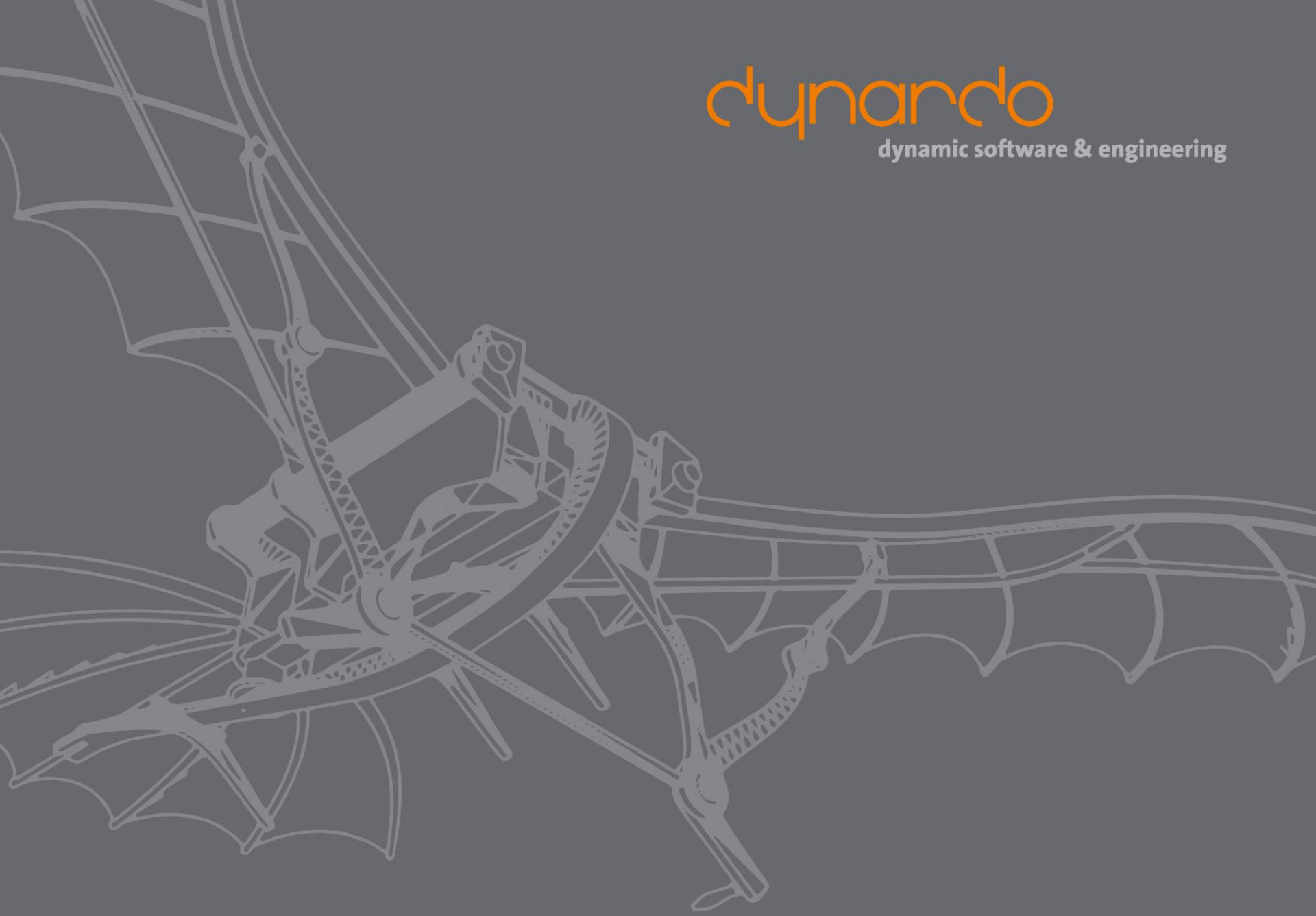

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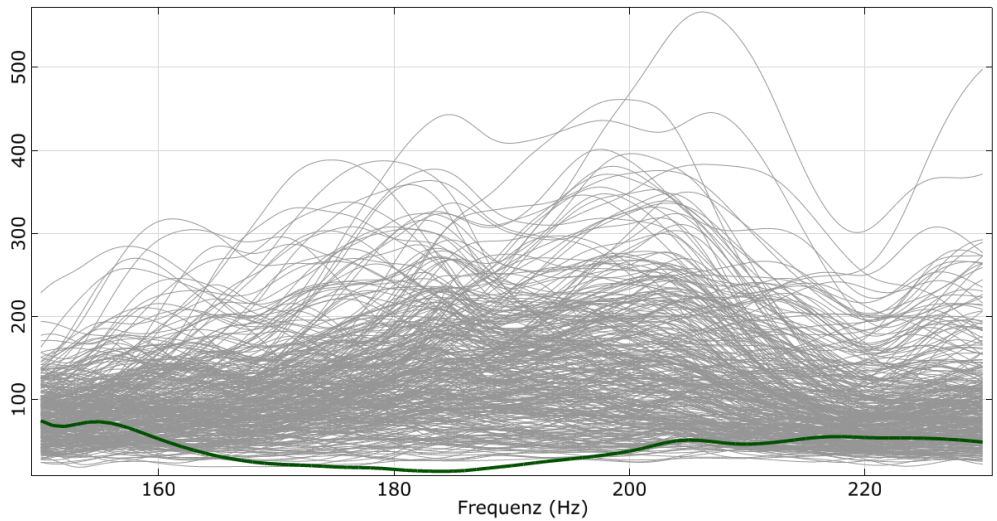
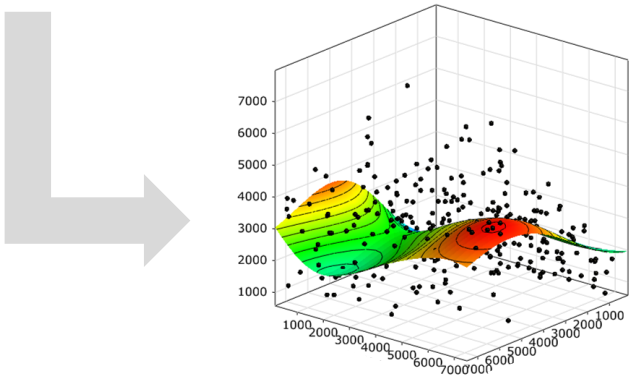
Meta modelling of signals in time or frequency domain for NVH applications





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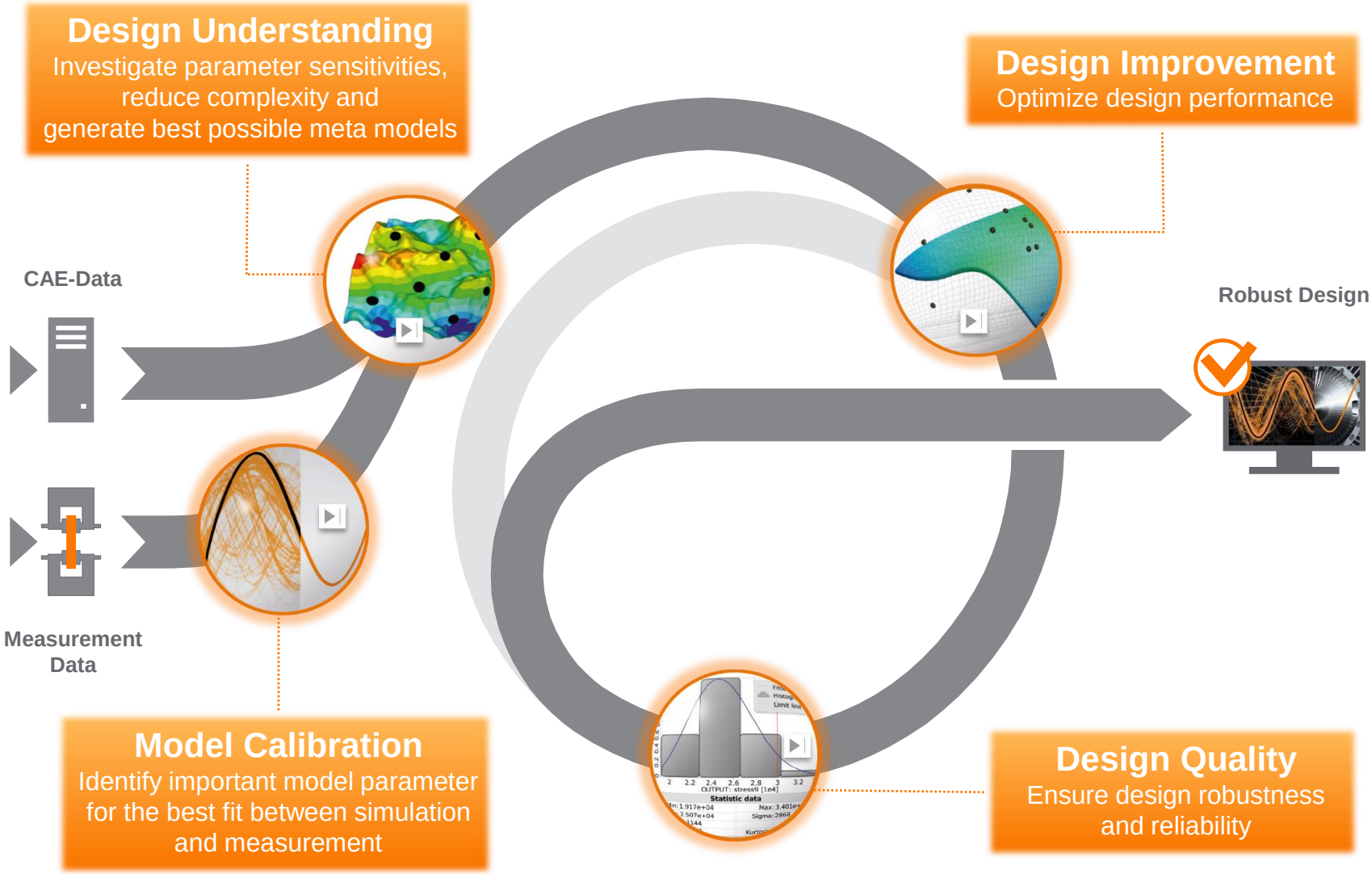
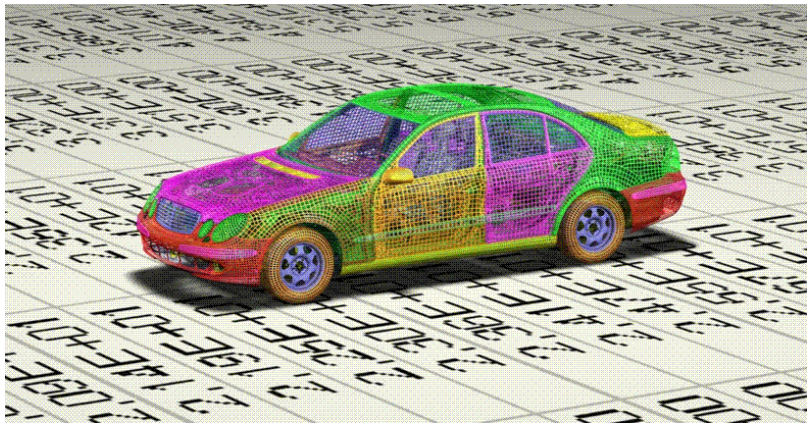


Sensitivity Evaluation of NVH Performance

Start in 2002, since 2003 used for Production Level
How does body and suspension system scatter influence the NVH performance?

- Conservative consideration of scatter of body in white, suspension system
- Prognosis of response value scatter
- Identify correlations due to the input scatter
- CAE-Solver: NASTRAN
- Up-to-date Sensitivity or Robustness evaluation of body in white have **300 to 600 scattering variables**
- Only by using MOP technology we can minimize the number of samples to identify main input contributors.



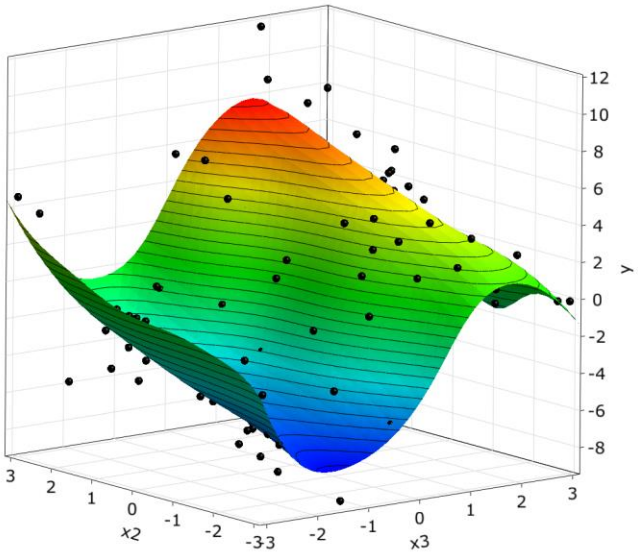
by courtesy of DAIMLER

Metamodel of Optimal Prognosis (MOP)

- Meta model for solver output by fast surrogate model
- Reduction of input space to get best compromise between available information (samples) and model representation (number of inputs)
- Assessment of approximation quality (CoP) – No run too much!

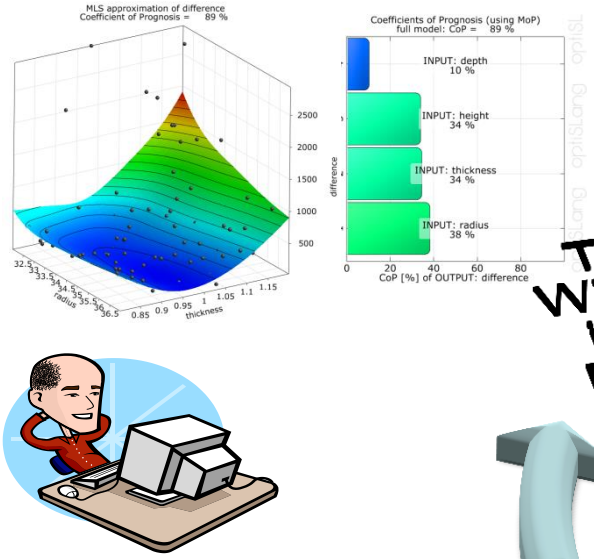
MOP automatically solves 3 important tasks:

- ➢ Select important parameters
- ➢ Identifies the best possible metamodel
- ➢ Estimates prediction quality of response variation



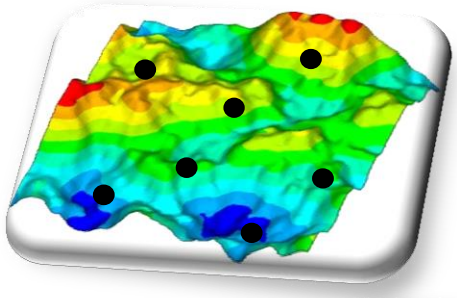
MOP Answers: Which inputs are responsible for which outputs.

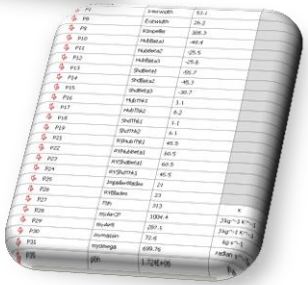
Dynardo's core technology MOP Workflow



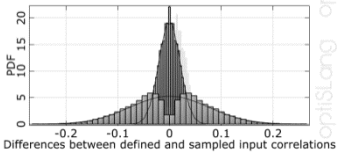
The Winner is ... MOP!

Response per Response based on ALHS Sampling

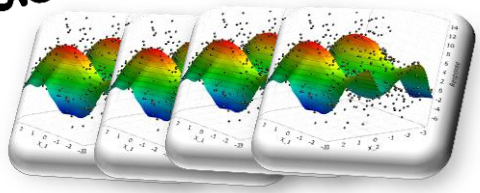




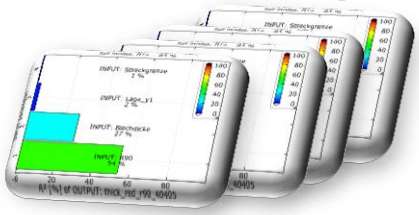
Filter important variables



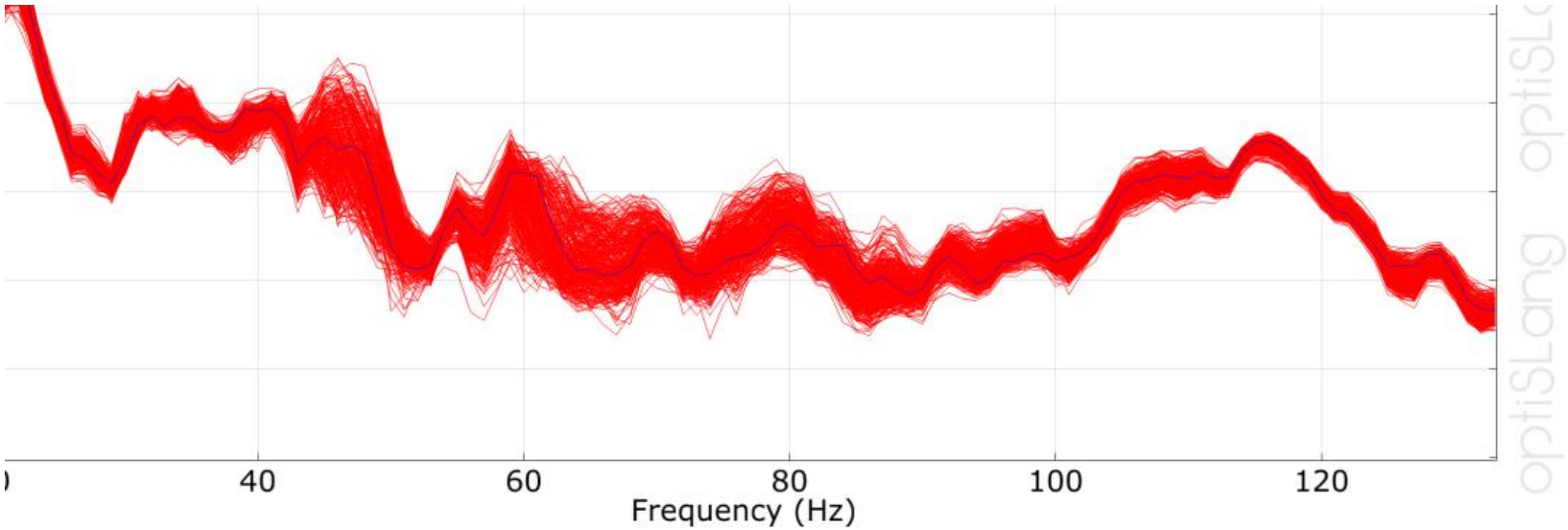
Run different metamodels



Calculate forecast quality using CoP

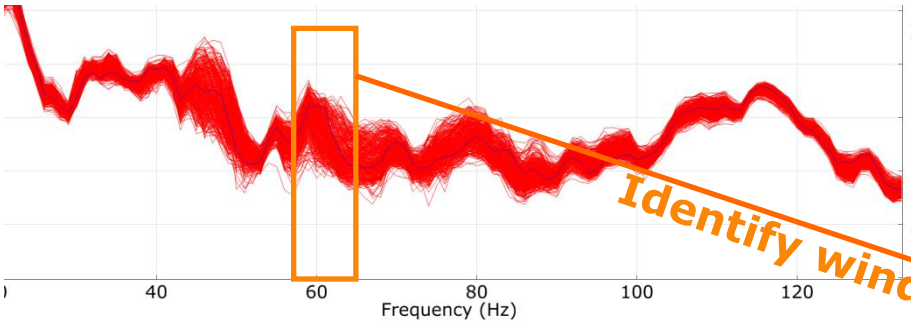


NVH signals and variation in time or frequency domain



- Useful responses: Signal intensities, areas, peak values, …
- **Response identification and model analysis becomes a multi-dimensional analysis problem in time or frequency domain!**

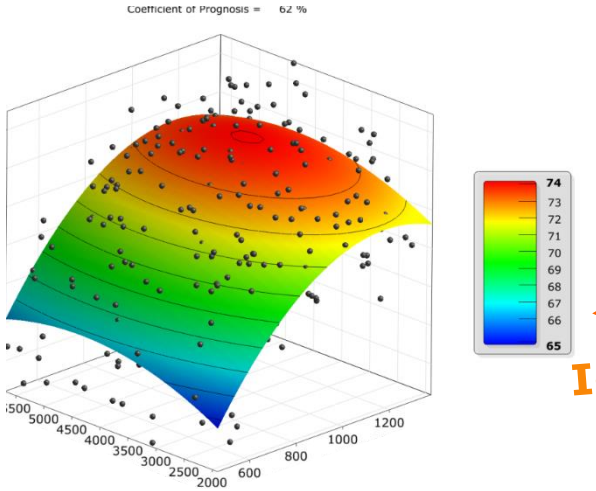
How is it done: Standardized and Automated Post Processing



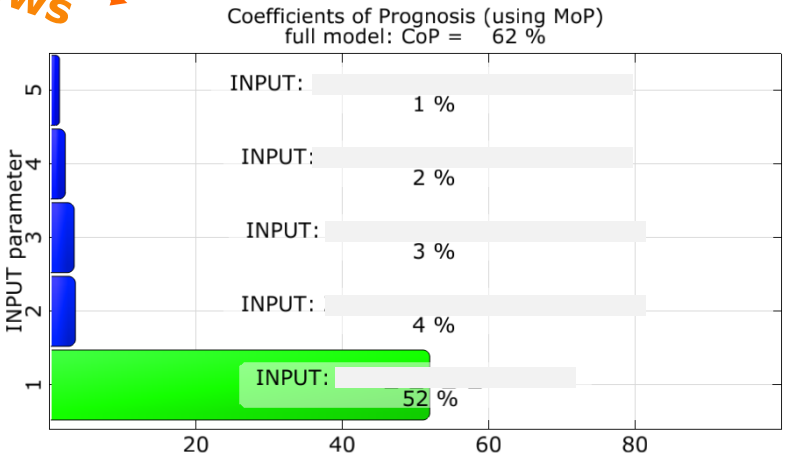
Identify windows

Because of overlaying of multiple phenomena in the frequency range the extraction of best possible windows of extraction with related **scalar** peaks **was** <u>a manual and tedious iterative process</u>.

Goal: find windows with high COP



Identify MOP



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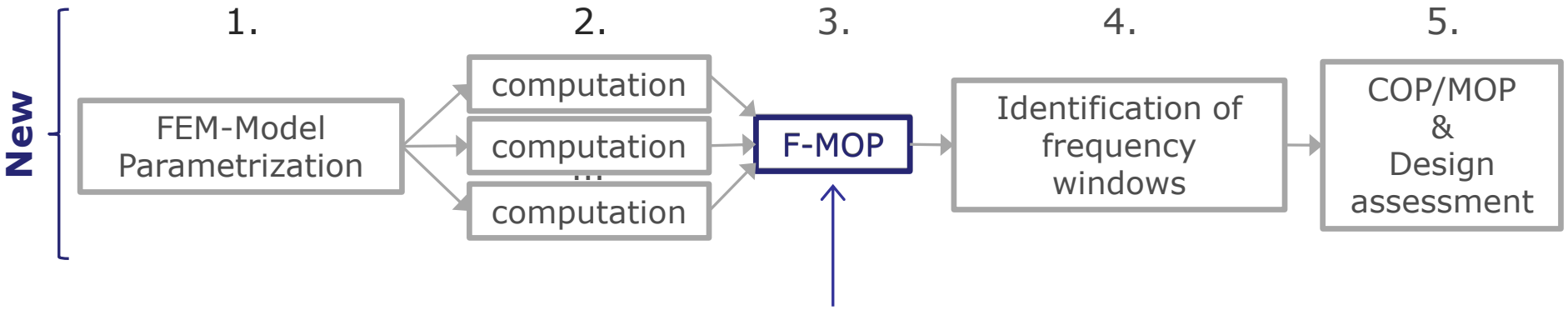
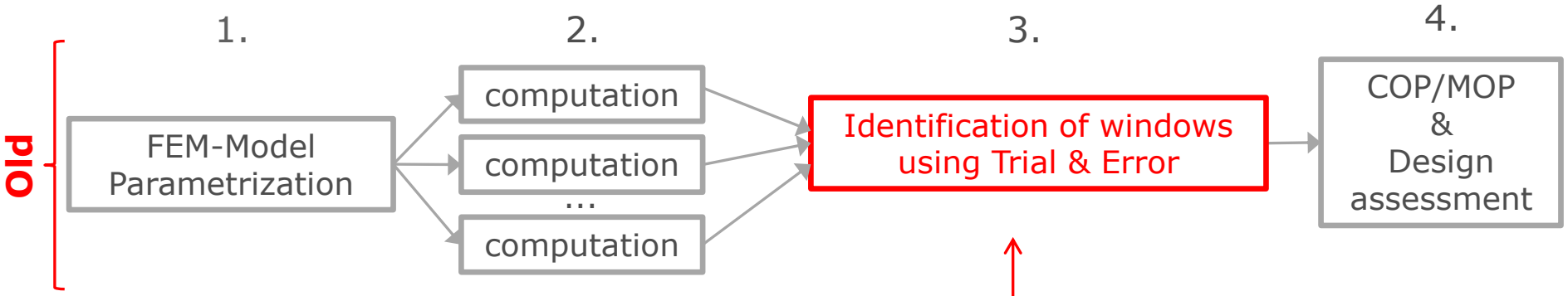
New efficient NVH process chain



New NVH process chain with F-MOP (Field-Metamodel of Optimal Prognosis)

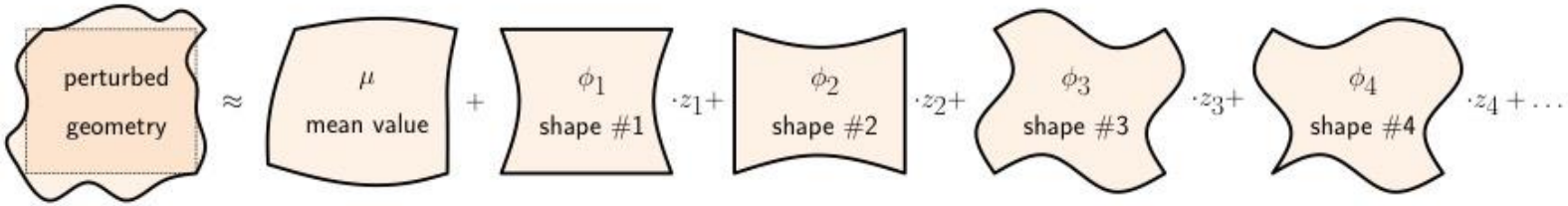


Major disadvantage of old process : time consuming / <u>manual</u> / iterative selection with <u>significant costs</u>

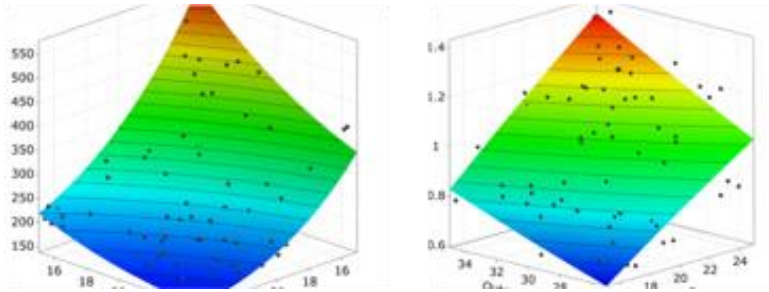
Field meta model (F-MOP) – What is it?

Combine Field with MOP: „Field MOP“

- Identify multi-dimensional response using multi-dimensional meta modelling.



- Black box model (F-MOP): Multi-dimensional data (time, frequency, spatial)



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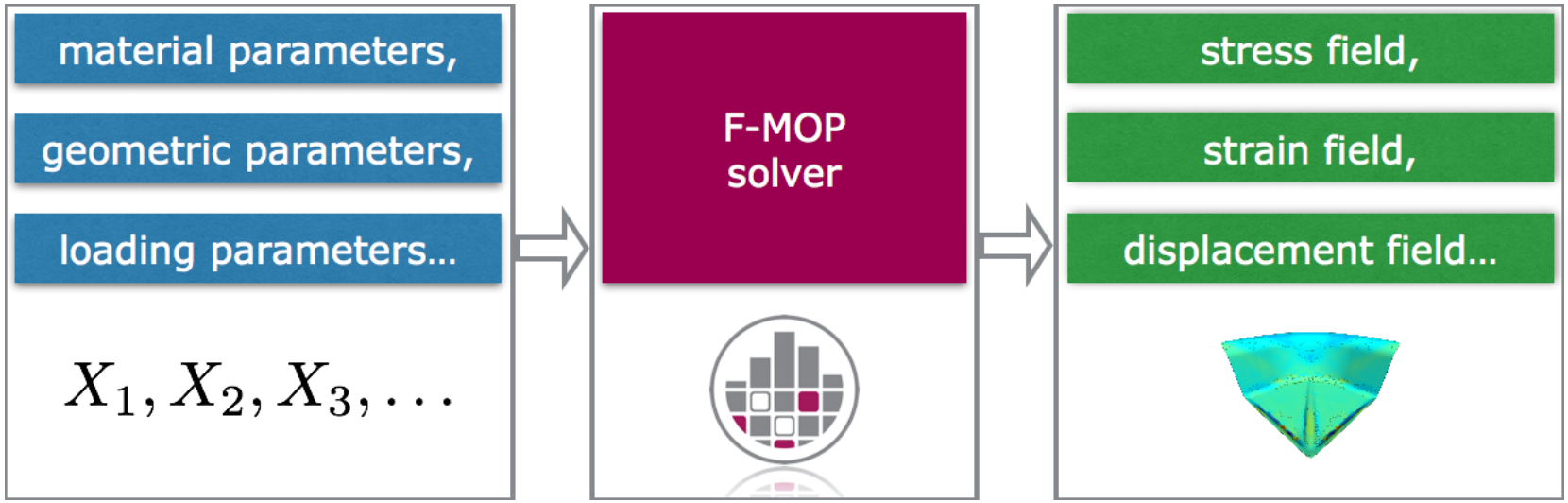
F-MOP Solver

Overview

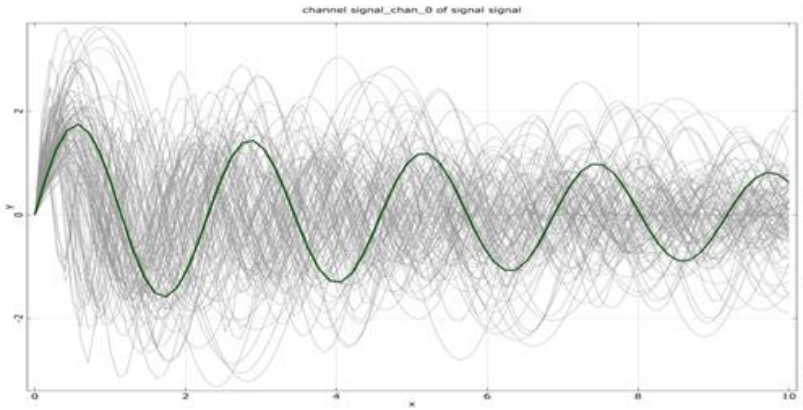
- Approximate field data by field meta modelling
- Replace the complete CAE solution by a meta model, fast evaluation
- Used in optimisation, model calibration, etc.



Meta modelling of signals using F-MOP

MOP: Metamodel für scalar quantities

- Typical: Maxima, Minima
- Problematic with hot-spots, changes over time

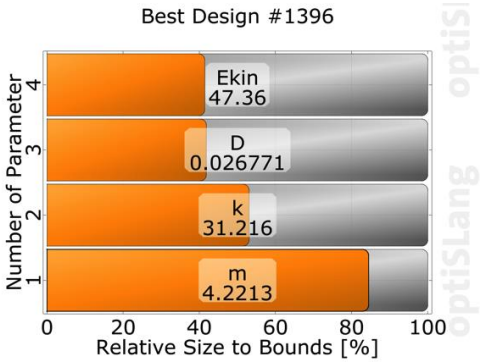


F-MOP: Metamodel for vector quantities

- Uses the total signal as input quantity

Application:

- Sensitivity analysis: Explainability over complete signal (F-MOP), **high knowledge-gain**



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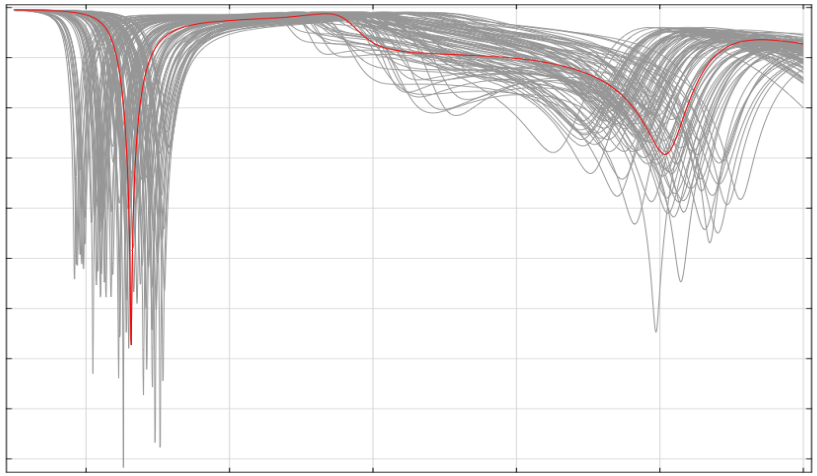
Meta modelling of signals using F-MOP

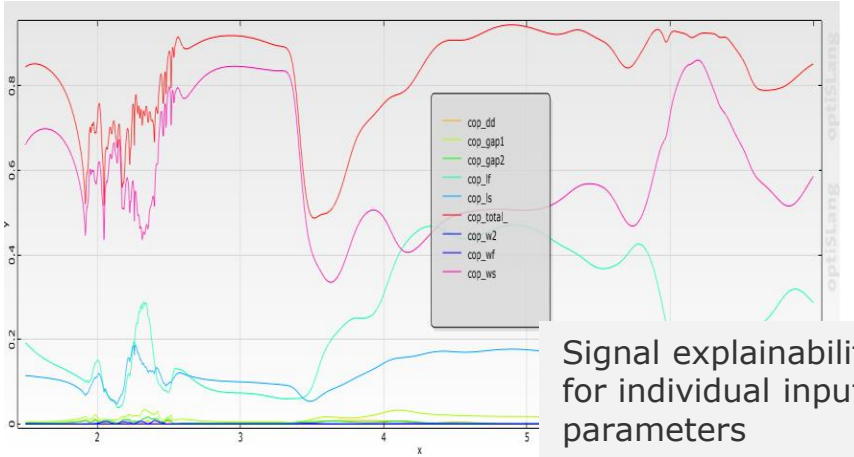
Example: Damping of a Dual-Band Antenna over frequency domain

In one view:

- Where are frequency intervals with bad or high explainability?
- Where are possibly model problems or uncertainties?
- Which input parameter is important for which frequency range?



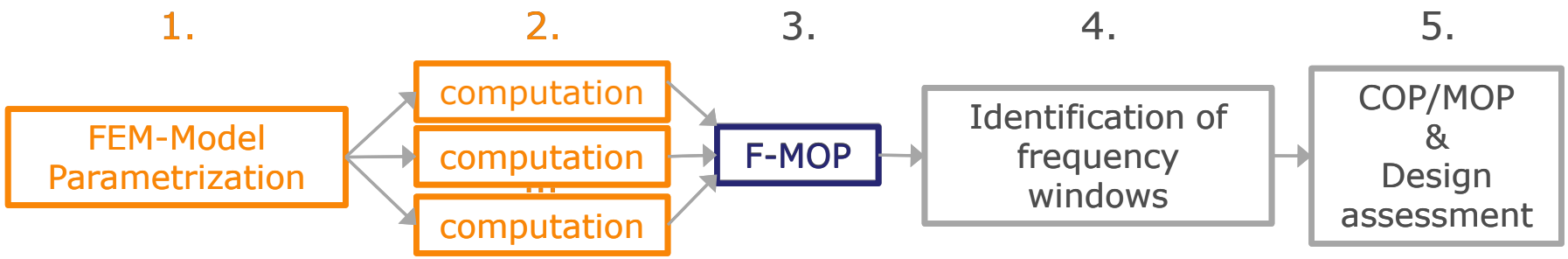
DOE-Signals

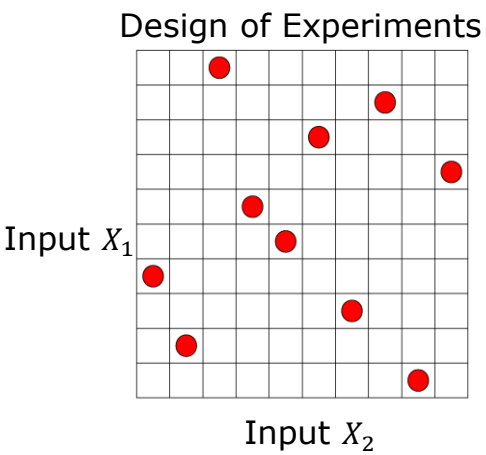


Signal explainability values for individual input parameters

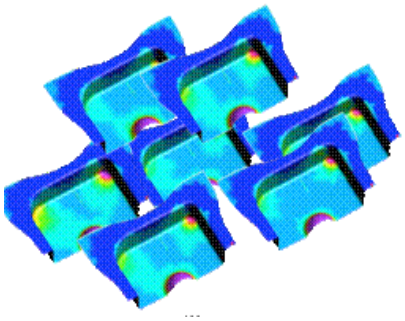
Example - courtesy of CADFEM

NVH F-MOP Process Chain

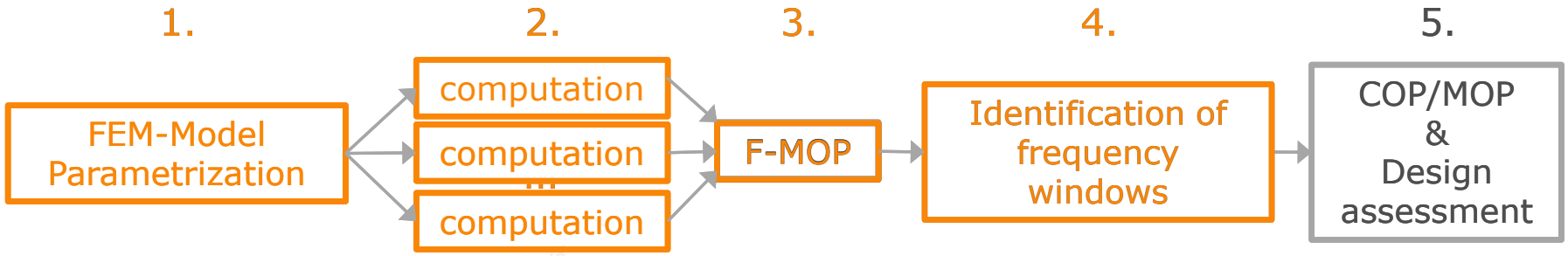


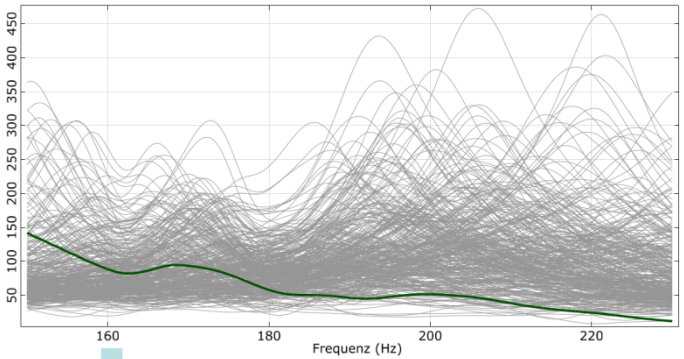


- Easy parametrization of input parameter variations using CSV-file
- Automatic generation of hundreds of design variations of complex NVH model

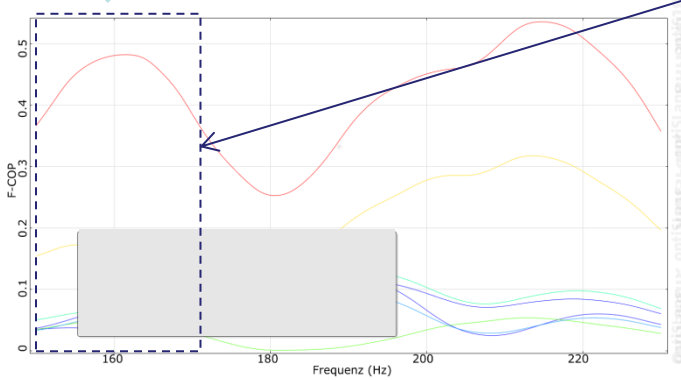


NVH F-MOP Process Chain



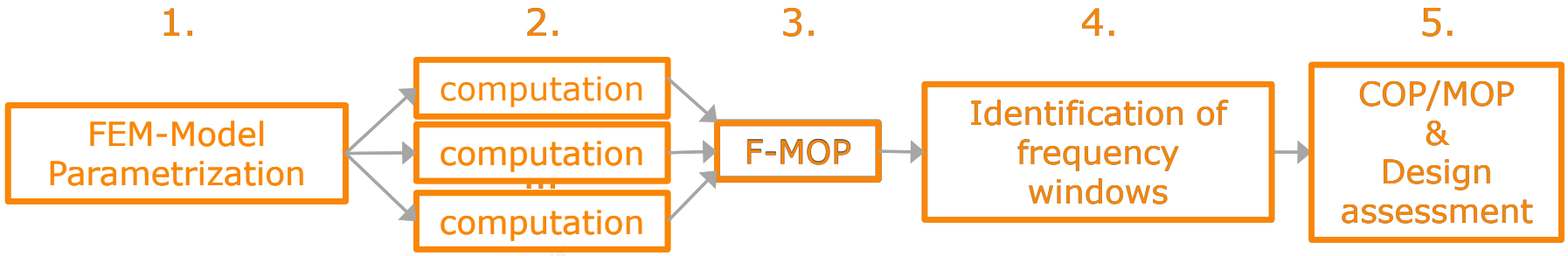


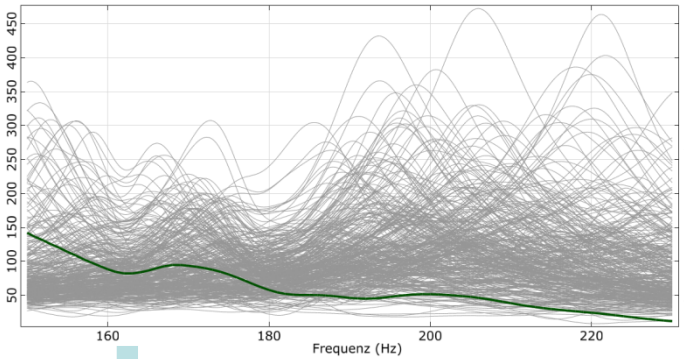
F-MOP - Explainability



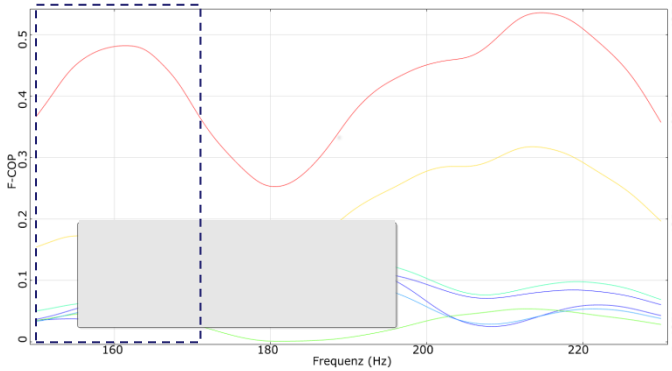
- Visualization of explainability of the response signals **<u>over full spectrum</u>** using F-MOP
- Identification of frequency windows with high explainability

NVH F-MOP Process Chain





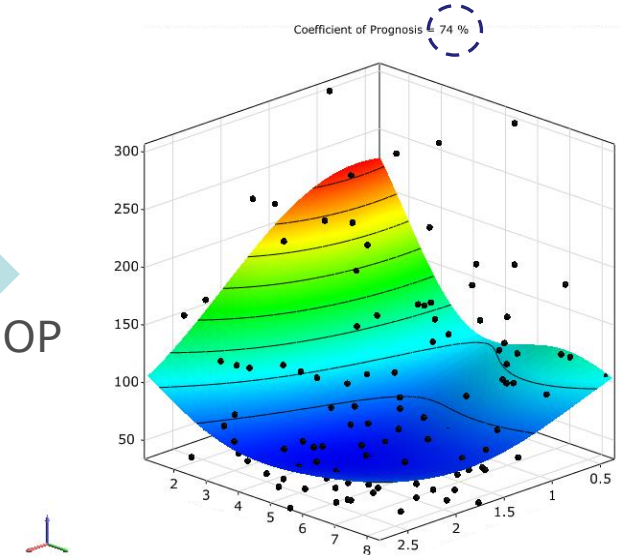
F-MOP - Explainability



- Metamodel generation for selected frequency ranges

High approximation quality

Metamodel - MOP



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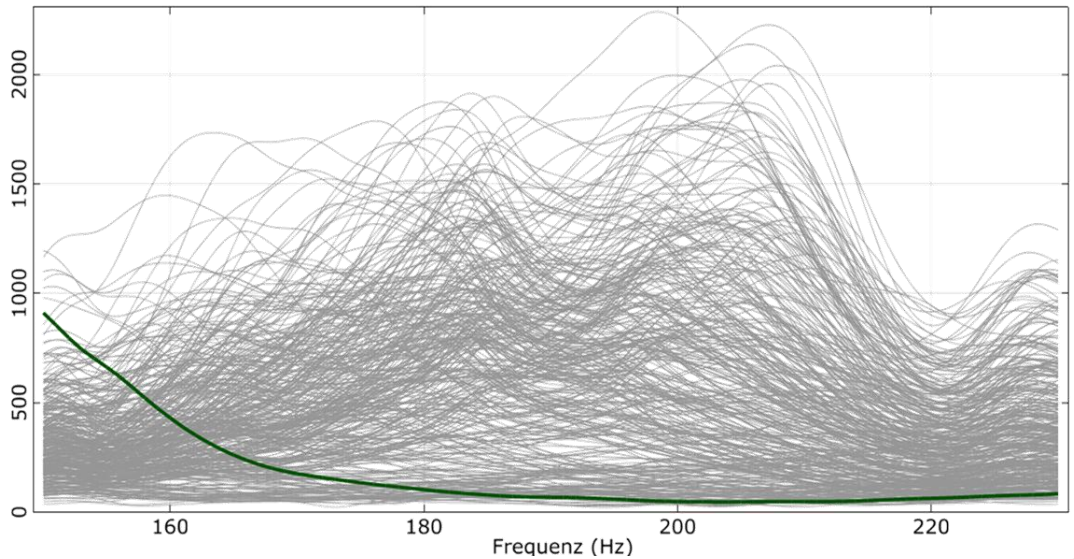
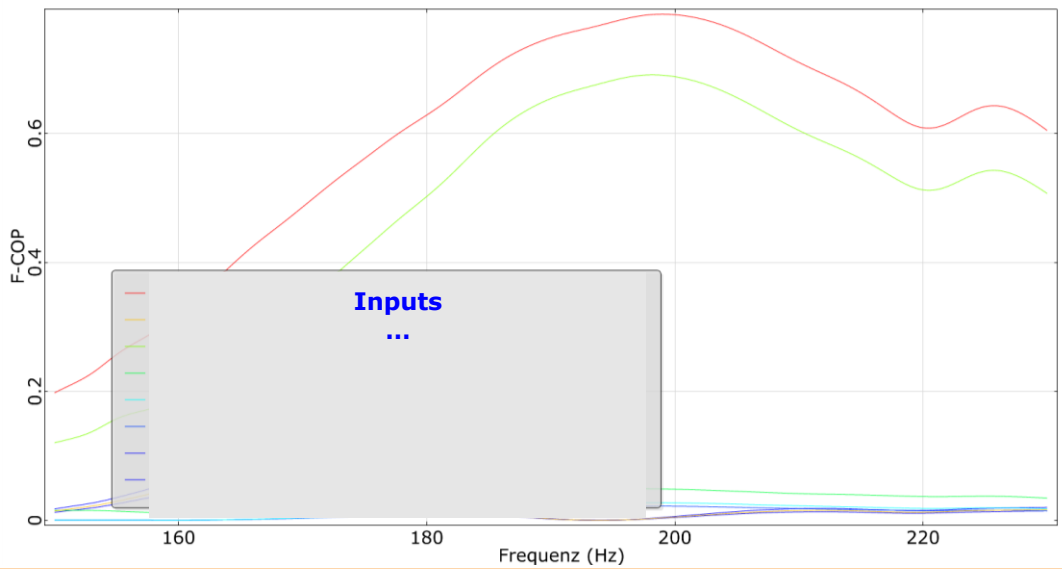
Example

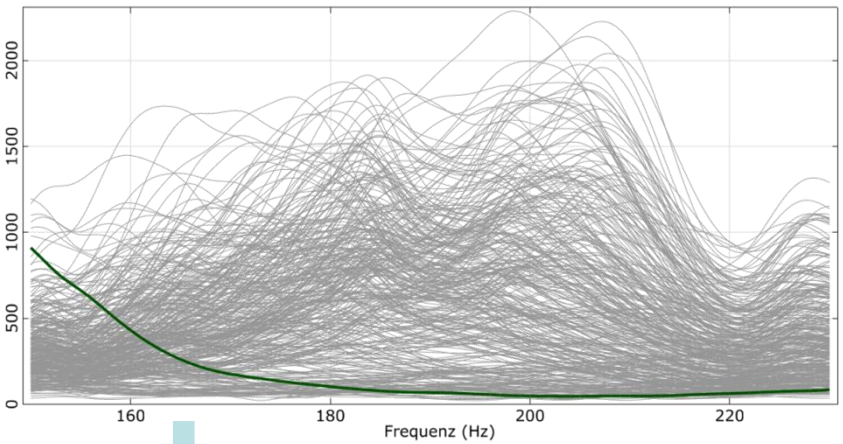
Variation of NVH signal response



Explainability of output variation very high for 170 - 220 Hz

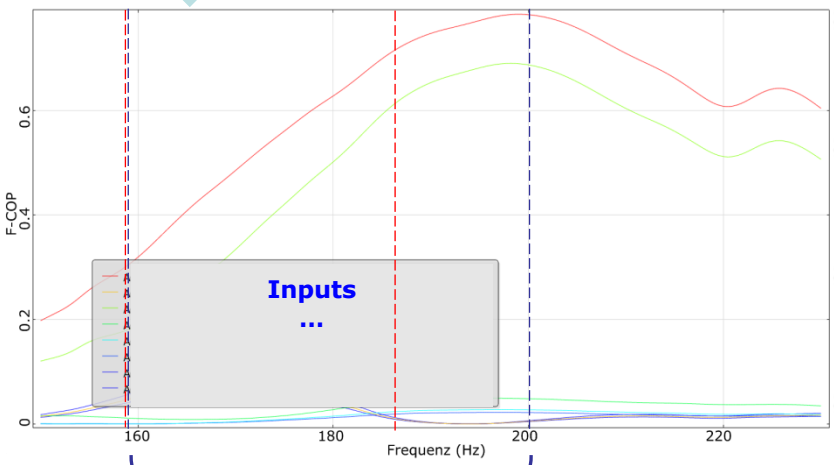


Example



- Using F-MOP the response domain for the metamodel could easily be selected.
- High knowledge-gain for selected frequency window.

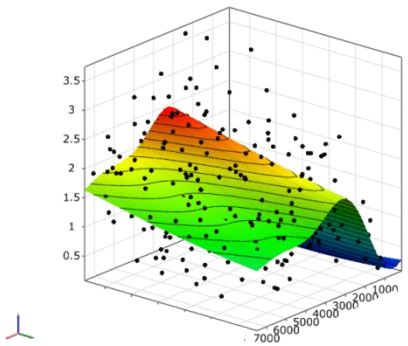
F-MOP - Explainability



F-MOP pick (160 -200 Hz)

Previous best manual pick (160-185 Hz)

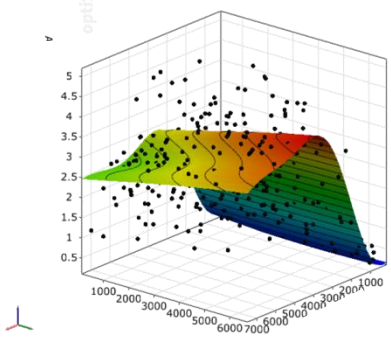
COP 66%



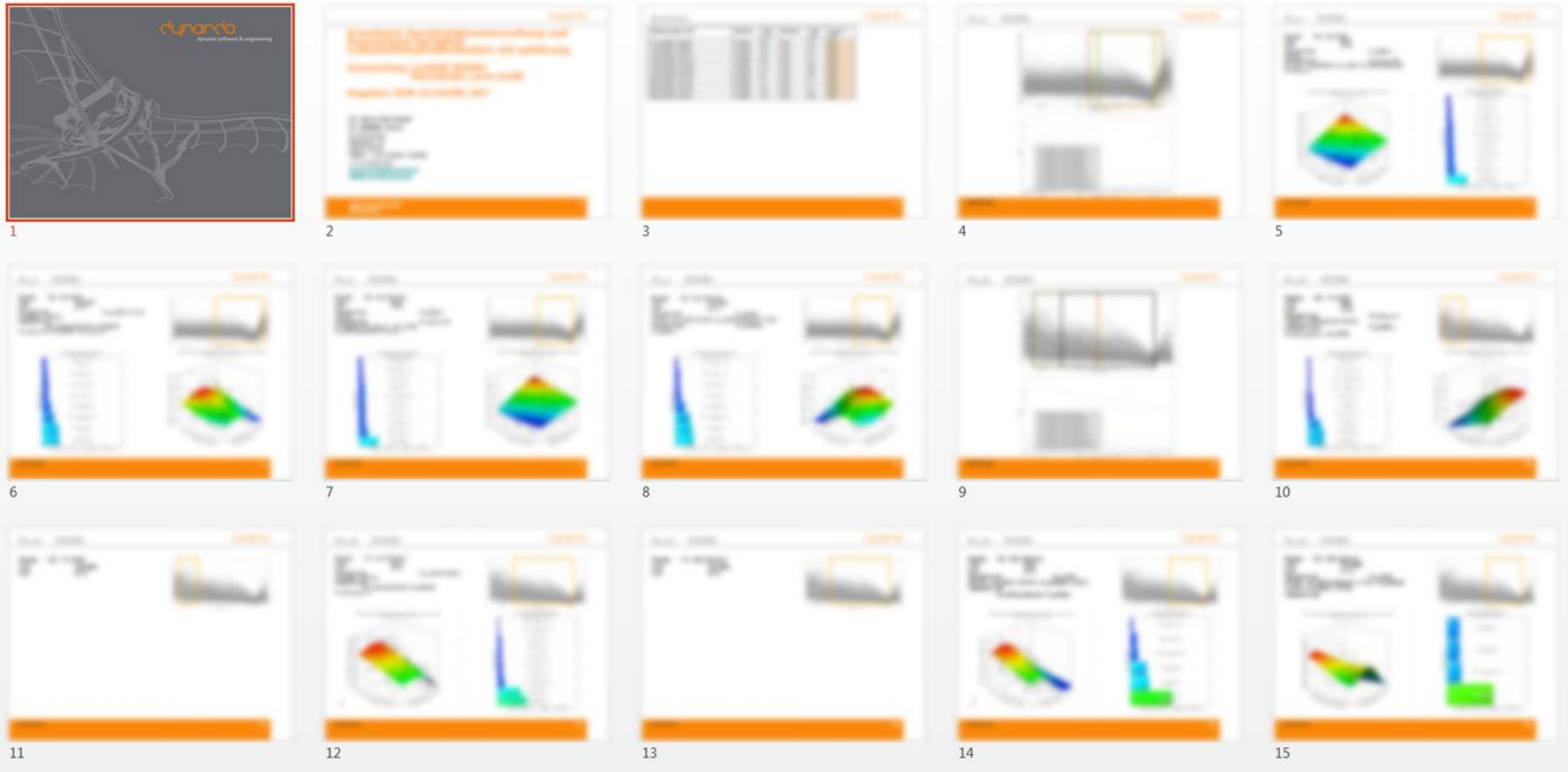
Great results without Trial & Error

MOP - Metamodell

COP 76%



Automatic Report



Advantages / Conclusion

- Design evaluation – meta modelling – knowledge-gain is now fully automated.
- Process can be used directly by the responsible design engineers (**in-house**).
- **Significant time-reduction during PDP** (product development process).
- Concentration from tedious technical labor to **real engineering design decisions**.
- Standardization using **QM-Tool-Chain**.
- **Minimization of time from idea to result**.

Thank you very much for you attention!

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