Anisotropic	False
Coefficient factor	8.00
Genetic Aggregation Response Surface	
Use	False
Support Vector Regression	
Use	False
Deep Feed Forward Network	
Use	False
Signal MOP	
Use	False
External	
ASCMO	False

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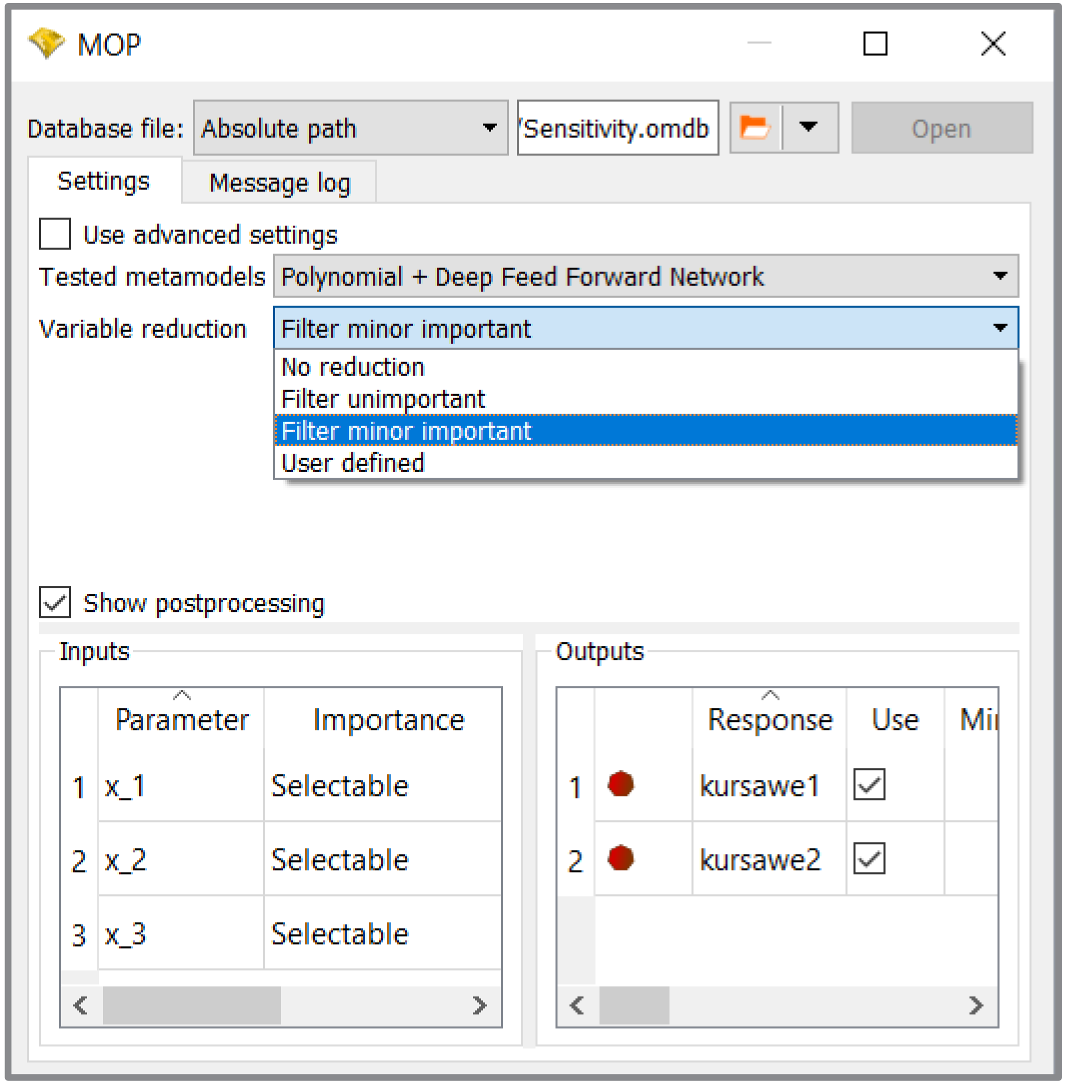
MOP– New Presets (2021 R2)

Tested metamodels

- Polynomial
- Polynomial + MLS+ isotropic Kriging
- **Polynomial + DFFN** *(requires Enterprise)*
- **All internal metamodels** *(incl. DX, Signal MOP)*

Variable reduction

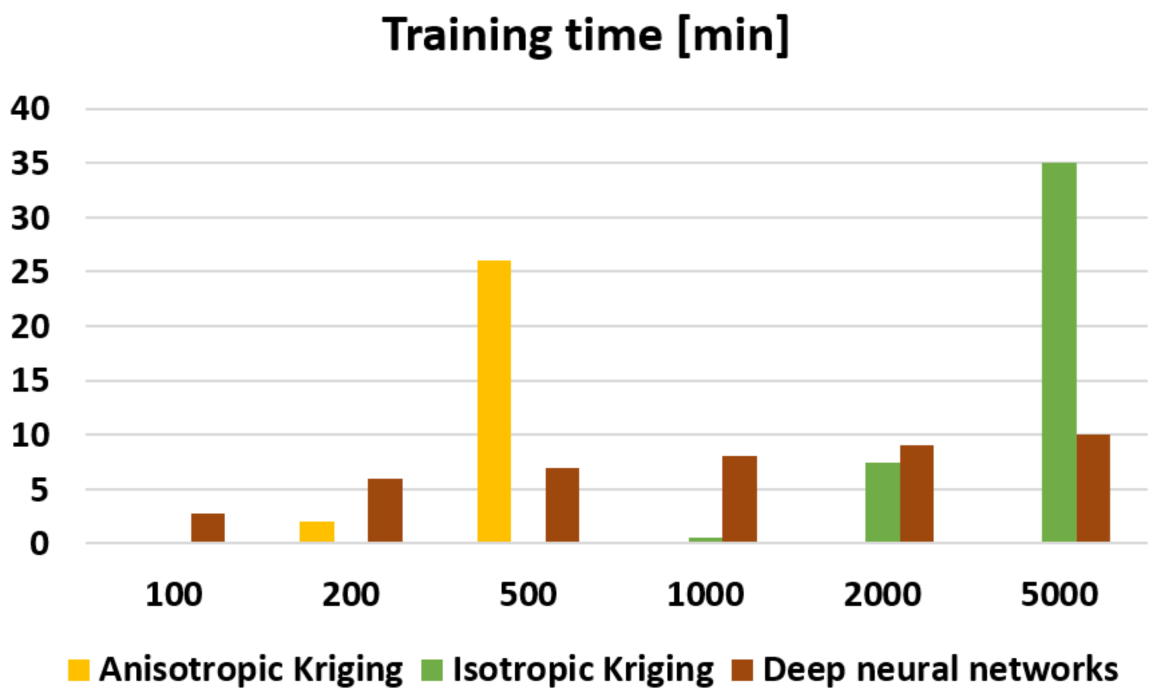
- No reduction (all inputs are mandatory)
- **Filter unimportant** (delta CoP = 0.001)
- **Filter minor important** (delta CoP = 0.01)
- User defined



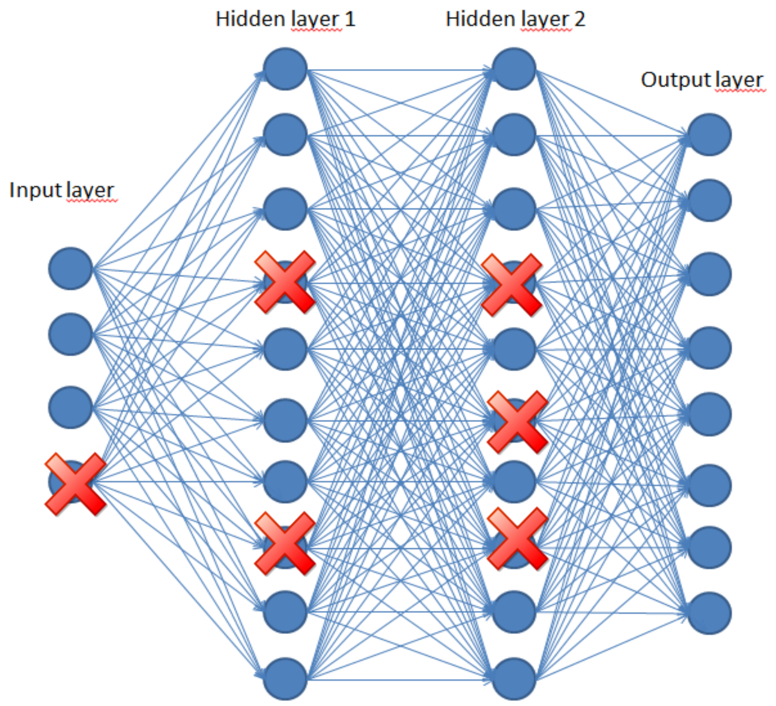
Deep Feed Forward Networks (2021 R2)

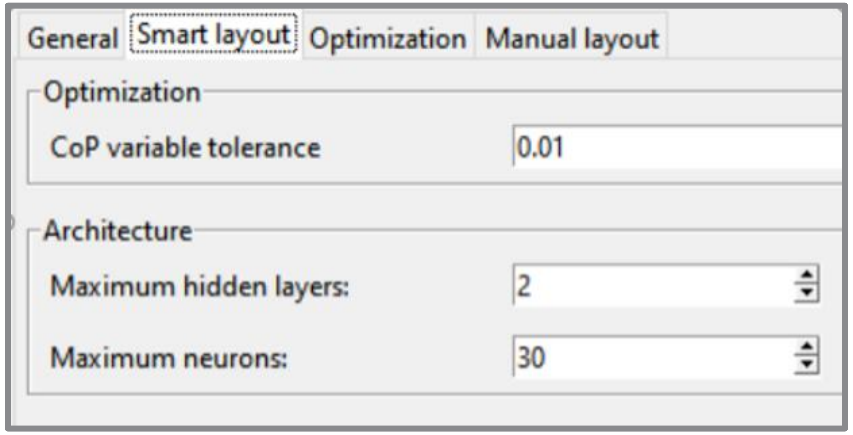
- Smart Layout – Automatic network configuration
- Simplified settings
- Training time increases linearly with # of samples

➢ Efficient especially for larger data sets



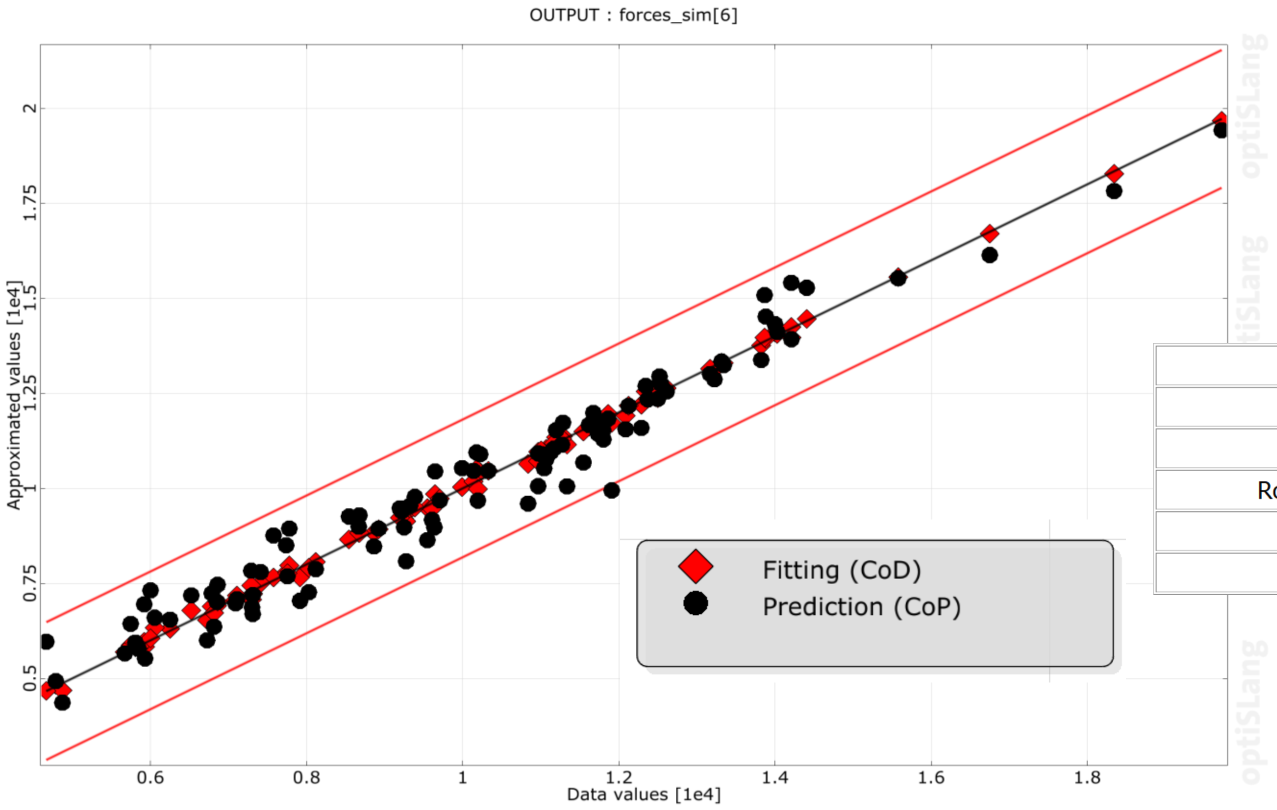
Example:
Noisy function
with 10 inputs





Residual Plot – Prediction vs. Fitting Errors (2021 R1)

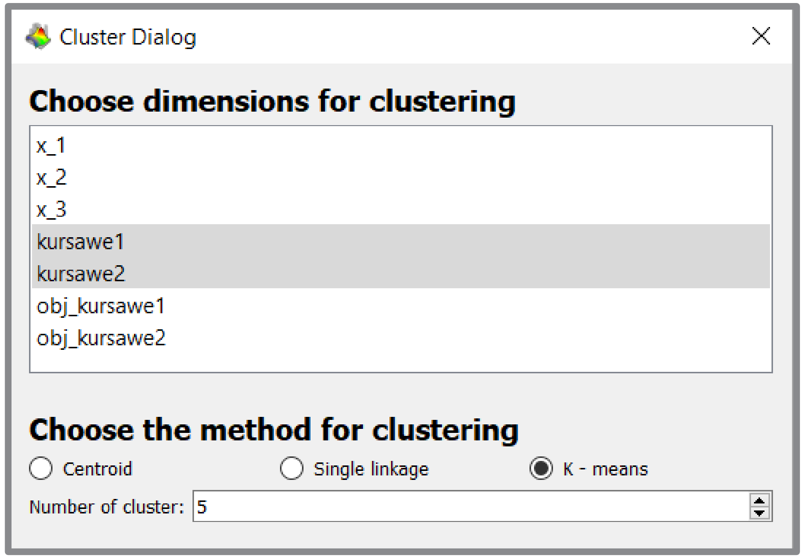
- Prediction errors from cross validation (default until 2020 R2) are shown in comparison to fitting errors
- Statistical values show both, which is equivalent of contribution to CoP and CoD

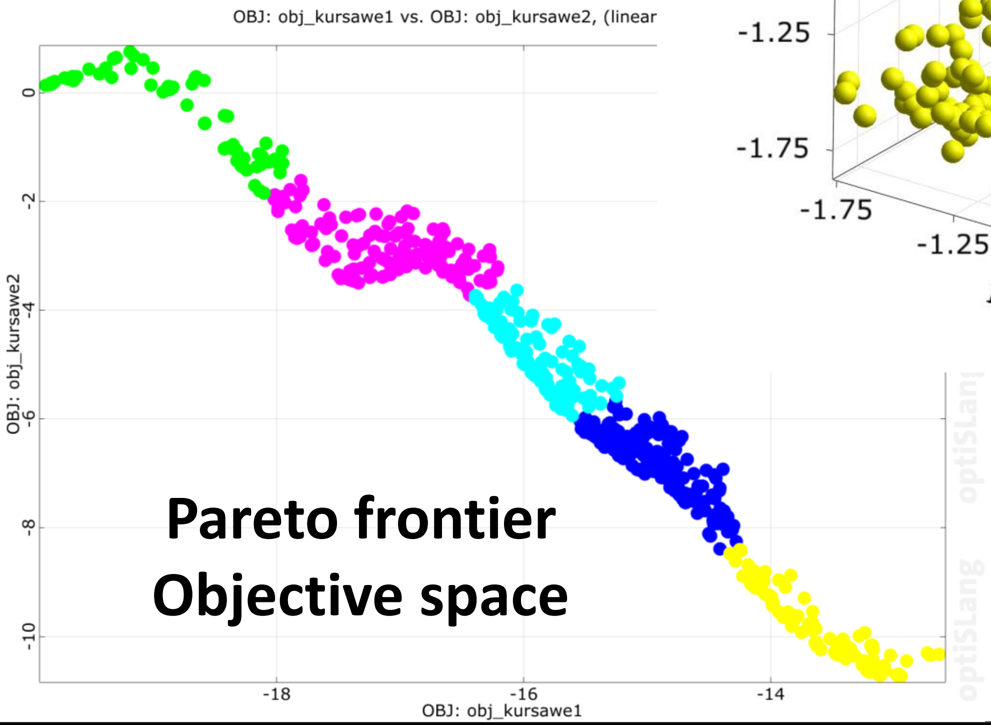


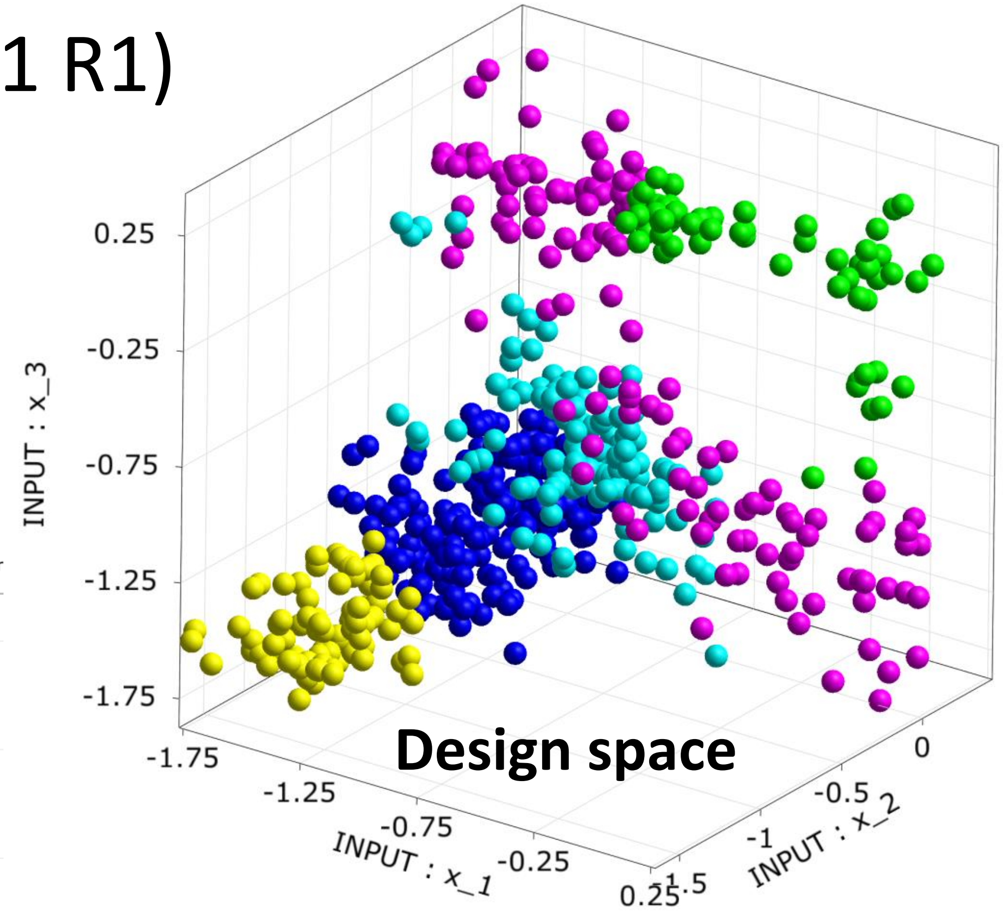
Prediction errors		Fitting errors	
Max Error:	1963.23	Max Error:	329.404
Mean Error:	467.766	Mean Error:	97.0591
Root Mean Square Error:	604.15	Root Mean Square Error:	122.057
CoP:	0.959501	CoD:	0.998347
		adjusted CoD:	0.998347

Cluster analysis in post-processing (2021 R1)

- Cluster analysis based on design point data is now available as global procedure
- Selection of inputs & outputs and cluster algorithm
- Design styles are available in all plots







Single- and Multi-Objective Optimization

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Optimization Wizard Update (2021 R2)

Classical algorithms

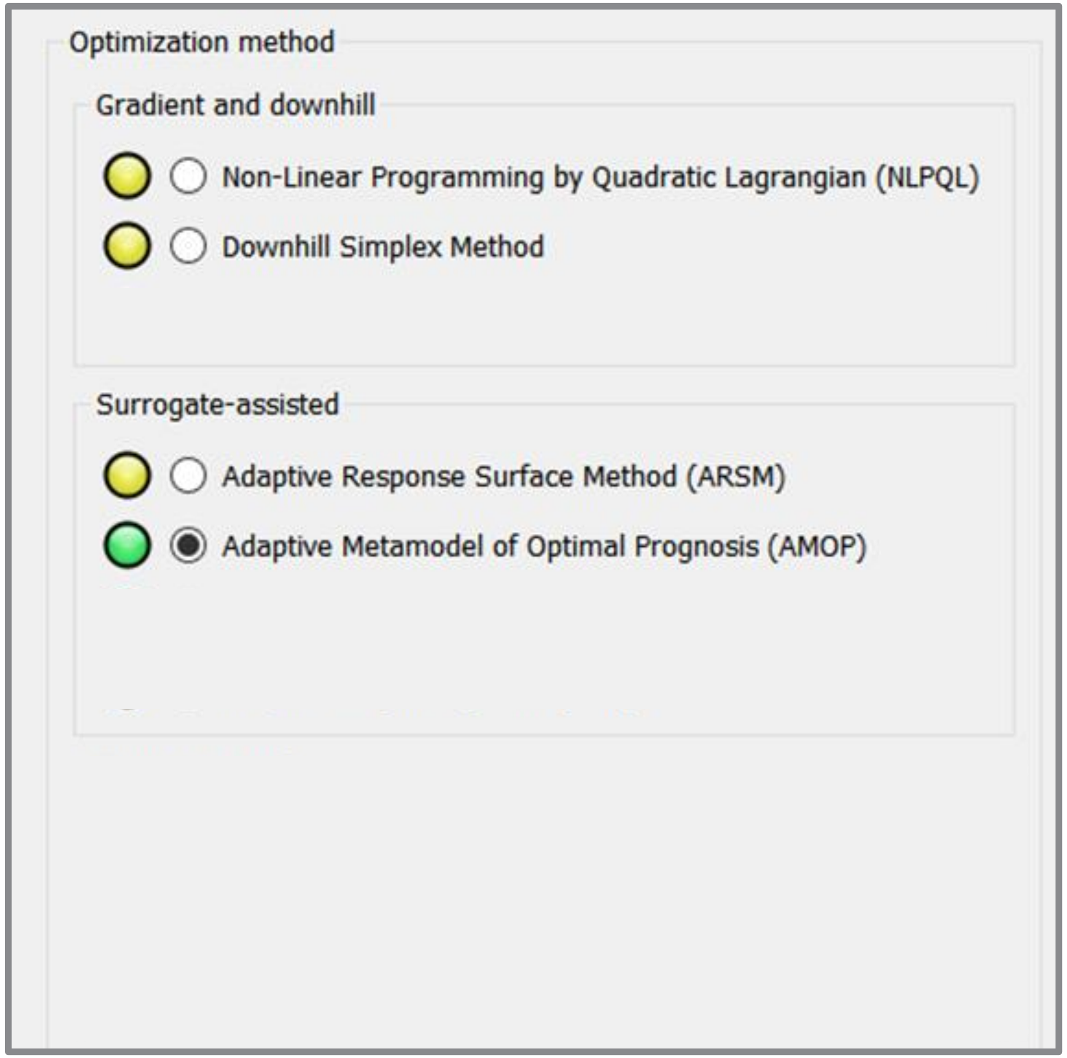
- NLPQL
- Downhill Simplex
- ARSM
- AMOP

New NOA algorithms

- Evolutionary Algorithm
- Particle Swarm Optimization
- Covariance Matrix Adaptation

DX algorithms

- Mixed-Integer MISQP
- Adaptive Single-Objective
- Adaptive Multi-Objective



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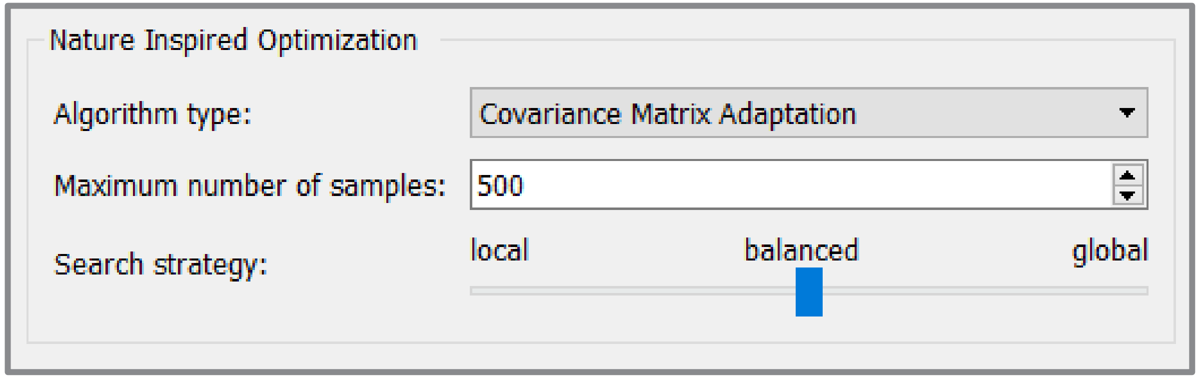
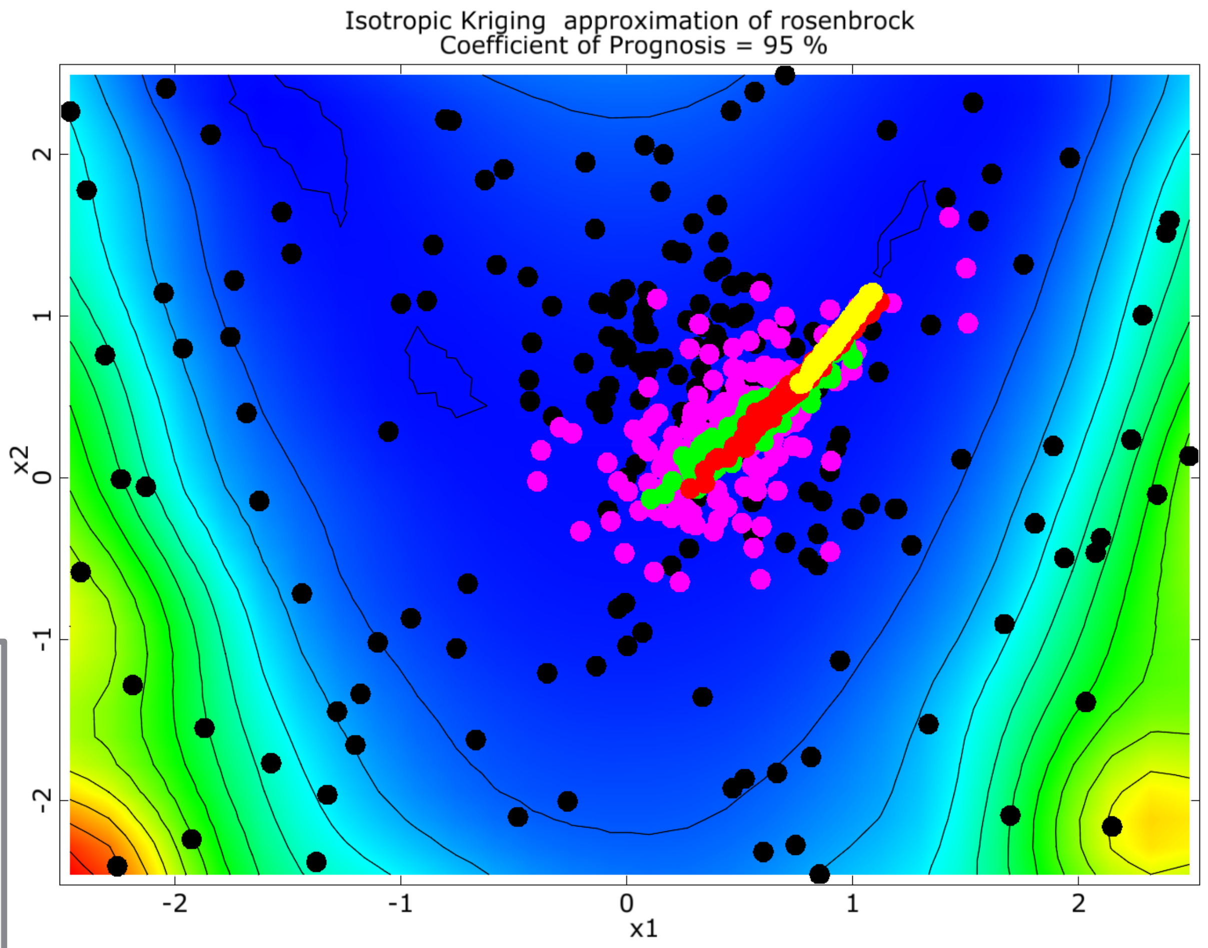
Covariance Matrix Adaptation Evolutionary Strategy (2021 R1)

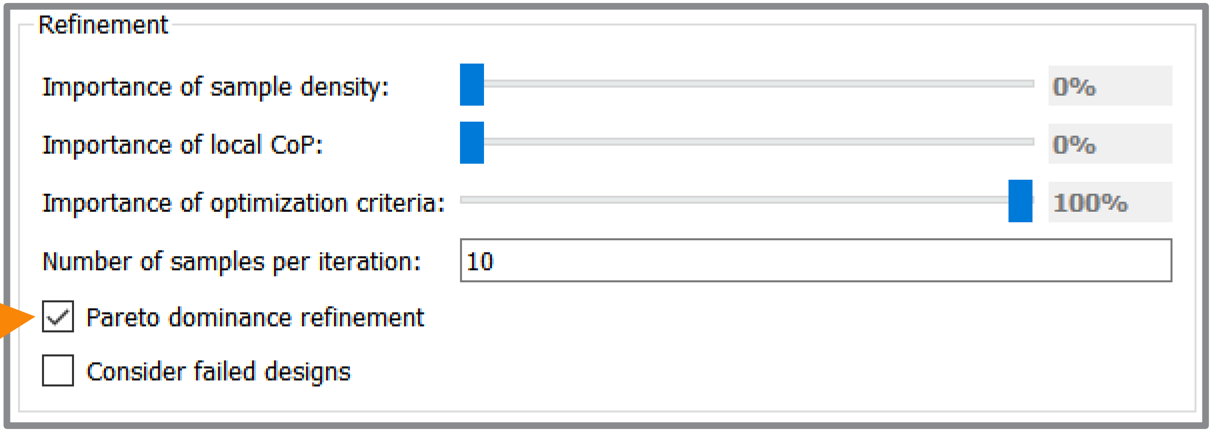
- New algorithm in NOA toolbox
- Automatic adjustment of sampling/mutation density to objective and constraints
- State-of-the-art in benchmarking and evolutionary research

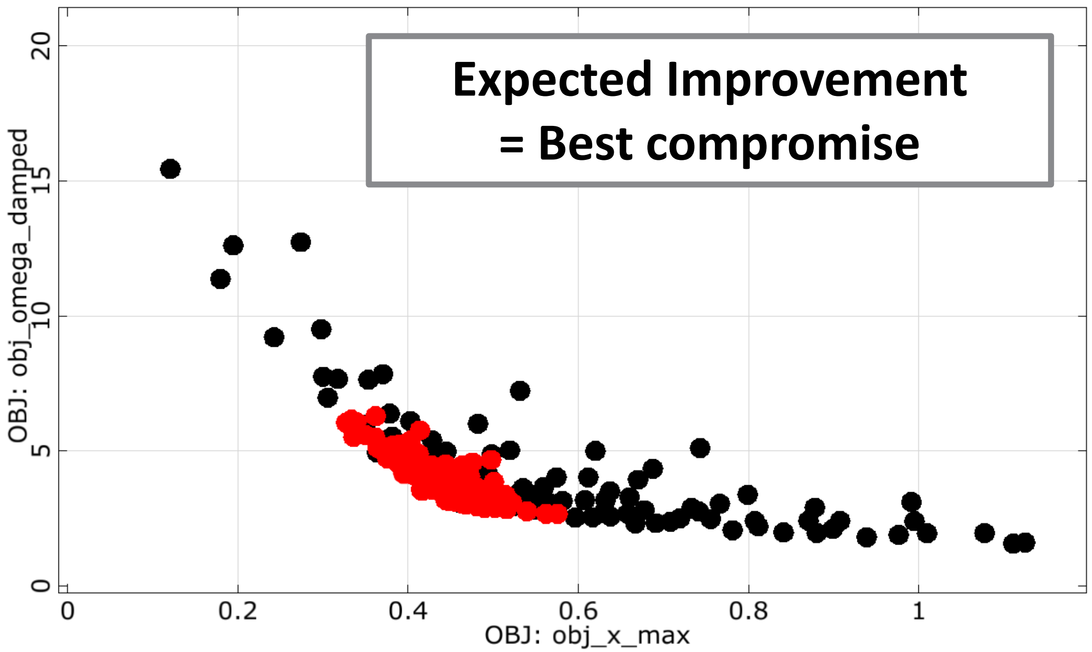


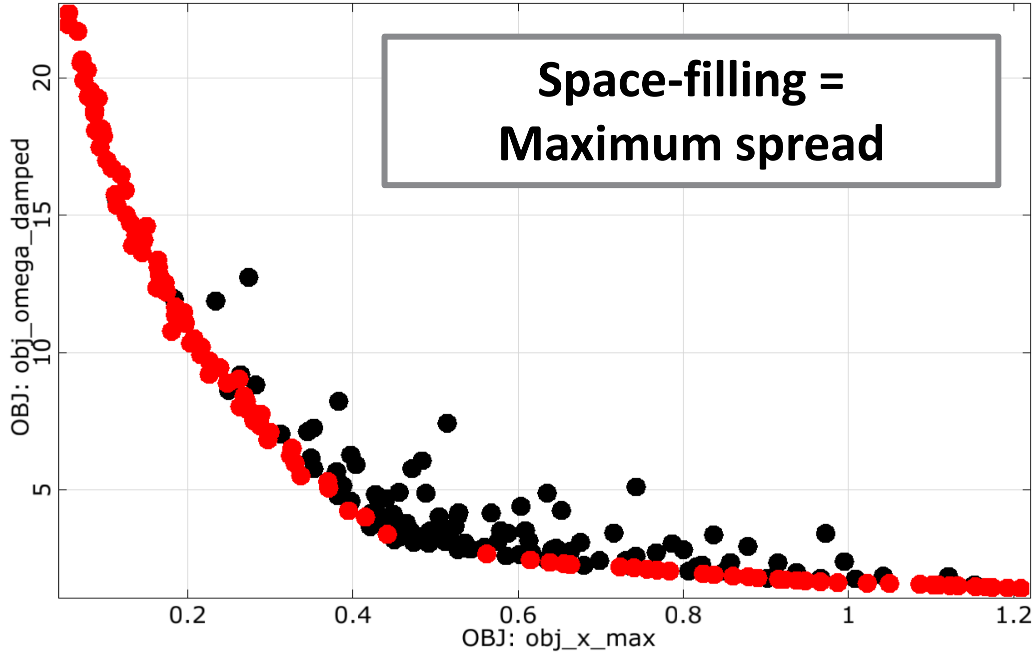


Adaptive MOP – Improved Multi-objective Optimization (2021 R1)

- Adaptive MOP uses now new NOA for multi-objective refinement
- Space-filling criterion for maximum spread of Pareto frontier

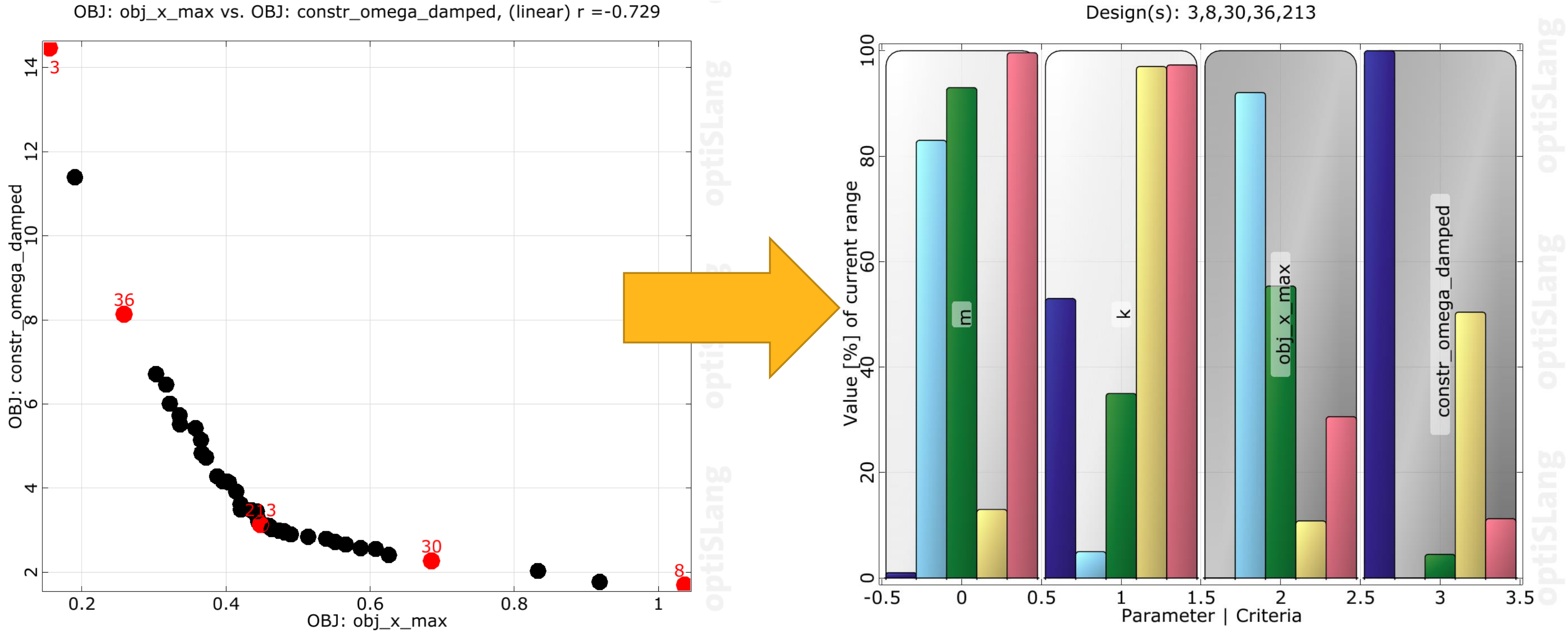




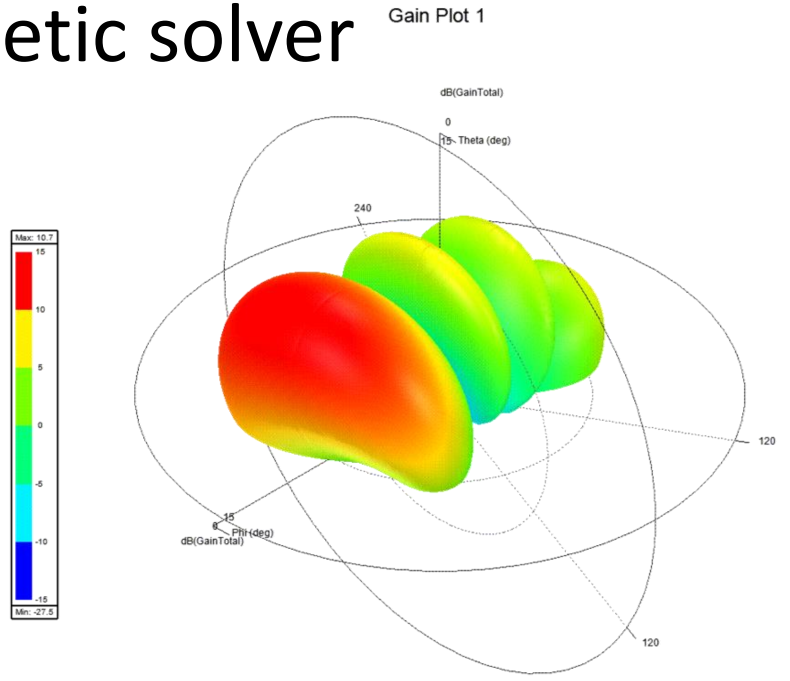


Design Comparison Plot (2021 R1)

- Directly compares input, response and criteria values of selected designs
- E.g. for comparison of initial vs. optimized designs, different Pareto designs



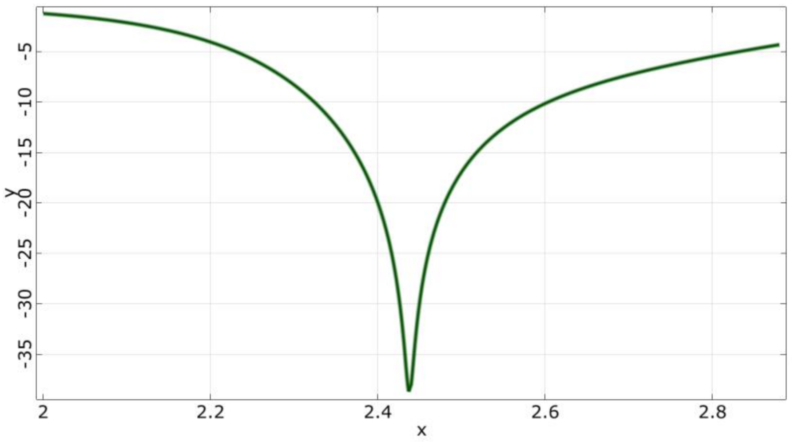
Ansys HFSS: 3D high frequency electromagnetic solver



- HFSS for antenna simulations
  - Common outputs: S-parameters, antenna impedance, radiation patterns, etc.

- HFSS can calculate partial derivatives of antenna responses w.r.t. optimization parameters such as geometry and material properties

Return loss on dB scale



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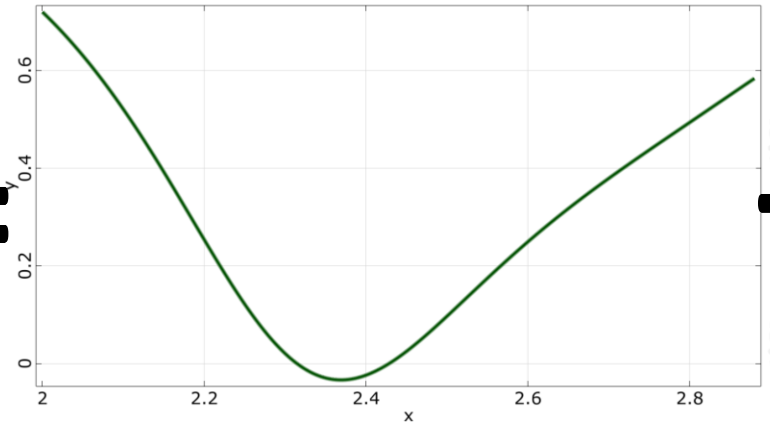
Real part



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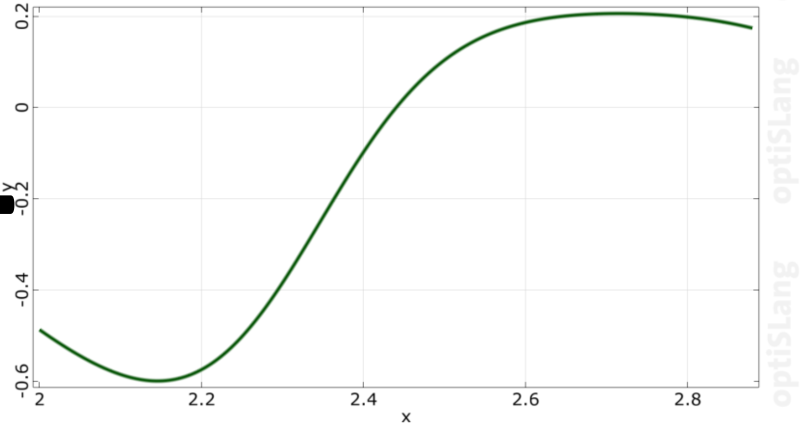
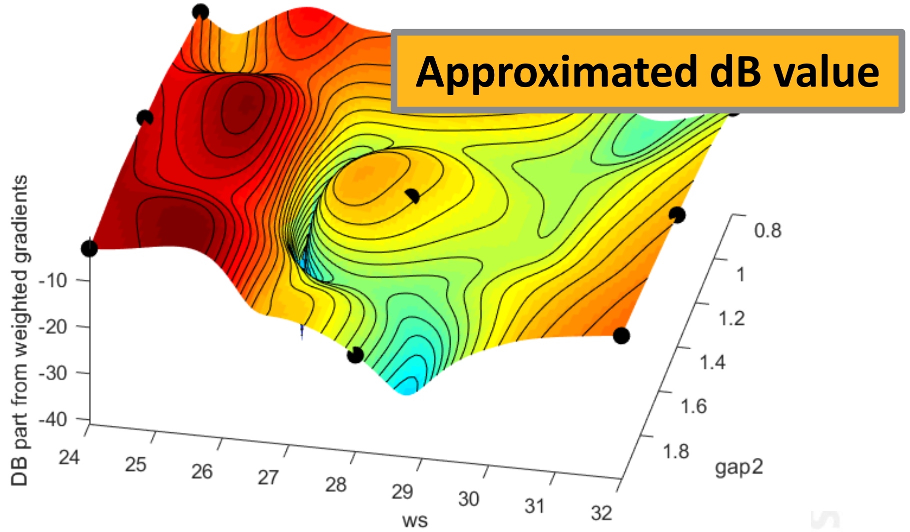
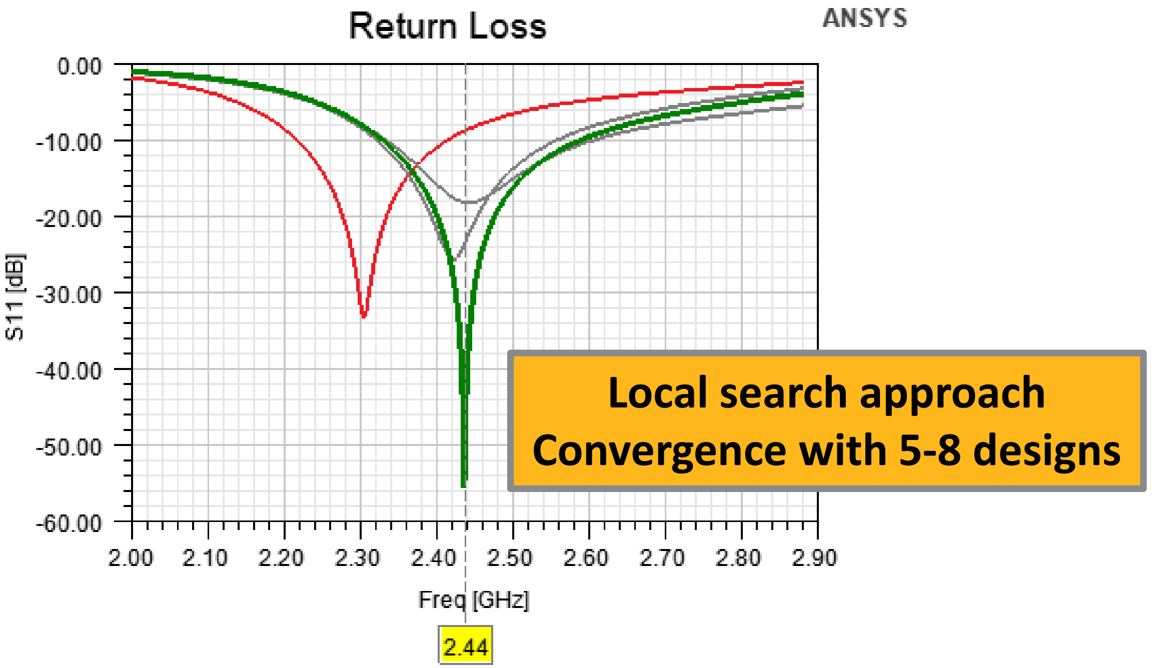
Imaginary part

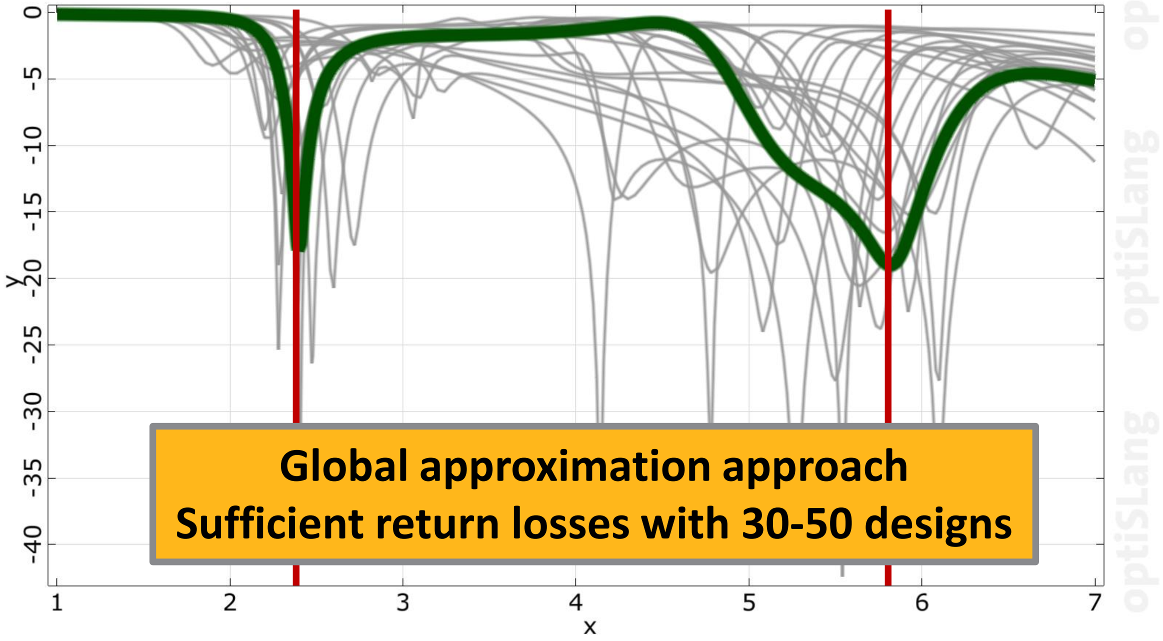


Derivative based approximation model

- Using partial derivatives, S-parameters can be predicted locally for tuned optimization parameters
- The real and imaginary parts of the HFSS signals are approximated in a global meta-model by weighting the individual local values and gradients of all available data points







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Uncertainty Quantification

Reliability Analysis

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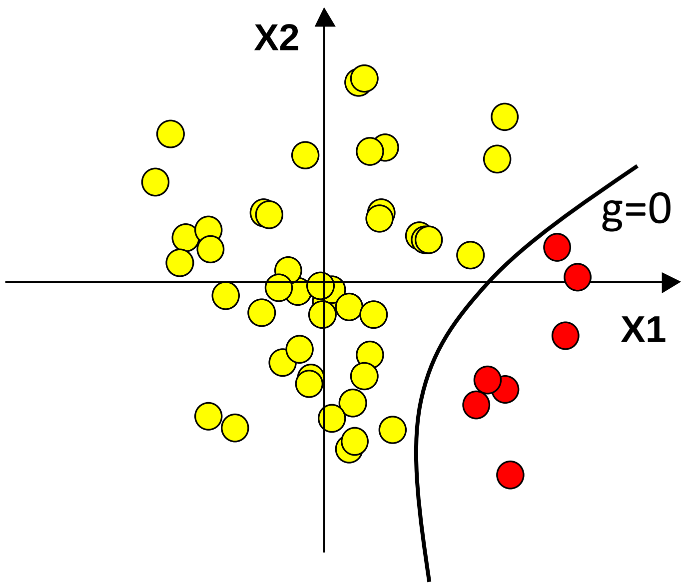
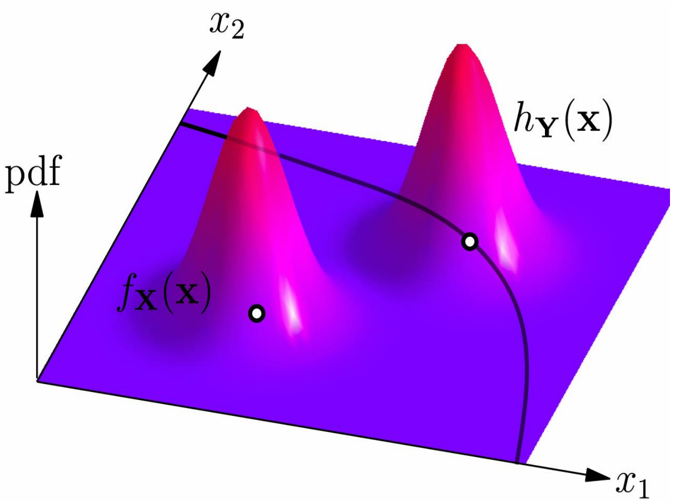
Reliability based Robustness Analysis

- Quantify rare event probabilities
  with minimum effort
  and maximum confidence

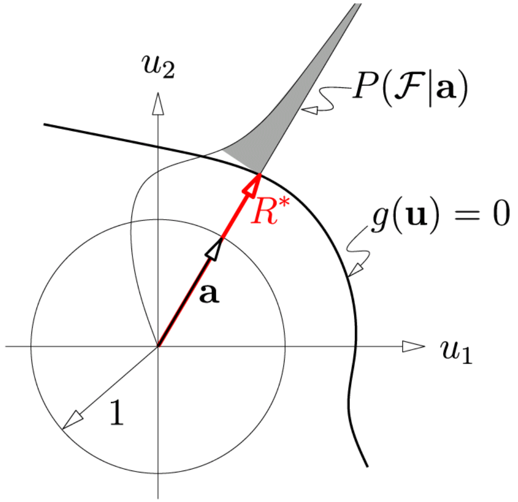
Monte Carlo Sampling



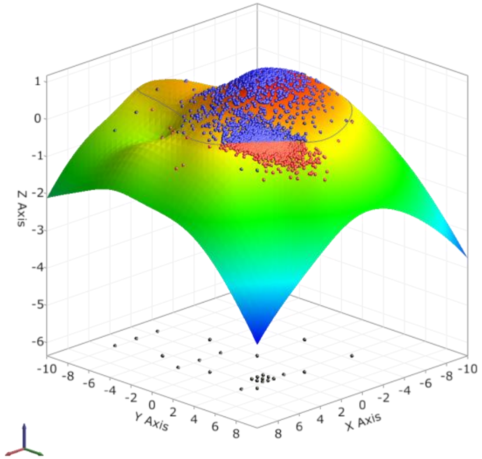
Importance Sampling



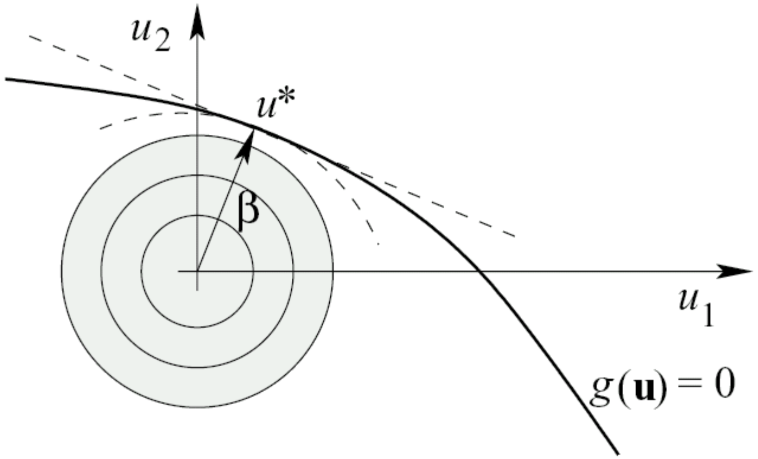
Directional Sampling



Adaptive RSM



First Order Reliability Method



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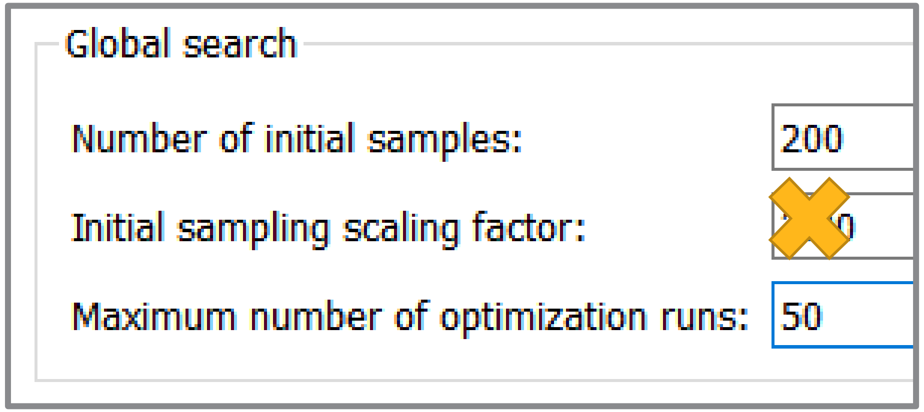
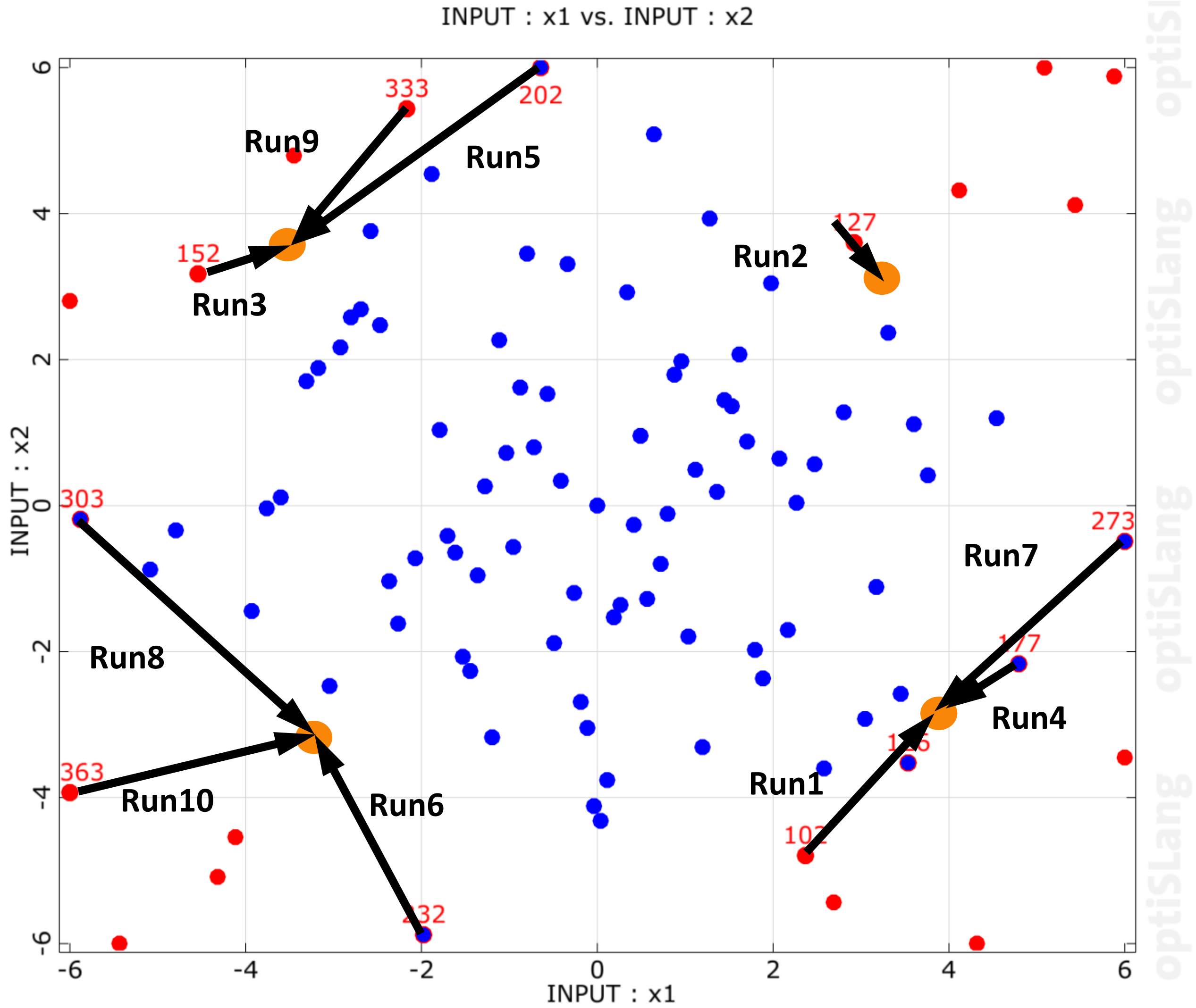
First Order Reliability Method (FORM)

- Multiple design point search is done be NLPQL optimizer with different start points
- This approach detects local optima and different failure regions
- New start design sampling (2021 R2)

➢Scaling factor becomes obsolete





Improved calculation of failure probability in FORM (2021 R2)

- Calculation of failure probability for multiple failure regions now considers the over-lapping of the estimated linearized regions

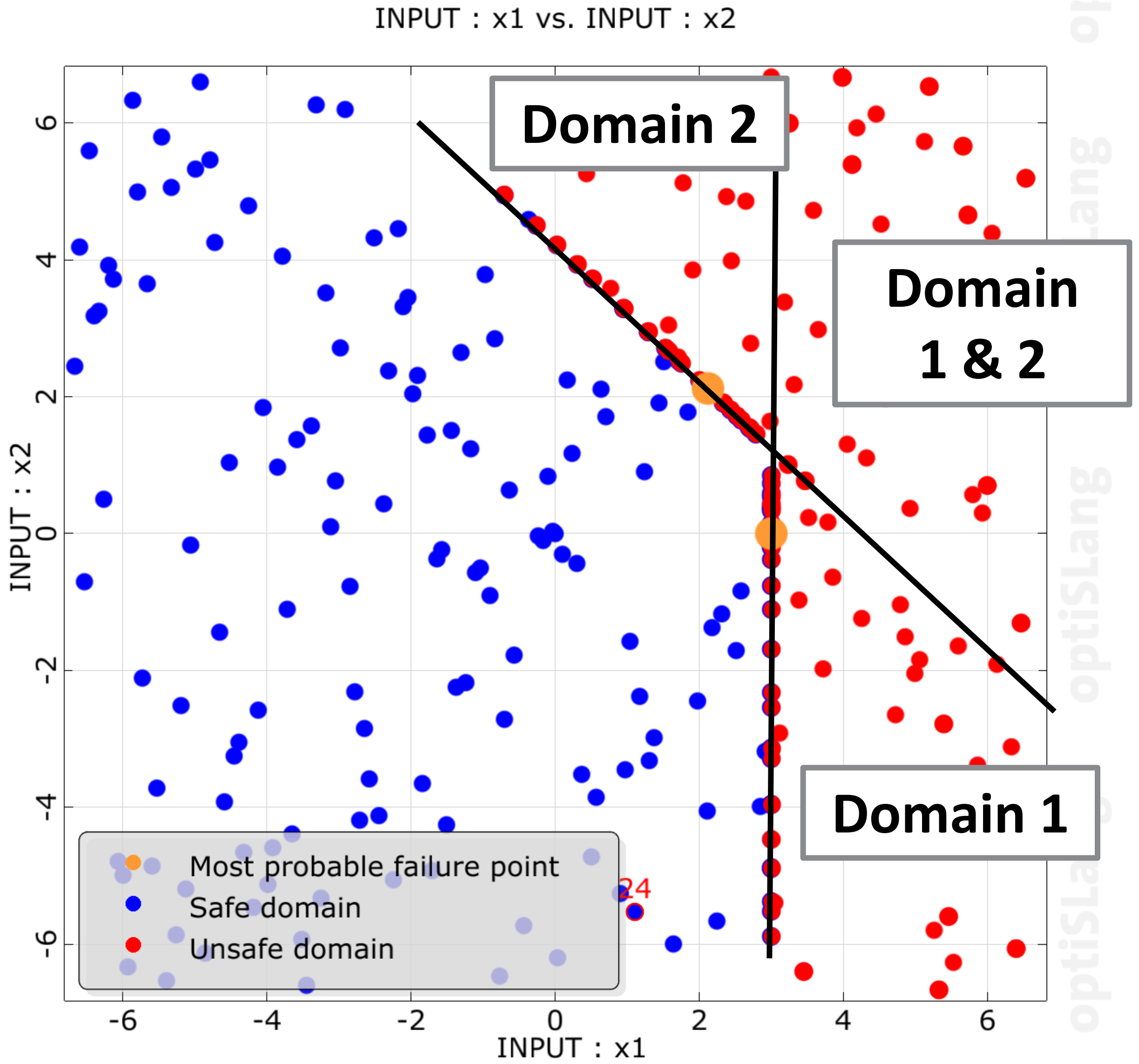
$$\hat{P}_F \leq \sum_{k=1}^{m} \hat{P}_F^k$$

Method : First Order Reliability Method (FORM)

Probability of Failure : 0.00244219
Reliability Index : 2.81456

Most probable failure point(s)

ID :	677	733
Input parameter values		
x1 :	2.12132	3
x2 :	2.12132	1.31347e-07
Reliability index (FORM) :	3	3
Probability of failure (FORM) :	0.0013499	0.0013499



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Importance Sampling Using multiple Design Points (2021 R2)

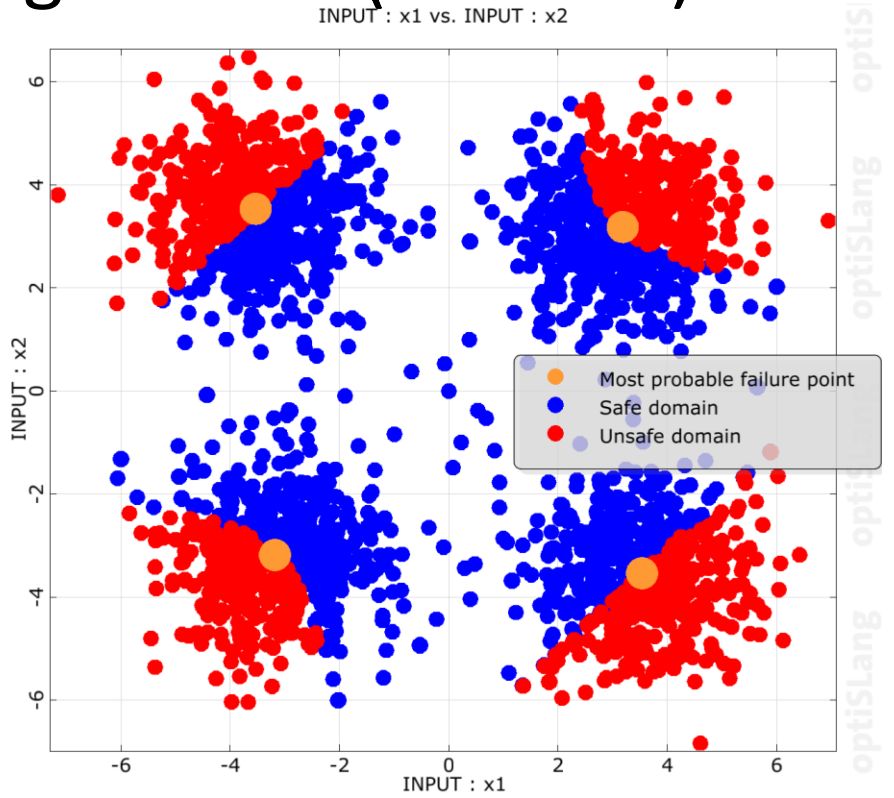
- Probability of failure is now estimated for each sampling density by considering the weights of only these samples, which belong to this single sampling density

$$\hat{P}_F^k = \frac{1}{N}\sum_{i=1}^{N_k} w(x_i^k)I(g(x_i^k))$$

- Sum of individual failure probabilities is equal to global probability

$$\hat{P}_F = \sum_{k=1}^{m} \hat{P}_F^k$$

- Center points (design points) of sampling densities and belonging failure probabilities are indicated in the post-processing



Most probable failure point(s)

ID :	82	37	47	57
Input parameter values				
x1 :	3.18198	-3.19872	3.47885	-3.53816
x2 :	3.18147	-3.16488	-3.59222	3.53291
Reliability index (ISPUD) :	4.62006	4.65424	4.9887	5.01011
Probability of failure (ISPUD) :	1.91815e-6	1.62587e-6	3.0394e-7	2.71992e-7

Reliability Sensitivity Measures

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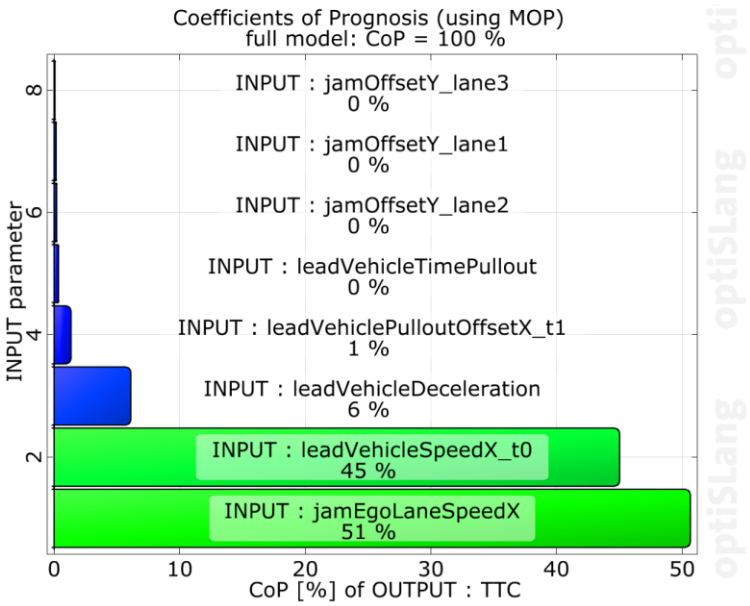
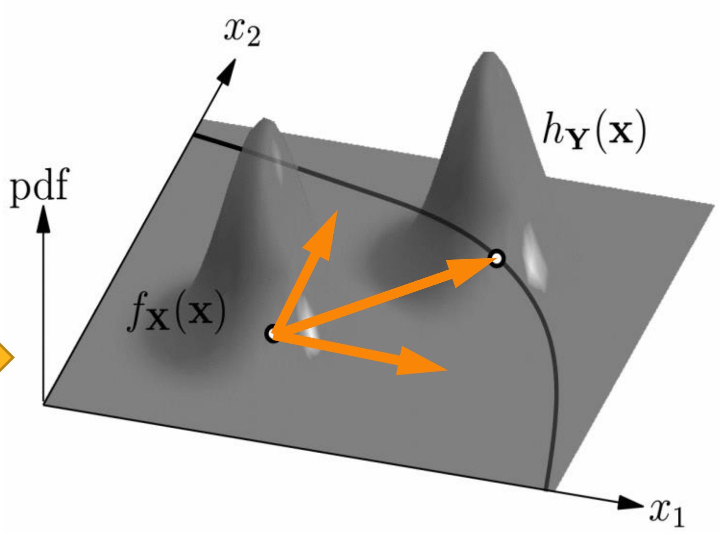
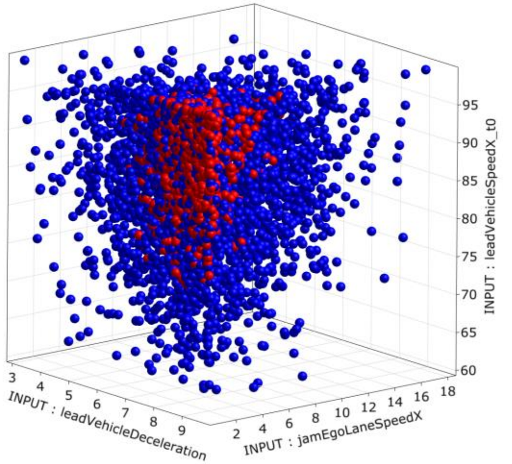
Reliability Sensitivity Measures

- Today, correlation and variance-based sensitivity analysis can assess the variable influence only around the mean!
- Sensitivities w.r.t. failure mechanisms are required!

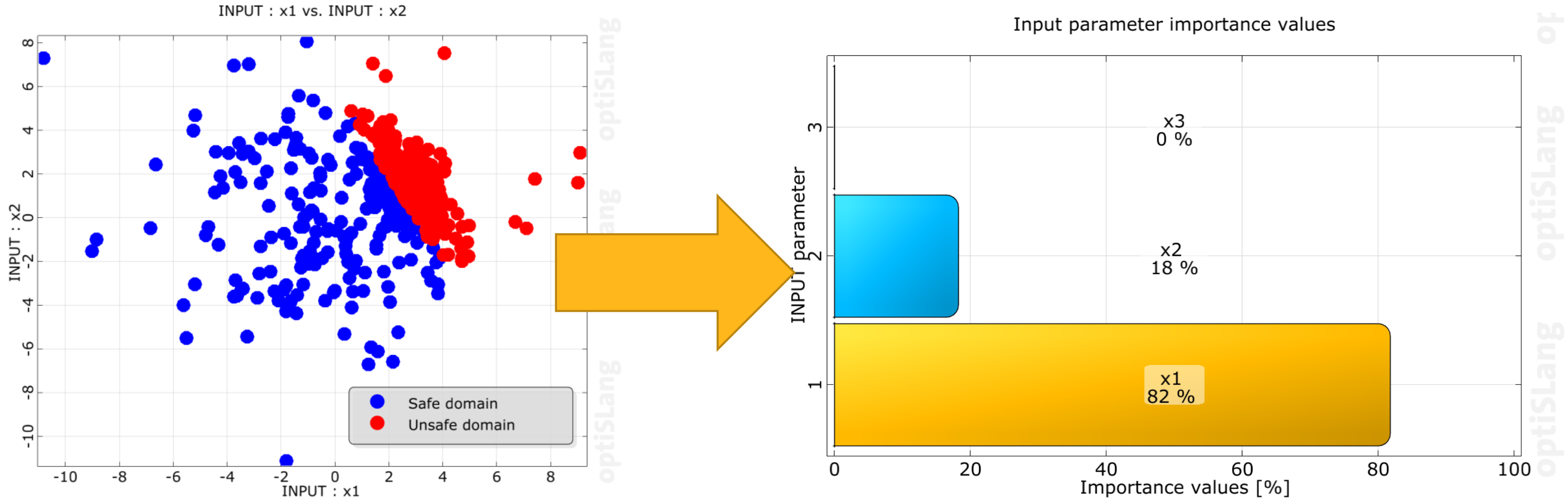






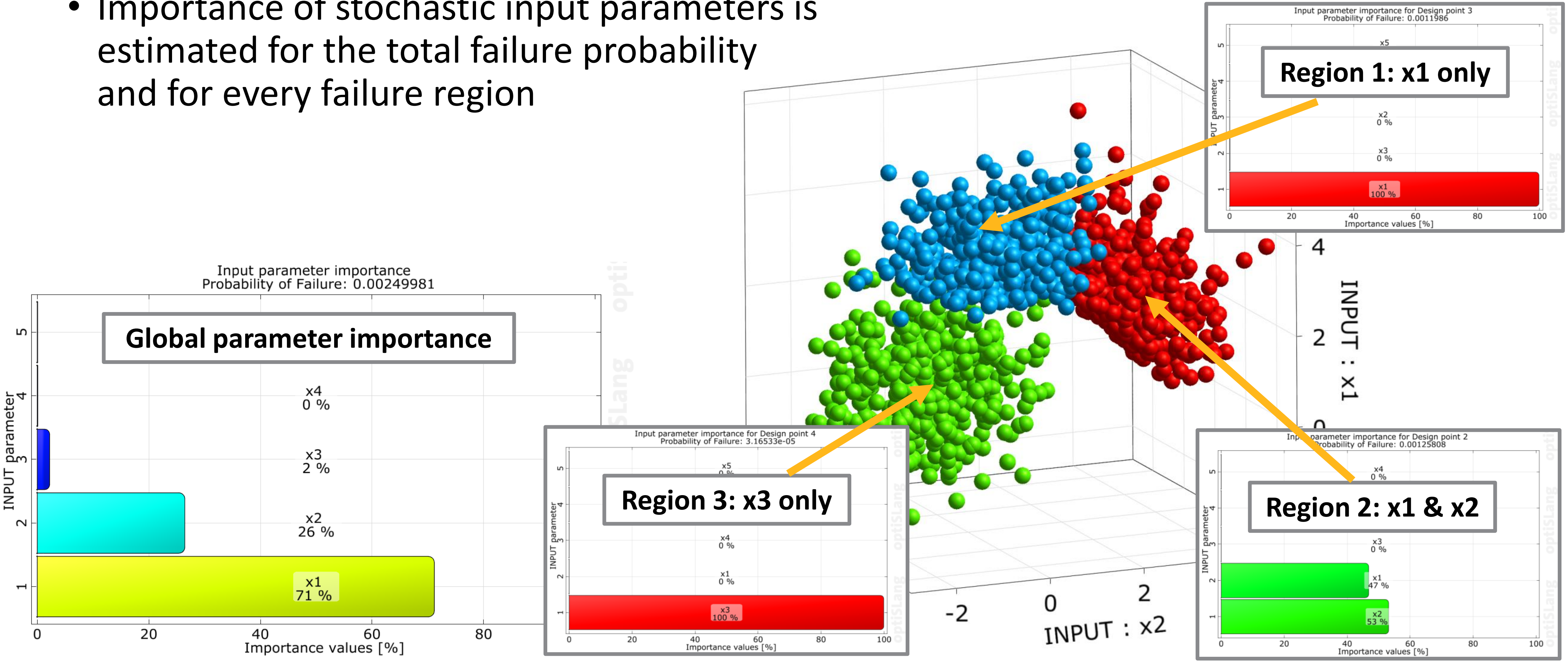
Reliability Importance Plot

- Contribution of variation of stochastic inputs with respect to failure probability
- ✓ Adaptive Sampling in 2021 R1
- ✓ ISPUD with multiple failure regions in 2021 R2

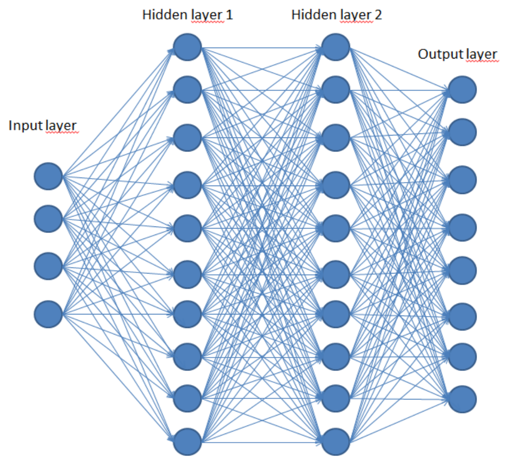


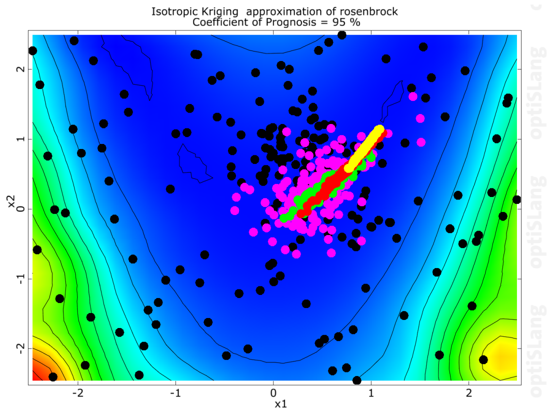
Reliability Importance Plot for multiple failure regions in ISPUD

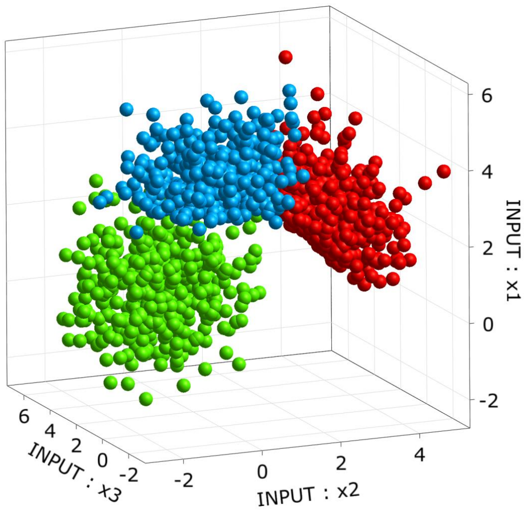
- Importance of stochastic input parameters is estimated for the total failure probability and for every failure region



Questions ?







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