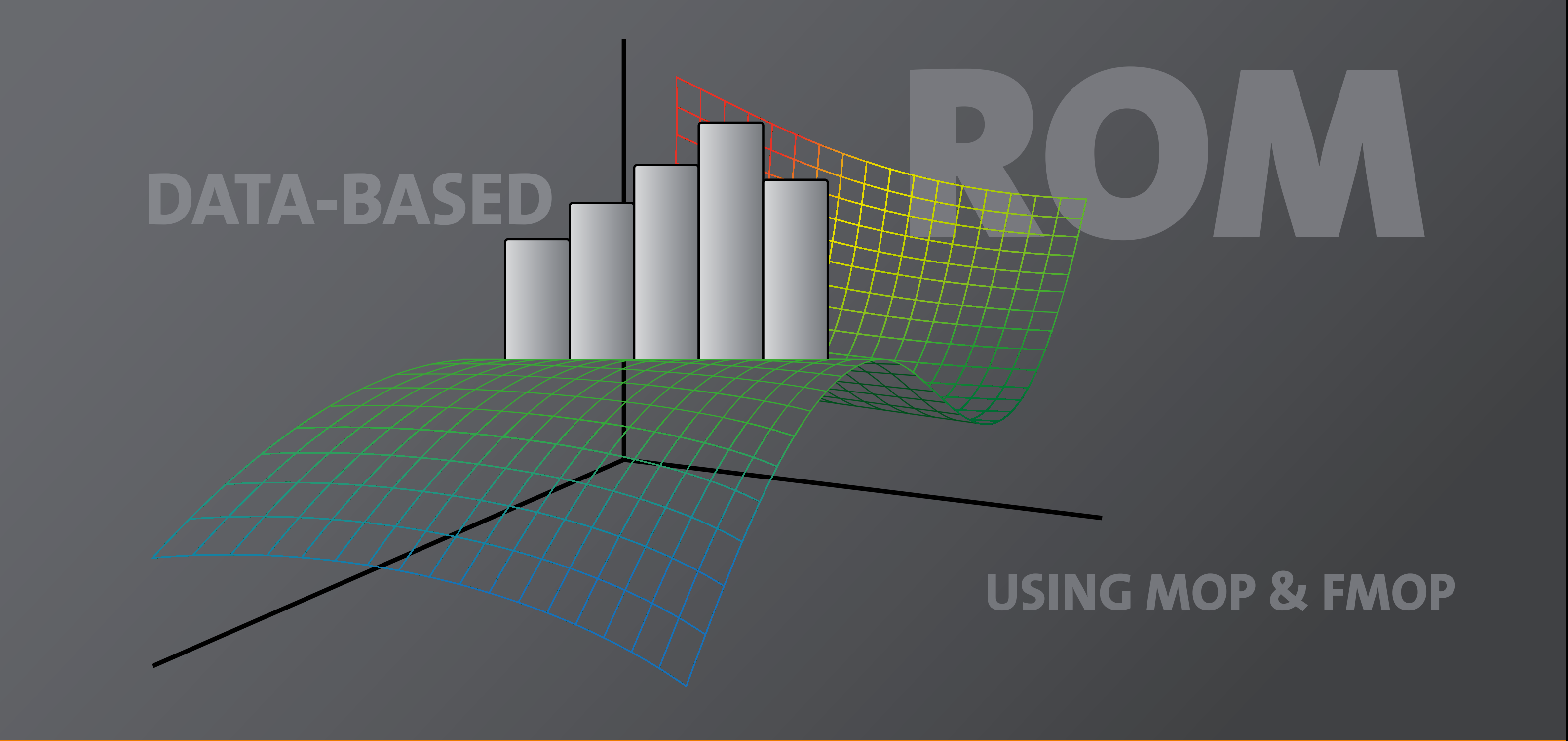


EXTENDED METAMODELING – FROM SCALAR VALUES TO FIELDS IN TIME AND SPACE

optiSLang's MOP reveals how scalar input variation affects scalar output variation. To analyze how field inputs affect field responses, Dynardo has developed Statistics on Structures (SoS).

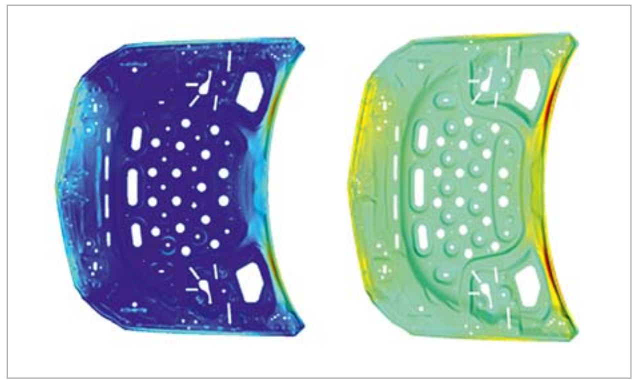
Using metamodeling for robust design optimization, in system simulation or on customer's hardware to operate and maintain products in an optimal way, customer ask for approximating responses in time or space. Using multiple scalar metamodels for discrete time and space support points, however, is often not successful, because existing correlations between individual points in time and space are missing. To extend correlation analysis to field variables Dynardo developed the software Statistics on Structure (SoS). SoS provides models to automatically identify relations in time or space.

SoS is specifically designed for the automatic identification and analysis of data relations between individual points in time and space. Thus, the coupling of optiSLang and SoS will extend correlation analysis and metamodeling from scalar values to input and output variables in time and space.

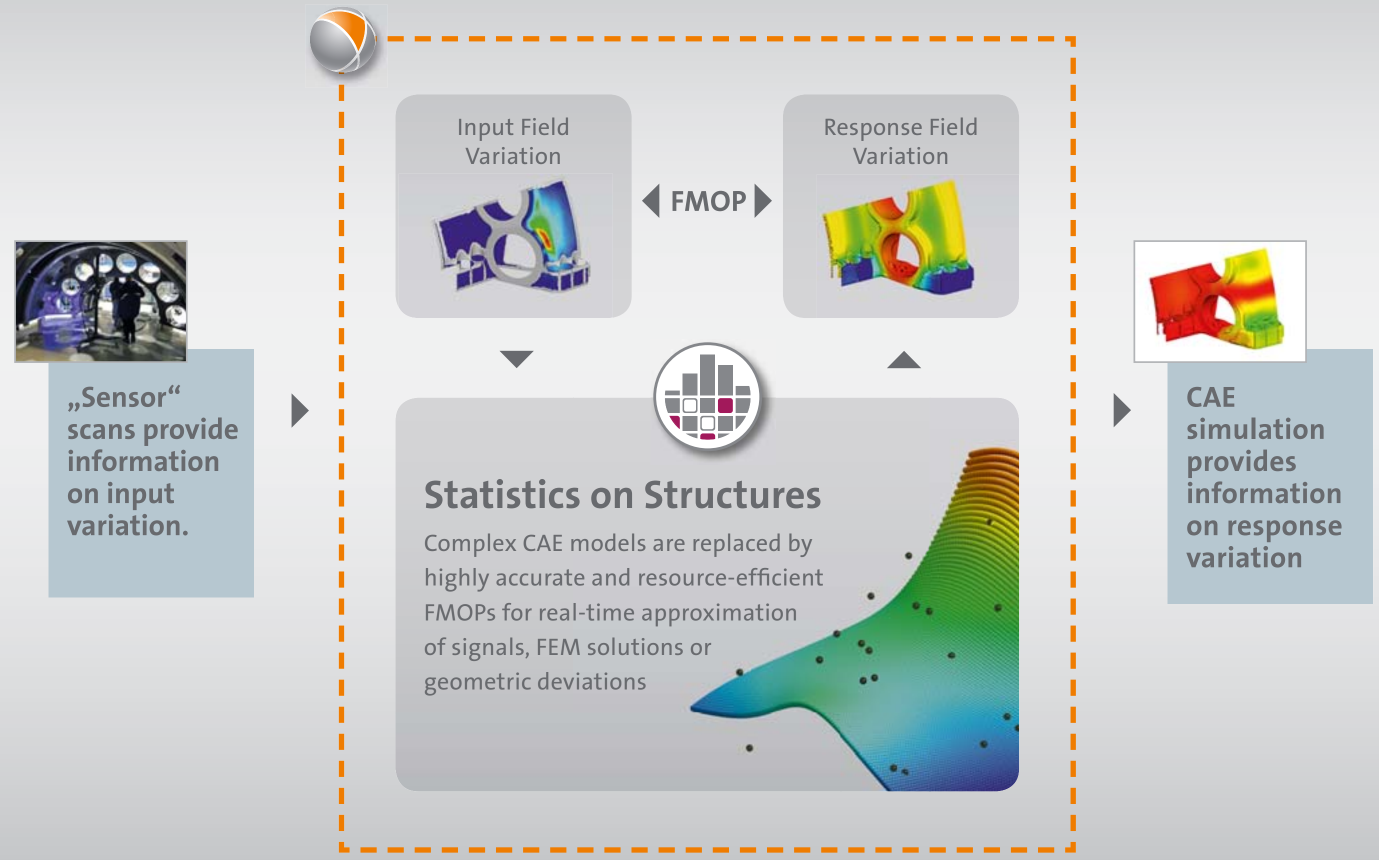
SoS decomposition and analysis of variation patterns

SoS analyzes variations from a given DOE or from measurements and it automatically identifies the dominant variation patterns including their "scatter shapes" and amplitudes. Thus, the variations in time or space are decomposed. This helps to explain their correlation to any other scalar or field variable. Successful applications include a response data decomposition distributed in time or frequency (1D signals, e.g. load-displacement curves), response on 2D grids (e.g. surface stress) or in 3D space (e.g. 3D temperature distribution). Similar to modal shapes, the variation patterns are sorted by their importance.

In addition to the application for correlation analyses, the automatically identified variation patterns are parameterizations of nearly arbitrary input data and can be used to



Standard deviation of response thickness variation after forming simulation (left) and the first scatter mode already representing 84% of the total variation (right)

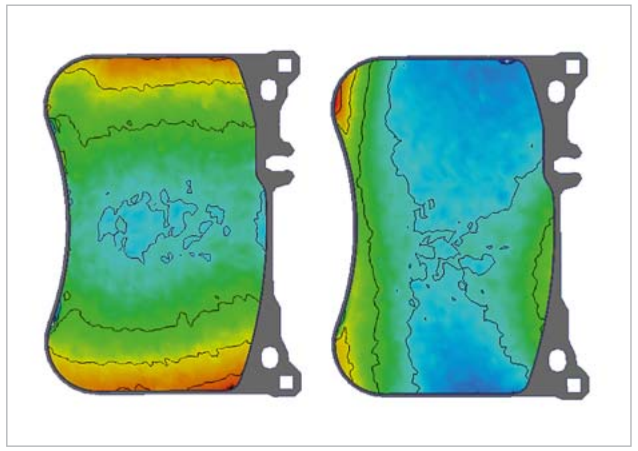


Worklow for the generation of a Field Metamodel of Optimal Prognosis (FMOP) connecting input and response field variation to be integrated in digital twins.

generate scattering design realizations. For example, based on a few real-life measurements, a statistical model can be automatically created, which is capable of generating hundreds of new virtual random samples representing the statistics of the measured data. This is particularly helpful when dealing with geometric imperfections from laser scans. With SoS, these laser scans can be statistically analysed directly on the FEM mesh. The parameterization how geometry deviates is also given. By generating and simulating a set of possible geometries, the user can quantify the effect of the variations on the structural performance.

Data-based Reduced Order Model (ROM)

ROMs are very important in system simulation and are expected to become a key technology for digital twins. In typical applications a detailed product simulation needs to be linked to sensor data in order to predict product parameters (e.g. life of turbine blades) accurately enough to be capable of optimizing the maintenance and operation. To fulfill the reaction time requirements from digital twin, the detailed simulation models need to be reduced. The classical approach of ROMs uses a matrix condensation which is called "physics-based" ROMs, because the formula still contains the physics of how input variation affects response. However, these reductions are often restricted to linear systems. The alternative for non-linear systems are data-based ROMs. They use functional models to approximate response surfaces considering the effect of input variations on the response variation based on the given sample set. For field data as input or response, SoS provides the Field Metamodel of Optimal Prognosis (FMOP) which can be used to approximate signals, FEM solutions or geometric deviations.



Picture of scatter shape parametric model of measured brake pad surfaces