dynardo
dynamic software & engineering

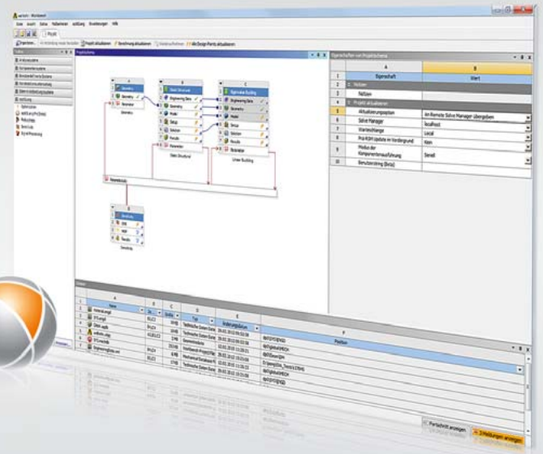
CAE-Software

Sensitivity analysis
Multiobjective optimization
Multidisciplinary optimization
Robustness evaluation
Reliability analysis
Robust Design Optimization (RDO)

optiSLang

optiSLang
multiPlas
ETK
SoS

ANSYS optiSLang

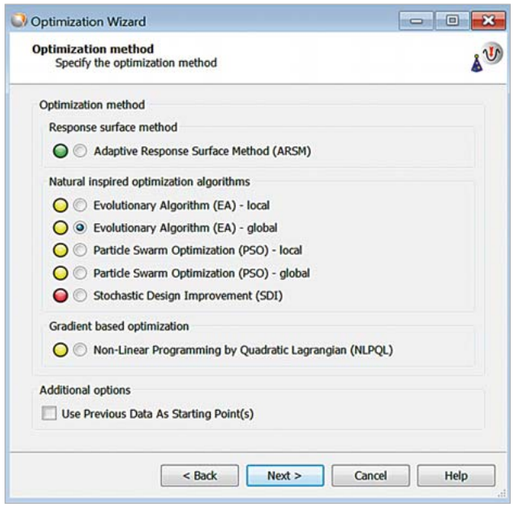


Combining powerful parametric model capabilities with Robust Design Optimization

ANSYS Workbench provides leading technology for parametric and persistent CAD and CAE modelling for simulation driven product development. optiSLang focuses on efficiency and automation of RDO methods for complex non-linear analysis models with many parameters, including stochastic variables. This includes robust handling of design failures and solver noise.

ANSYS optiSLang offers several modes of interoperability

- using the optiSLang Workbench plugin to expose optiSLang technology within the ANSYS Workbench GUI
- using text-based interfacing between ANSYS and optiSLang
- using parametric ANSYS Workbench models with the optiSLang GUI with the help of the optiSLang ANSYS Workbench integration node

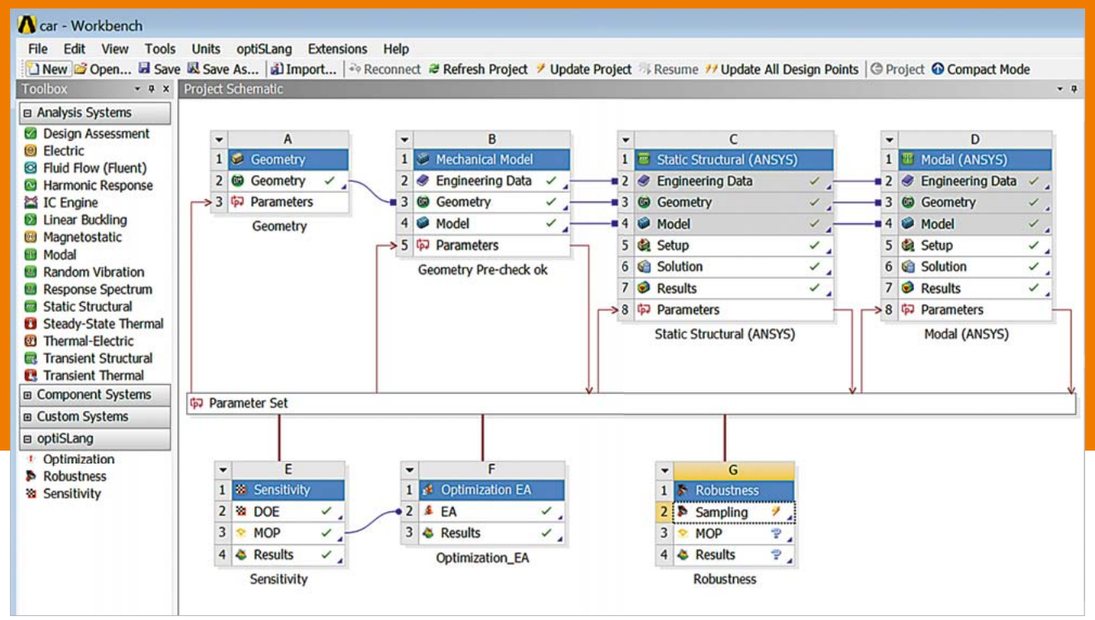


Wizard to select the most appropriate optimization algorithms

The optiSLang Workbench plugin toolbox includes the modules for sensitivity analysis, optimization and robustness evaluation which can easily be dragged and dropped onto the desktop to form an interactive process chain.

optiSLang Workbench plugin - General Features

- Automatic identification of important parameters during sensitivity analysis
- Automatic buildup of best possible regression functions (meta models) having best possible forecast quality to response variation in a given sample set
- Multidisciplinary and multiobjective optimization
- Robustness evaluation
- optiSLang's minimalist philosophy reduces the number of CAE solver runs
- Designed for large numbers of parameters and non-linear RDO tasks
- Predefined insightful and efficient result post-processing module



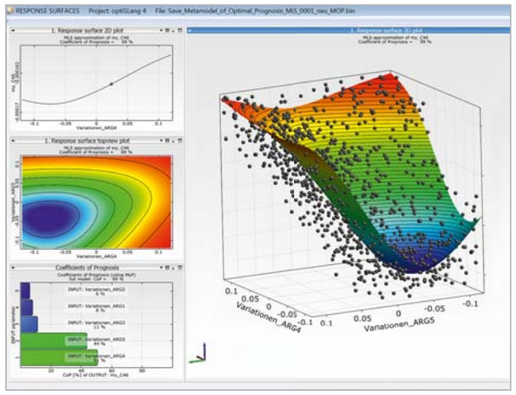
ANSYS Workbench project screen with the three optiSLang drag and drop modules sensitivity analysis, optimization and robustness evaluation to define an RDO analysis.

In addition ANSYS optiSLang provides

- Flexible text-based interfacing tools that can connect ANSYS products, or any scriptable products, that may be part of your engineering process
- Interfacing between optiSLang GUI and parametric ANSYS Workbench models via optiSLang's ANSYS Workbench integration node
- Easy to switch from Workbench integrated to interfacing mode at any time
- Full functionality, including support for parameters and responses not extractable or integrated in ANSYS Workbench, e.g. non-scalable responses such as load displacement curves
- Flexilbity to include 3rd party solvers, along with ANSYS technology, in the process chain

Application

From ANSYS Workbench version 14.0, the optiSLang integration can be used easily with drag and drop functionality. The user only needs to set up the variation space and the objectives. Then, optiSLang automatically identifies the Metamodel of Optimal Prognosis. Afterwards, a Best-Practice-Management generates the appropriate methods for optimization. The options for parallel computing at several cores with ANSYS Remote Solve Manager and the use of ANSYS HPC Pack Parametric Licenses for simultaneous computing of different designs are fully integrated. With the continue crashed session option, further processing of aborted analyses is secured using all previously computed data. All successful designs are stored in optiSLang's database and can be used independently from the ANSYS Workbench design table. Furthermore, adding designs or recalculation is possible at any time.



Extensive GUI for MOP-Postprocessing

PRODUCT OVERVIEW ANSYS OPTISLANG

Since market launch in 2002, optiSLang has evolved into one of the leading software solutions for CAE-based sensitivity analysis, optimization and robustness evaluation. Due to user-friendly automated workflows, efficient methods and a powerful post-processing, optiSLang provides the basis for your efficient CAE-based Robust Design Optimization (RDO).

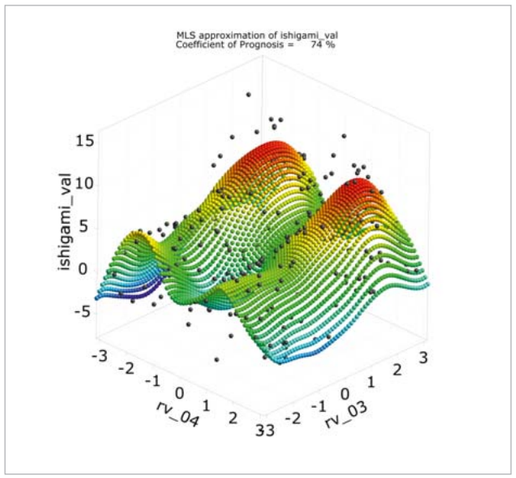
RDO in virtual prototyping

The goal of CAE-based optimization in virtual prototyping is often to achieve an optimal product performance with a minimal usage of resources (e.g. material, energy). This pushes designs to the boundaries of tolerable stresses, deformations or other critical responses. As a result, the product behavior may become sensitive to scatter with regard to material, geometric or environmental conditions. Subsequently, a robustness evaluation has to be implemented in the optimization task leading to a Robust Design Optimization (RDO) strategy that consists of:

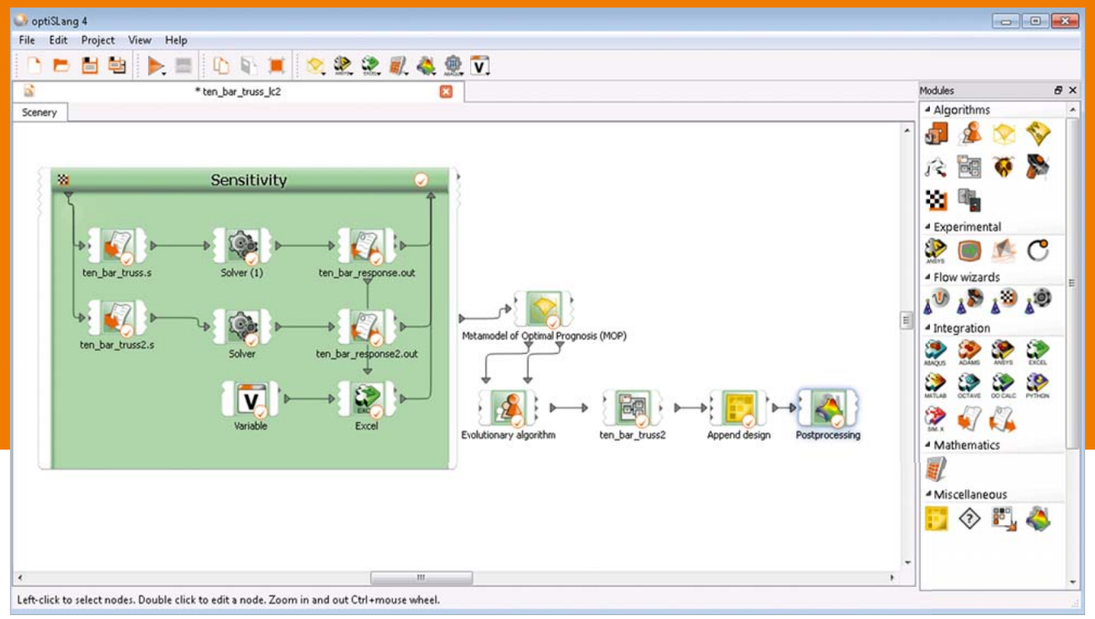
1. Sensitivity analyses to identify the most affecting parameters regarding the optimization task
2. Multi-disciplinary and multi-objective optimizations to determine the optimal design
3. Robustness evaluations to verify robustness values and failure probabilities

RDO with optiSLang

optiSLang expands the capabilities of parametric optimization studies to RDO. For example, the software includes the influence of scattering inputs, uses statistics to identify the important scattering variables and quantifies and explains result variations of product behavior. The distinctive features of optiSLang provide you with a maximum of variation prognosis quality and result reliability for decision



3D visualization of the Metamodel of Optimal Prognosis



Typical workflow using sensitivity analysis, optimization using meta-models and validation of the best design

making while only requiring a minimum of solver runs. Consequently, even RDO tasks involving a large number of optimization variables, scattering parameter as well as non-linear system behavior can be efficiently solved. During this process, optiSLang's Best-Practice-Management feature automatically selects the appropriate optimization algorithms and their settings. The procedures are guided by intuitive drag & drop-workflows and powerful post-processing tools. Within a controlling workflow, any CAE simulation data can easily be integrated and again made accessible for external solvers as well as pre and post processors. Thus, optiSLang gives you the opportunity to benefit from the full capabilities of parametric studies in order to innovate and accelerate your virtual product development.

Coefficient of Prognosis (CoP) and the Metamodel of Optimal Prognosis (MOP)

Variable reduction and the application of reliable quantitative measures of variable importance are the main challenges in parametric sensitivity analysis. optiSLang's sensitivity module generates the CoP which enables you to filter the relevant input parameters. This ensures that the most appropriate functional model is chosen to result in the best possible prognosis quality of variation based on a given set of designs. Here, the MOP represents the most important correlations between parameter input and result variation. If the prognosis quality of variation is high, MOPs can be used to replace the CAE-calculations in optimization procedures or robustness evaluations.

Robustness Evaluation and Reliability Analysis

When optimized designs are sensitive toward scattering geometry, material parameters, boundary conditions or loads, a verification of product robustness as early as possible in the development process becomes a core requirement of CAE-based virtual product development. The implementation of robustness evaluation procedures has always been a key feature in Dynardo's software development. Today, optiSLang provides one of the most powerful sets of algorithms available for commercial application. It enables the user to conduct a reliable determination of failure probabilities by evaluating the result value variation including the identification and consideration of relevant scatter input parameters.

MASTER OF DESIGN – CAE-BASED ROBUST DESIGN OPTIMIZATION WITH OPTISLANG

Sensitivity analysis, optimization and robustness evaluation with a minimum amount of user input and solver runs for your effective virtual product development

OPTIMAL DEFAULTS

AUTOMATED

MODULAR

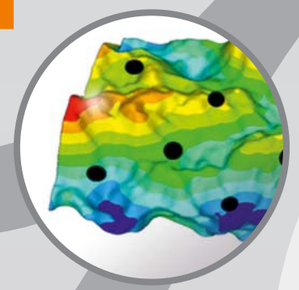
MINIMAL PARAMETER VARIATION

LESS SOLVER-RUNS

SENSITIVITY ANALYSIS

- Stochastic sampling (LHS) for optimized scanning of multi-dimensional parameter spaces
- Quantification of prognosis quality (CoP) of meta-models
- Generation of the Metamodel of Optimal Prognosis (MOP)

CAE-Data



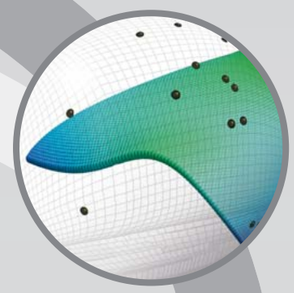
Measurement Data

MODEL CALIBRATION

- Find the best fit for simulation and measurement

OPTIMIZATION

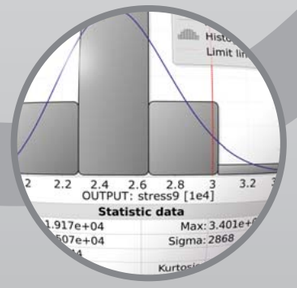
- Identification of the relevant input parameters and response values (sensitivity analysis + CoP/MOP)
- Pre-optimization of the parameter sets with MOP without additional solver runs
- Further optimization of the parameter sets with the most appropriate algorithms (Best-Practice-Management)



Optimal Design

ROBUSTNESS EVALUATION

- Efficient methods of stochastic analysis for the determination of failure probabilities
- Evaluation of result value variation
- Identification of the relevant scatter input parameter (CoP + MOP)



Coefficient of Prognosis (CoP)

The CoP quantifies the forecast quality of a meta-model (regression model) for the prognosis of a result value.

Metamodel of Optimal Prognosis (MOP)

The MoP represents the meta-model with the best prognosis quality of the result value. For the determination of the MOP, subspaces of important input variables are evaluated with the help of meta-models. Thus, a No Run Too Much-strategy will be implemented with a maximum of prognosis quality for correlations in regard to design evaluations.

PROCESS INTEGRATION AND AUTOMATION

Interactive process automation and integration as well as constant access to design parameters are the key for successful CAE - based parametric studies. In optiSLang, this procedure is guided and supported by wizards and default settings.

Process integration

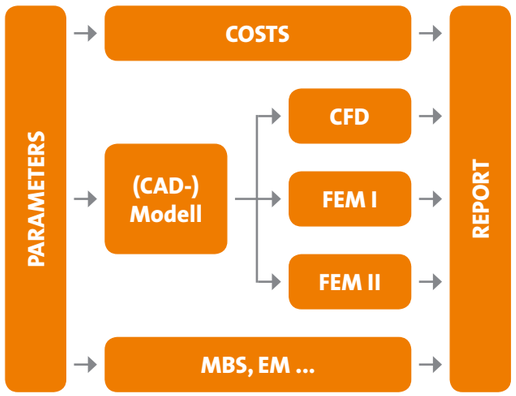
optiSLang supports the interfacing to almost any software tool which is used in virtual product development. The interfaces are mainly used "inside optiSLang". Thus, in optiSLang context, they are called "tool integrations". Nowadays, more than 100 different CAx software solutions are coupled with optiSLang. The new generation of optiSLang gives access to:

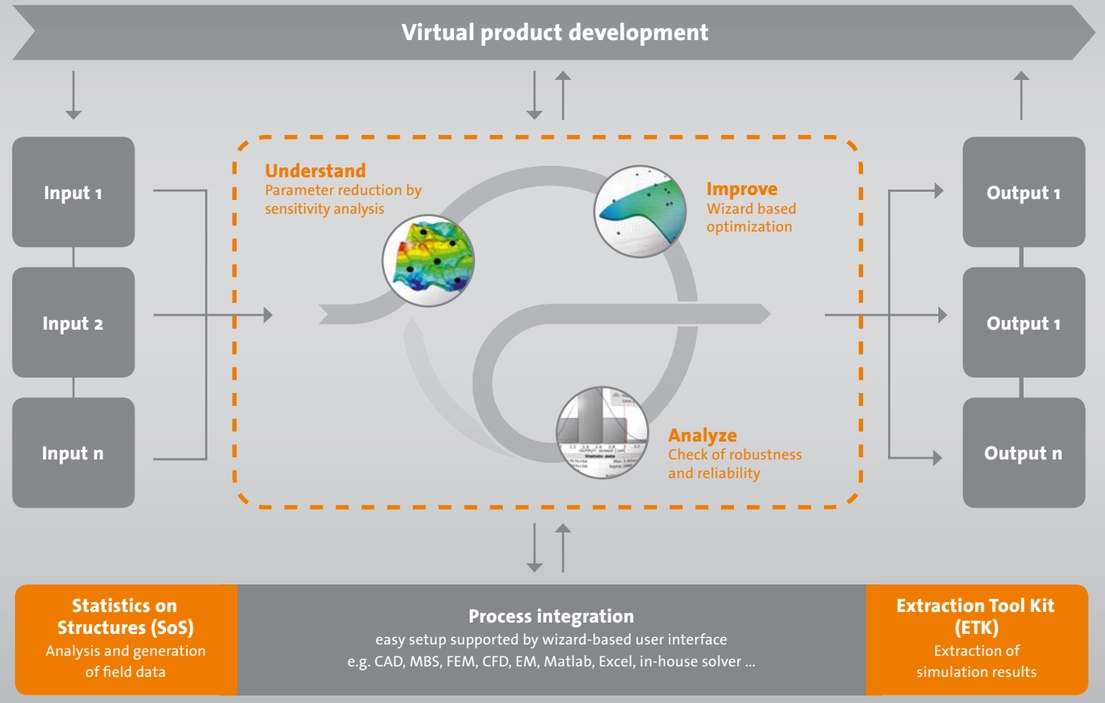
- CAD (Catia, Nx, Creo, Solidworks ...)
- CAE (ANSYS, Abaqus, AMESim ...)
- MS Excel, Matlab, Python ...
- In-house solver

Different parametric environments can be collected and combined to one automatized parametric workflow for modern product development.

Definition of CAx Workflows

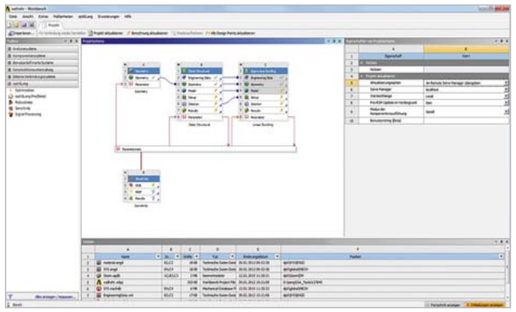
The graphical user interface supports the workflow approach visually by single building blocks and algorithms which are graphically coupled in order to show dependencies and scheduling. The relationships can be determined and controlled in one context. Easily understandable charts as well as control panels are displayed at the same time. This enables full access and traceability of the complete workflow. The user can connect any complex simulation processes of CAE solvers, pre- and postprocessors in heterogeneous networks or clusters. They are automatized either in a single solver process chain or in very complex multidisciplinary / multidomain flows. Even performance maps and their appraisal can be part of standardized projects.





optiSLang inside ANSYS Workbench

optiSLang inside ANSYS Workbench provides the user with a direct integration into the parametric modeling environment of this standard CAE software. Thus, it can be accessed through a minimized user input. The Workbench functionality is also broadened by optiSLang's signal processing integration. Users are able to implement responses not yet extractable or integrated in ANSYS Workbench, e.g. non-scalar responses like load displacement curves. Alternatively, for integration of ANSYS Workbench projects in optiSLang, an integration node is available.



Graphical user interface of ANSYS Workbench with optiSLang integration

Interfaces and automation

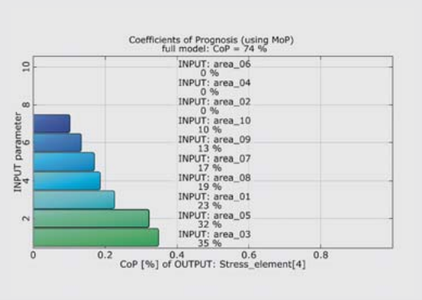
optiSLang provides several interfaces. The provided Python, C++ and command line interfaces allow the automatic creation, modification and execution of projects. As a consequence, the usage within custom applications is secured and optiSLang projects can be integrated into customized platforms. Repetitive and exhausting tasks can be standardized and automatized.

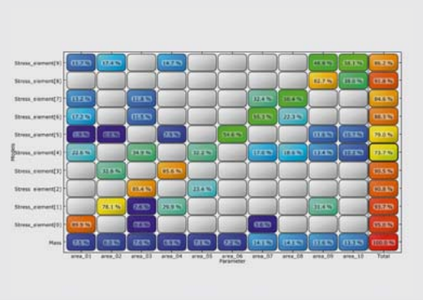
Extensibility

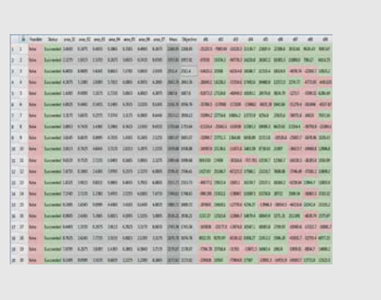
The openness of Dynardo's premium software also enables users to plug-in their own:

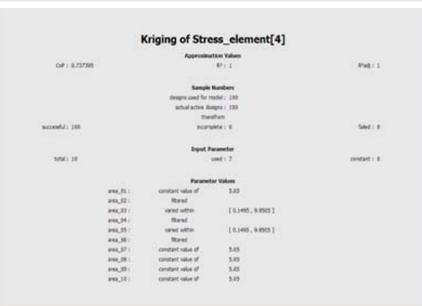
- Algorithms for DOE, Optimization, Robustness etc.
- Meta-models
- Tool integrations

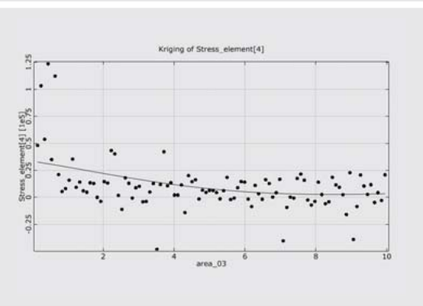
Current requirements for flexibility and upcoming requests for extensibility are satisfied by those interfaces. Therefore, optiSLang is the platform to address future needs of virtual product development.

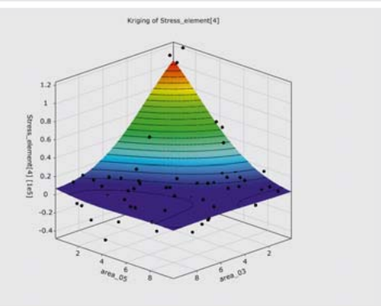












SENSITIVITY ANALYSIS

By means of a global sensitivity analysis and the automatic generation of the Metamodel of Optimal Prognosis (MOP), optimization potential and the corresponding important variables are identified. With this previous knowledge, task-related objective functions and constraints can be defined as well as suitable algorithms can be selected.

Practical Application

Design variables are defined by their lower and upper bounds or by several possible discrete values. In industrial optimization tasks, the number of design variables can often be very large. With the help of a sensitivity analysis, engineers can accurately identify those variables which effectively contribute to a possible improvement of the optimization goal. Based on this identification, the number of design variables is decisively reduced and an efficient optimization can be conducted. Additionally, a sensitivity analysis helps to formulate the optimization task appropriately concerning the choice and number of objectives, their weighting or possible constraints. Furthermore, it is used to estimate the numerical noise of the CAE solver as well as the proper physical formulation of the design problem.

Best Practice

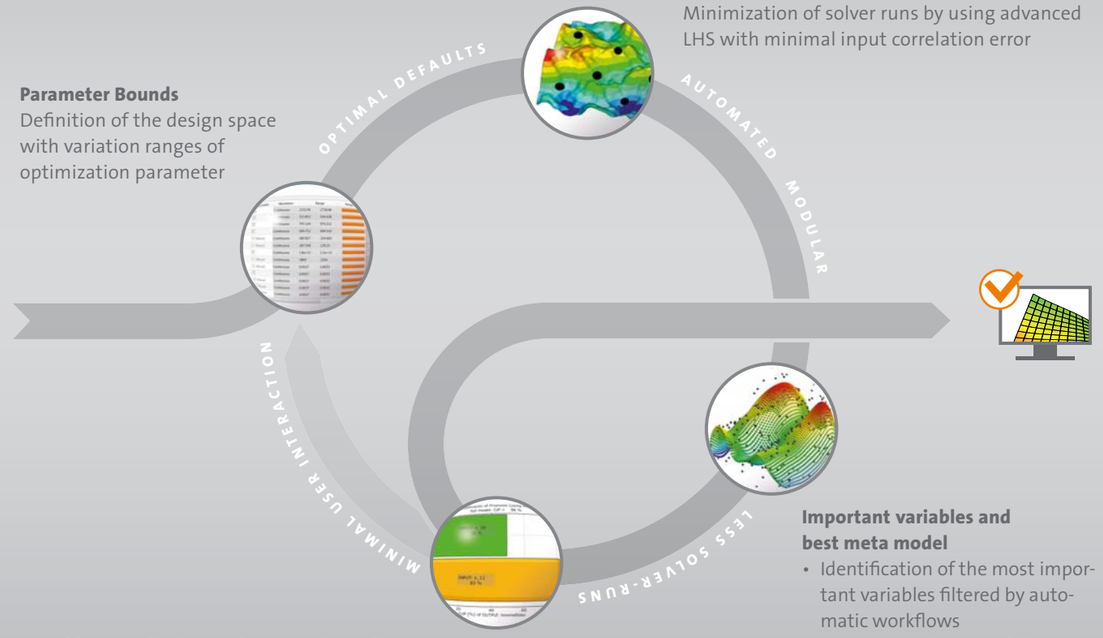
- Coverage of the entire design space by optimized Latin Hypercube Sampling (LHS) and minimization of correlation errors among input variables
- Identification of optimization potential and conflicting objectives
- Identification of the meta-model with the best prognosis quality of the result value variation in the most fitting sub space of important variables by MOP workflow
- Quantification of the forecast quality of a meta-model (regression model) for the prognosis of result value variation by the Coefficient of Prognosis (CoP)
- Identification of the most important input variables related to each result value, constraint and objective
- Minimization of solver runs by MOP/CoP workflow

Methods

- Definition of optimization variables with upper and lower bounds
- Definition of the Design of Experiments (full factorial, central composite, D-optimal)
- Latin Hypercube Sampling for optimal scanning of multi-dimensional parameter spaces
- Automated generation of the MOP
- Quantification of the prognosis quality by the CoP

Postprocessing & Visualization

- Histograms
- Correlation matrix / Parallel Coordinate Plots
- 2D and 3D anthill plots / 2D and 3D plots of the MOP
- Principal Component Analysis

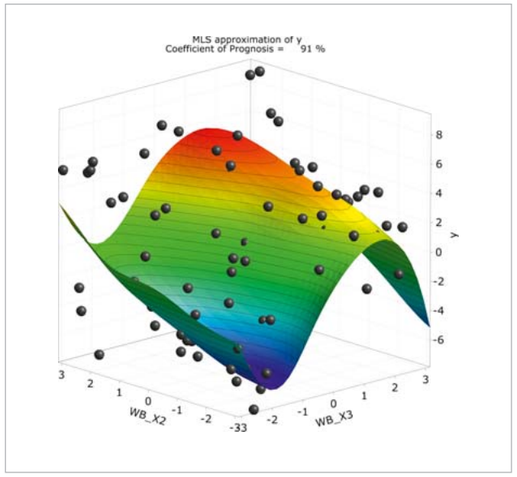


Latin Hypercube Sampling (LHS)
Minimization of solver runs by using advanced LHS with minimal input correlation error

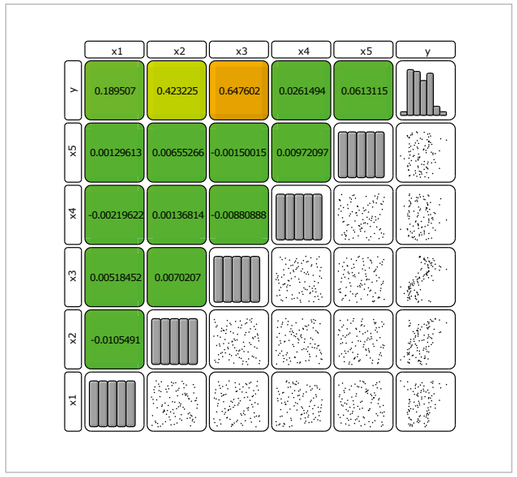
Parameter Bounds
Definition of the design space with variation ranges of optimization parameter

Important variables and best meta model
- Identification of the most important variables filtered by automatic workflows
- Automatic selection of the meta model with the best possible forecast quality (MOP)

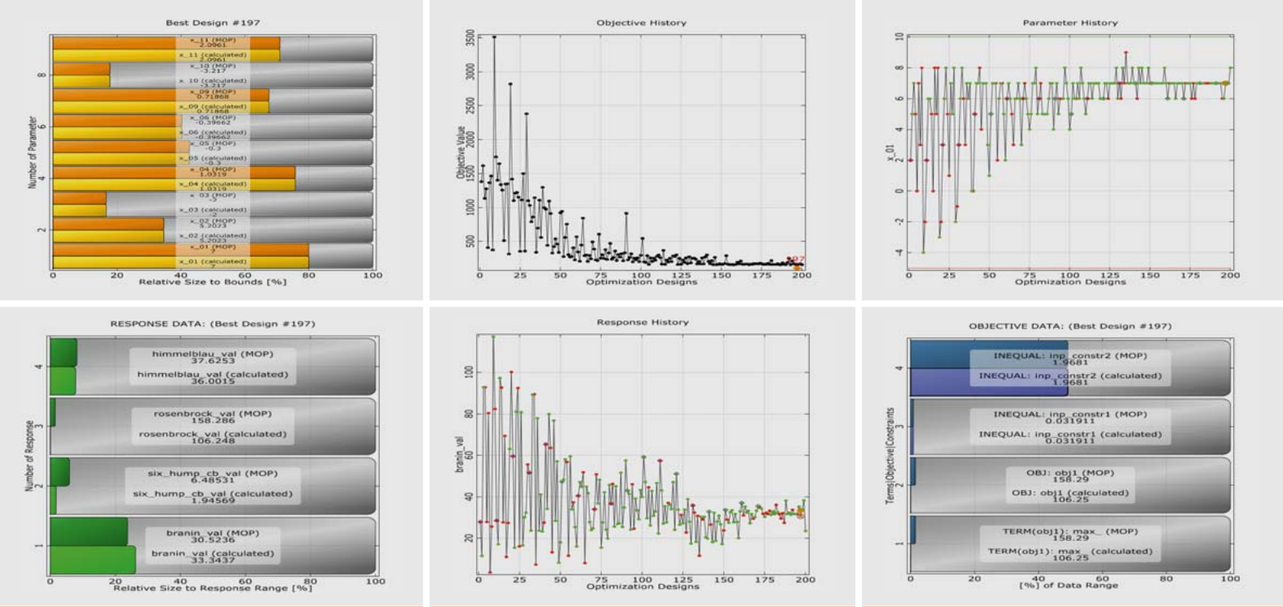
Variable Contribution and Prognosis Quality
- Verification of prognosis quality for response variation
- Verification of optimization parameter contribution



3D plot of single response with respect to the most important variables



Extended linear correlation matrix



MULTIDISCIPLINARY OPTIMIZATION

optiSLang provides powerful optimization algorithms and automated workflows for an efficient determination of optimal design parameters regarding various multidisciplinary, nonlinear and multicriteria optimization tasks.

Practical Application

Structures and sub-systems need to often be designed to withstand multidisciplinary load cases. For example, vehicle body structures are exposed to crash (non-linear transient), Noise Vibration Harshness (frequency domain), stiffness (linear static), durability (linear static) and aerodynamics (CFD). The structural requirements to meet loads in one discipline are very often different to requirements for loads in other disciplines. Unless loads from all disciplines are considered simultaneously during the optimization process, the resulting design will not be well balanced for structural performance. Multi-disciplinary optimization is essential to achieve this objective.

Best Practice

- Identification of the most relevant input parameters and response values with the help of a sensitivity analysis and CoP/MOP
- Pre-optimization of parameter sets using the MOP with only one additional solver call
- Optimization wizard for automatic selection of the most fitting algorithms for design optimization
- Easy definition of parameter range, objectives and constraints

Methods

- Gradient-based methods (NLPQL)
- Nature-inspired Optimization Algorithms (NOA) incl. Genetic Algorithms (GA), Evolutionary Strategies (ES) and Particle Swarm Optimization (PSO)
- Automatic Adaptive Response Surface Method (ARSM) in case of less than 20 important optimization variables

Postprocessing & Visualization

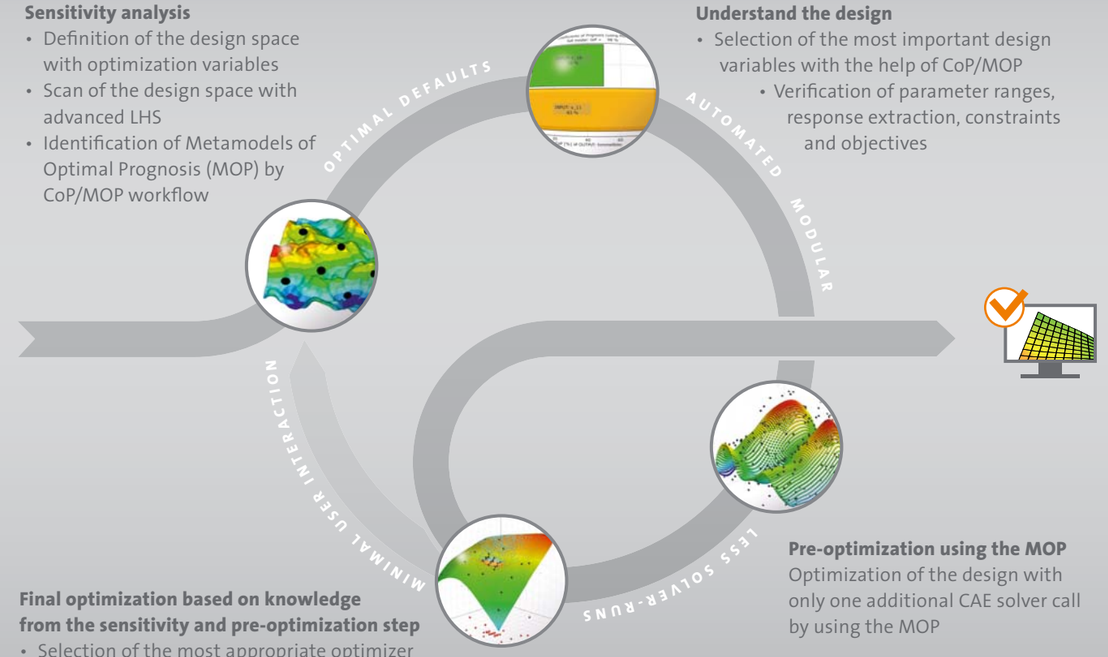
- Interactive post processing adapted to the optimization algorithm
- Fast investigation of optimization performance using different visualization options
- Selection of individual designs

Sensitivity analysis

- Definition of the design space with optimization variables
- Scan of the design space with advanced LHS
- Identification of Metamodels of Optimal Prognosis (MOP) by CoP/MOP workflow

Understand the design

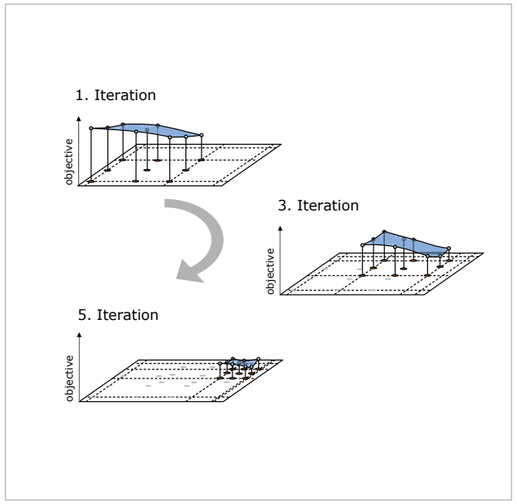
- Selection of the most important design variables with the help of CoP/MOP
  - Verification of parameter ranges, response extraction, constraints and objectives



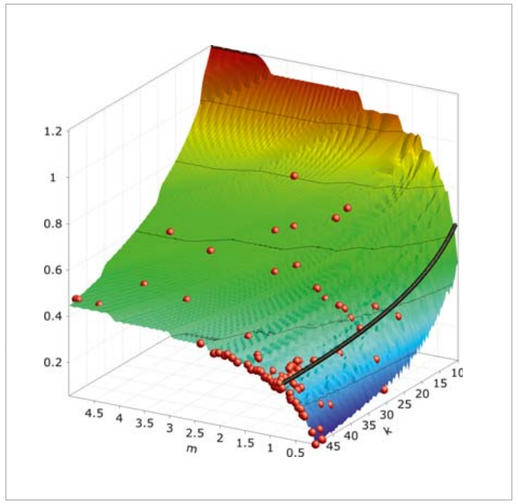
Pre-optimization using the MOP
Optimization of the design with only one additional CAE solver call by using the MOP

Final optimization based on knowledge from the sensitivity and pre-optimization step

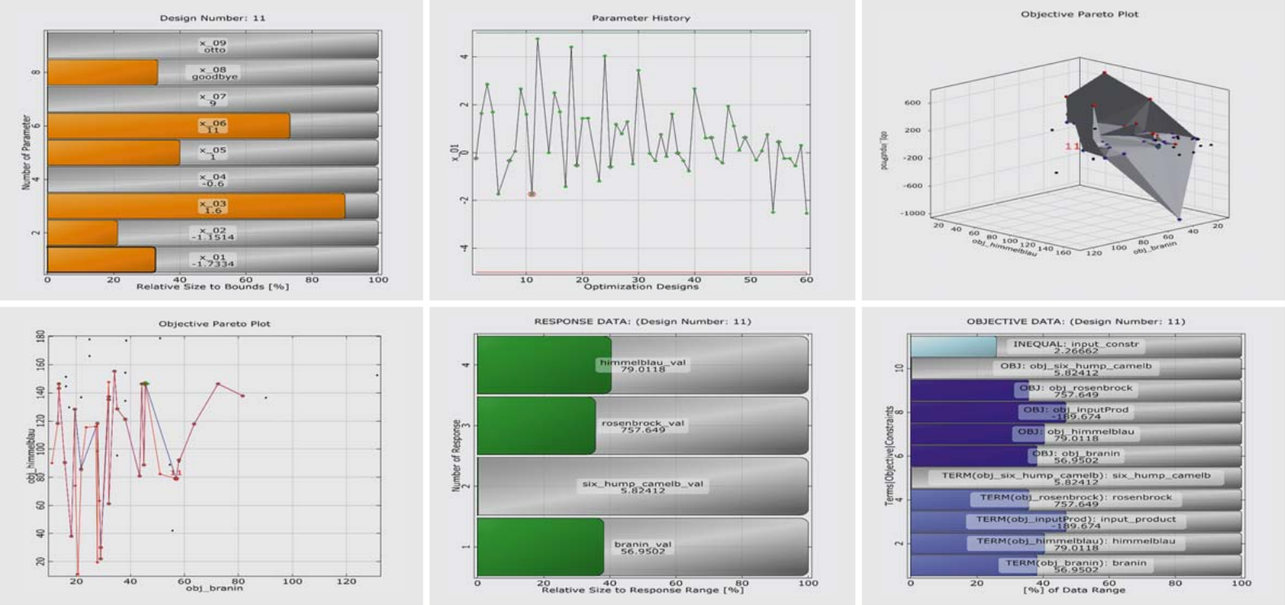
- Selection of the most appropriate optimizer and start design
- Exploring the limits of the design



Adaptation scheme of the ARSM algorithm



Evolutionary Algorithm solving constraint optimization problem with noisy objective function



MULTIOBJECTIVE OPTIMIZATION

Multiobjective optimization is applied when several conflicting objectives occur. Considering these objectives simultaneously leads to a set of Pareto optimal solutions which can be used for choosing the best production design.

Practical Application

Optimization, robustness and reliability studies have an increasing importance in industrial engineering. Often, there are conflicting objectives in the optimization task, for example minimum mass versus maximum stiffness of the product. A sensitivity study is performed in order to identify the most relevant parameters for conflicting objectives and to formulate the objective functions properly. As a result, the frontier of Pareto optimal solutions allow to quantify the trade-offs in satisfying conflicting objectives and to choose an optimal design which represents the best compromise between the objectives for the particular design application. Finally, this design can be evaluated in a subsequent robustness analysis.

Best Practice

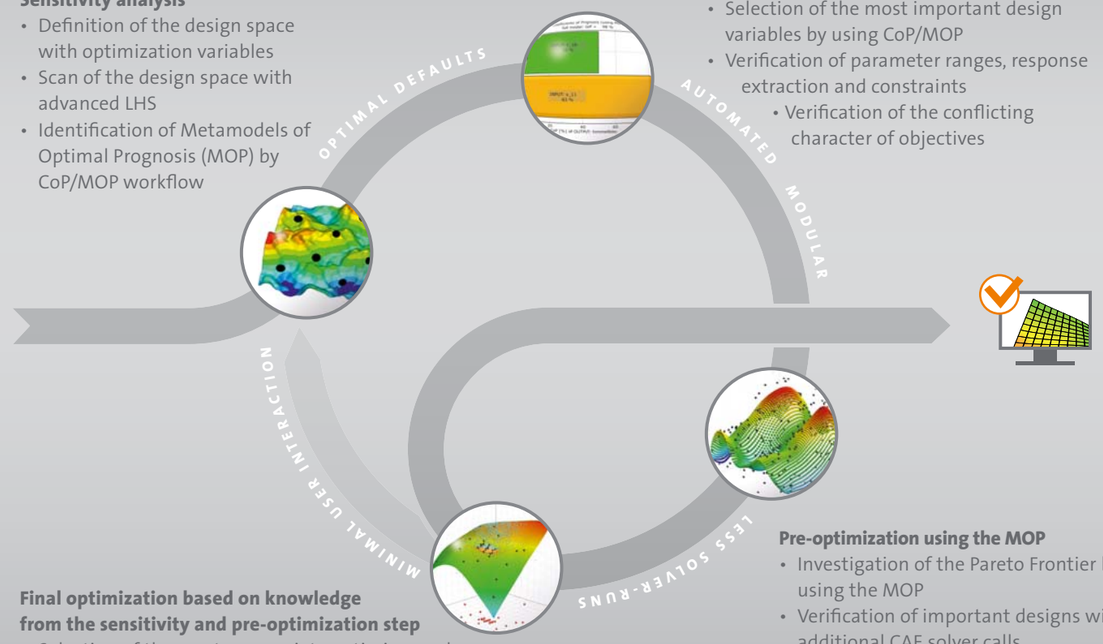
- Detection and evaluation of conflicting objectives
- Verification of conflicting objectives by single optimizations with weighted objective functions
- Integration of the previous knowledge obtained from sensitivity analyses and weighted optimizations into the initial function of Pareto optimization

Methods

- Use of evolutionary algorithms and Particle Swarm Optimizations
- Fitness assignment using dominance-based ranking
- Dominance based constraint handling
- Verification of diversity by density estimation

Postprocessing & Visualization

- Visualization of the objective space
- Selection of 2D or 3D subspace visualizations
- Parallel coordinate plots and cluster analysis for best design selection



Sensitivity analysis

- Definition of the design space with optimization variables
- Scan of the design space with advanced LHS
- Identification of Metamodels of Optimal Prognosis (MOP) by CoP/MOP workflow

Understand the design

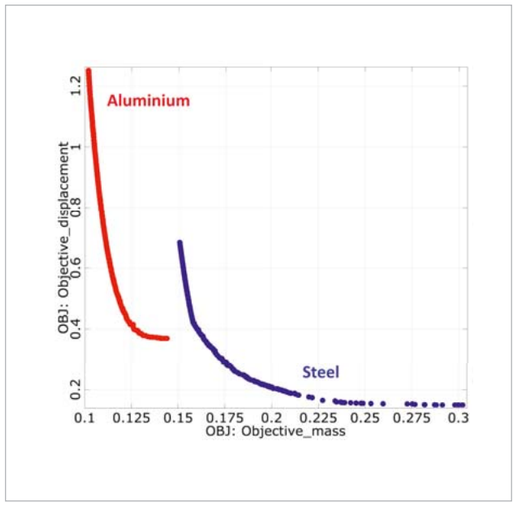
- Selection of the most important design variables by using CoP/MOP
- Verification of parameter ranges, response extraction and constraints
  - Verification of the conflicting character of objectives

Pre-optimization using the MOP

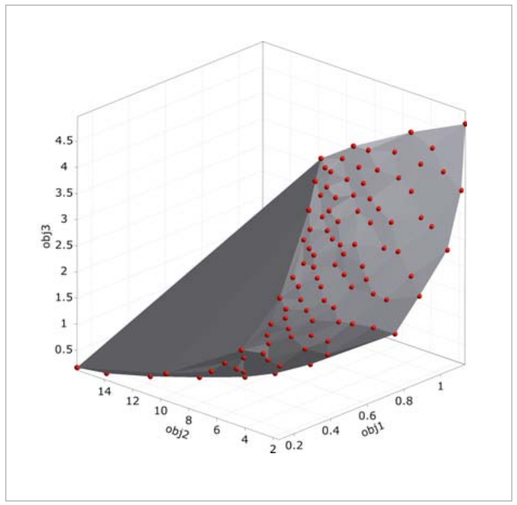
- Investigation of the Pareto Frontier by using the MOP
- Verification of important designs with additional CAE solver calls

Final optimization based on knowledge from the sensitivity and pre-optimization step

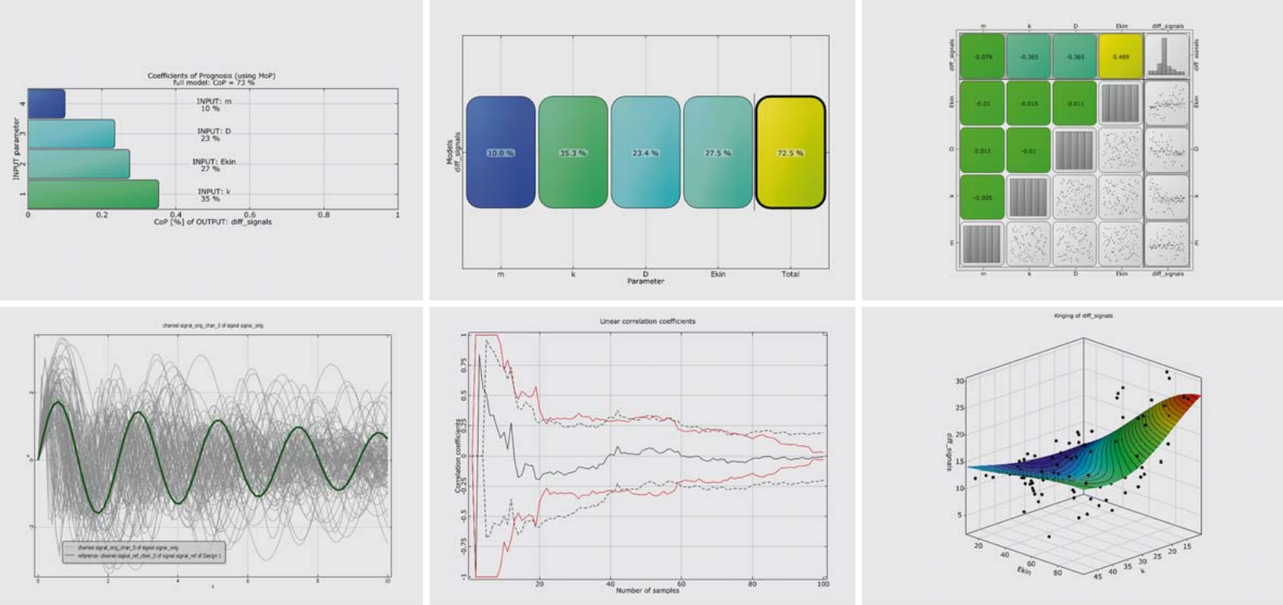
- Selection of the most appropriate optimizer and start designs
- Derivation of the Pareto Frontier



Pareto frontier of two objective functions



Three-dimensional Pareto frontier



PARAMETER IDENTIFICATION

The parameter identification, also named model update, identifies parameters of CAE models suitable for the best possible calibration with test results. Methods of parameter identification can also identify values that are not directly measurable, such as material parameters.

Practical Application

Measurement data represents characteristic system responses that are critical to validate and to improve the physical model of the system. In the context of parameter identification, model update means using field observations and simulation runs to approximate simulation model parameters. By means of sensitivity analyses, it is first detected which parameters actually have an influence on the simulation results and the calibration procedure. Furthermore, the analysis helps to define suitable measures to quantify the difference between measurement and simulation. Finally, it can be analyzed whether the inverse problem can be solved non-ambiguously, which means there is a unique parameter combination that allows optimal matching between measurement and simulation.

Best Practice

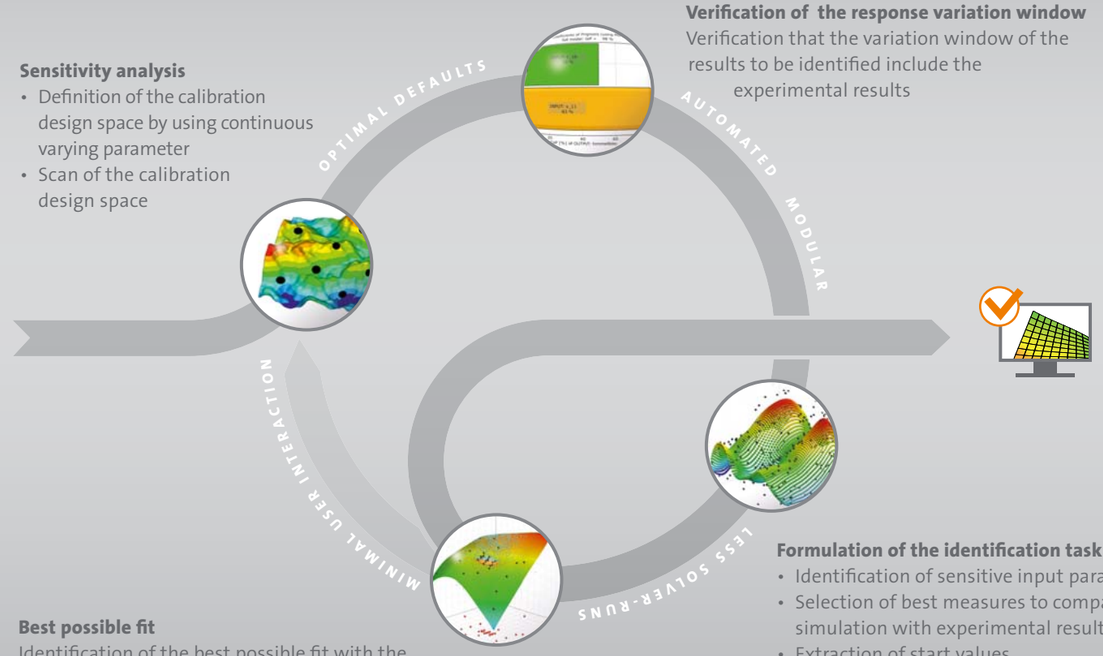
- Sensitivity analysis to check unknown parameters for significant influence on the model response
- CoP identifies the best possible result extraction by comparing model and measured values
- CoP verifies the uniqueness of the best possible correlation model between parameter and result variation
- Check for non-unique (multiple) parameter sets due to coupling of parameters which need to be identified

Methods

- Consideration of scalar response values
- Definition of multi-channel signals, e.g. time-displacement curves
- Extensive library of functions, e.g. local values as maximum and minimum amplitudes, global values as integrals of certain properties and more complex signal calculations
- Definition of individual objective functions
- Metamodel of Optimal Prognosis (MOP) for sensitivity analysis of different signal properties and pre-evaluation
- Several optimization algorithms (e.g. gradient-based or nature-inspired)

Postprocessing & Visualization

- Histograms
- Illustration of statistical evaluations
- Visualization of signal functions and the corresponding with reference value for each design evaluation

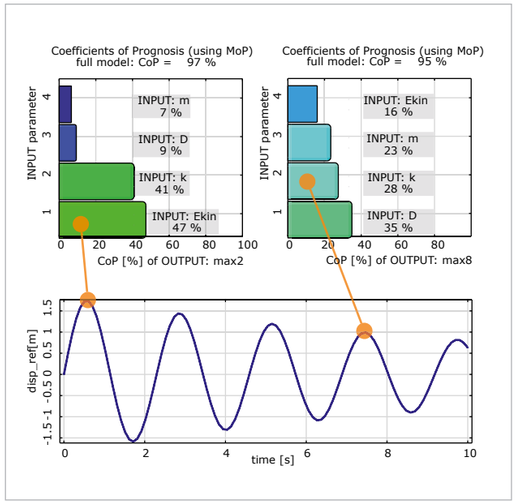


Sensitivity analysis
- Definition of the calibration design space by using continuous varying parameter
- Scan of the calibration design space

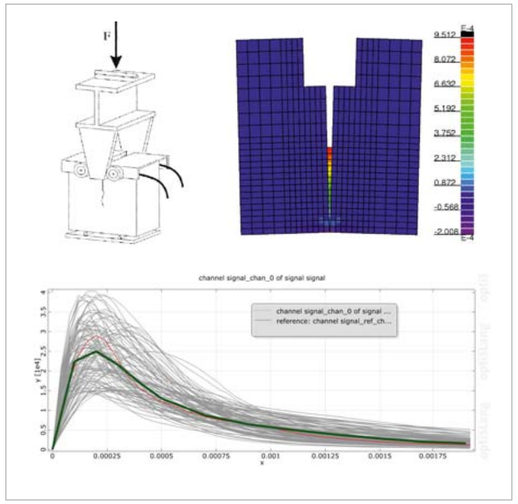
Verification of the response variation window
Verification that the variation window of the results to be identified include the experimental results

Formulation of the identification task
- Identification of sensitive input parameter
- Selection of best measures to compare simulation with experimental results
- Extraction of start values

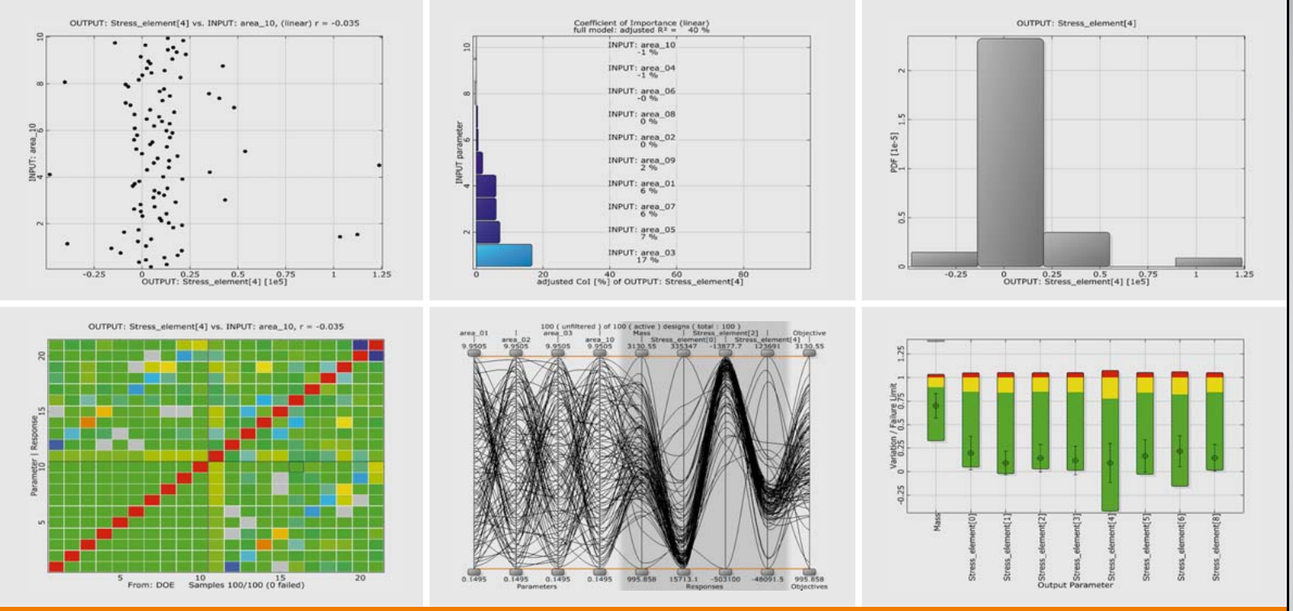
Best possible fit
Identification of the best possible fit with the appropriate optimizer depending on the dimension and/or type of sensitive optimization parameter



Sensitivity analysis at different signal values



Experimental setup of a wedge splitting test [Trunk 1999] (top left) | 2D simulation model (top right) | simulated curves from the sensitvity analysis (bottom)



ROBUSTNESS EVALUATION

optiSLang quantifies the robustness of designs by generating a set of possible design realizations on the basis of scattering input variables. Optimized Latin Hypercube Sampling and the quantification of the prognosis quality of the result variation by the Coefficient of Prognosis (CoP) ensure the reliability of the variation and correlation values with a minimum of design calculations.

Practical Application

Often, highly optimized designs are pushed to the boundaries of their feasible performance. For this reason, it is necessary to investigate how these designs are affected by scattering input variables, which could be geometry, material parameters, boundary conditions or loads. In order to cope with the unavoidable uncertainties in operating conditions as well as in manufacturing process, it is essential to introduce appropriate robustness measures based on uncertainty analysis. A possible first measure is the variance indicator where the relative variations of the critical model responses are compared to the relative variation of the input variables.

Best Practice

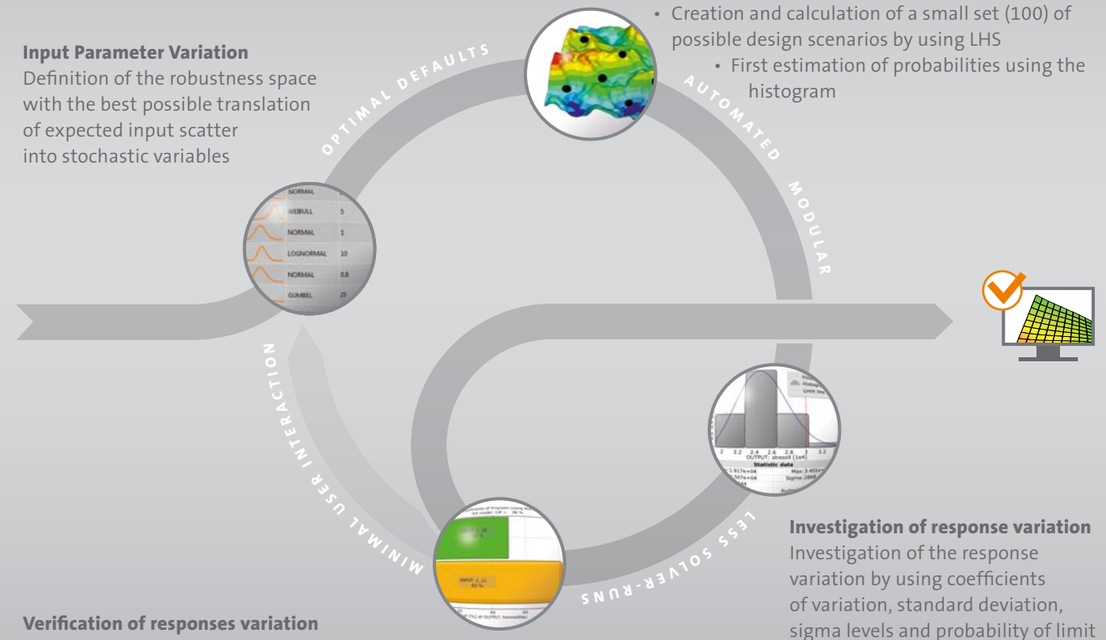
- Definition of uncertainties as the crucial input of a robustness analysis
- Predefined distribution function types and an input correlation matrix to support the definition of scattering input variables
- Automated generation of optimized Latin Hypercube Samples (LHS) to scan the robustness space
- Identification of the most affecting input scatter using the MOP/CoP workflow
- Quantification of robustness by the histogram of result values including fitting of distribution function and approximation of violation probability

Methods

- Stochastic input variables with distribution types and input correlation
- Optimized Latin Hypercube Sampling
- Fitting of distribution function in the histogram of result values
- Approximation of Sigma margins
- Approximation of violation probability

Postprocessing & Visualization

- Histograms to illustrate scatter of result values
- Correlation matrix, MOP-based CoPs for statistical evaluation
- Distribution fitting, Sigma values, violation probabilities
- Traffic light plot to check the violation of limit values of critical responses

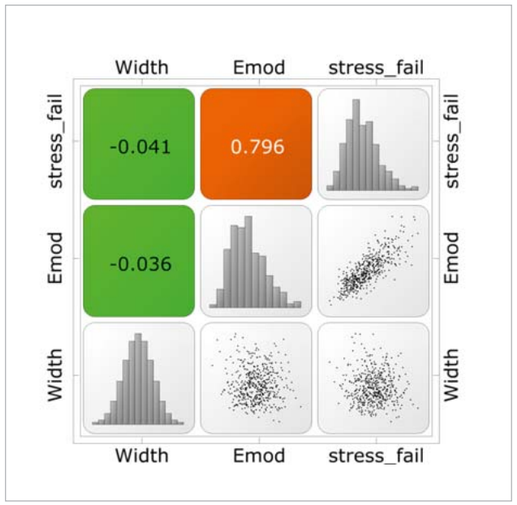


Input Parameter Variation
Definition of the robustness space with the best possible translation of expected input scatter into stochastic variables

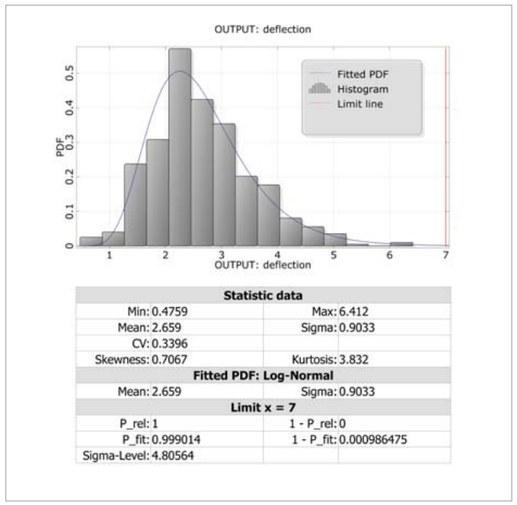
Scan the Robustness Space
- Creation and calculation of a small set (100) of possible design scenarios by using LHS
  - First estimation of probabilities using the histogram

Investigation of response variation
Investigation of the response variation by using coefficients of variation, standard deviation, sigma levels and probability of limit violation

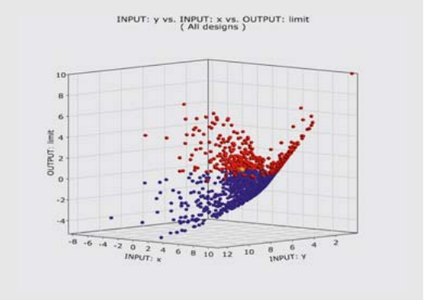
Verification of responses variation
- Identification of the causes of responses variations and the related scattering of in/out variables
- Identification of the best strategy to improve robustness

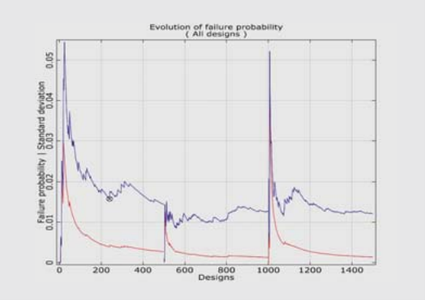


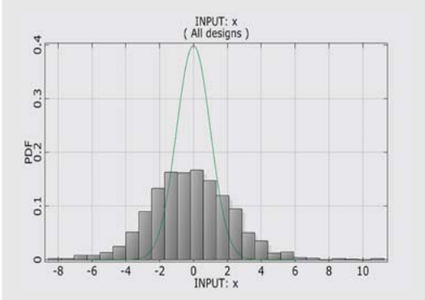
Extended matrix of correlations



Histogram with probability of violation and Sigma margins







Method : Adaptive Sampling (AS)

Complete iterations : 3 / 3
Selected data : All designs

Number of designs :
Total : 1500 / 1500
Safe domain : 825
Unsafe domain : 447
Failure strings : 0
Unsuccessful : 228

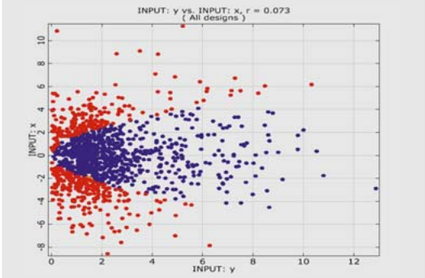
Probability of failure : 0.0122
Standard deviation error : 0.001396
Reliability index : 2.2508

Most probable failure point

ID : 841

Input parameter values
y : 1.47027101149
x : -2.10816273323

Reliability index (FORM) : 2.605
Probability of failure (FORM) : 0.004598



RELIABILITY ANALYSIS

The reliability analysis in optiSLang provides powerful numerical algorithms for the determination of small violation probabilities (less than 1 out of 1000). Thus, a reliability analysis allows the necessary final verification of small probabilities of failure after the conduction of a robustness evaluation or Robust Design Optimizations (RDO).

Practical Application

In many cases, optimized designs need to meet high safety or quality requirements that have to correspond with low failure probabilities (less than 1 out of 1000). Here, a reliability analysis is necessary to investigate how these designs are affected by scattering input variables, e.g. geometry, material parameters, boundary conditions or loads. As an alternative to the estimation of safety distances by using standard deviations in robustness evaluations, a reliability analysis calculates the probability whether a certain limit will be exceeded by using stochastic analysis algorithms. With a reliability analysis, the rare event of violation can be quantified and proven to be less than an acceptable value.

Best Practice

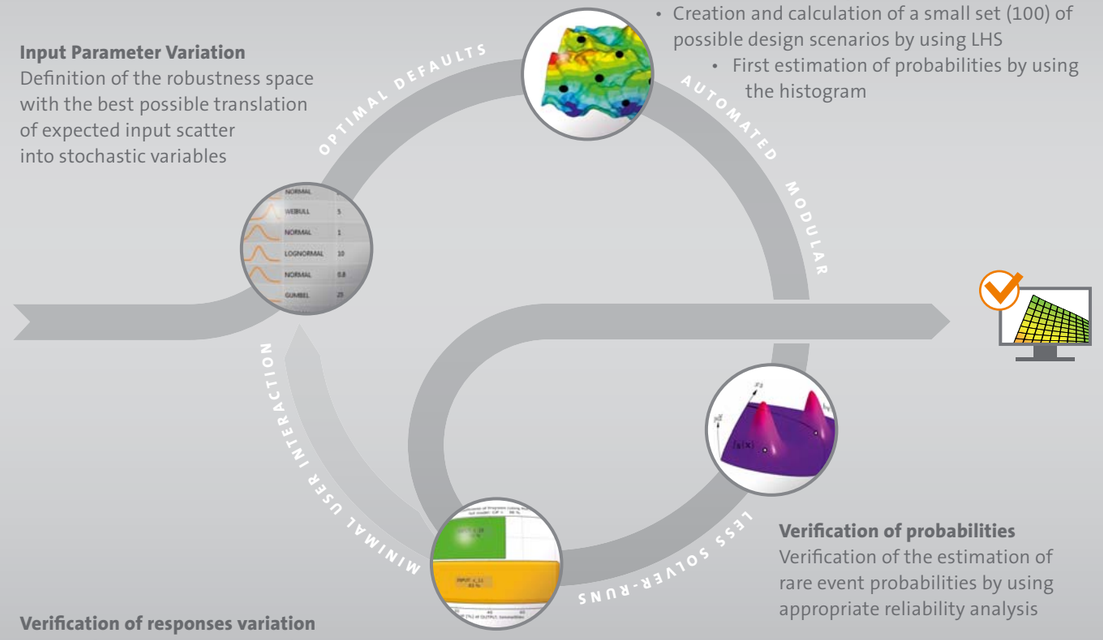
- Robustness evaluation for the approximation of violation probabilities and for the identification of important random variables as the basis for an appropriate selection of methods regarding a reliability analysis
- Definition of one or various failure mechanisms using limit state functions
- Recommendation of verifying low probabilities of failure with two alternative algorithms of reliability analysis

Methods

- First Order Reliability Method (FORM) and Importance Sampling Using Design Point (ISPUD) for continuously differentiable limit state functions
- Directional Sampling and Adaptive Sampling (AS) for a moderate number of random variables, multiple failure mechanisms and small probabilities of failure
- Adaptive Response Surface Method (ARSM) as most efficient method for less than 20 random variables

Postprocessing & Visualization

- Histograms
- 2D/3D anthill plots
- History plots
- Violation probabilities

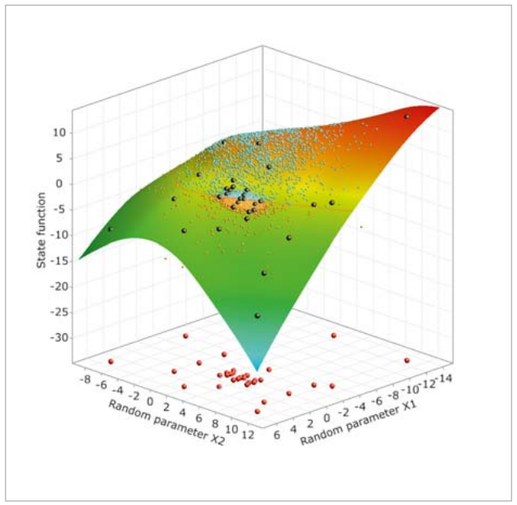


Input Parameter Variation
Definition of the robustness space with the best possible translation of expected input scatter into stochastic variables

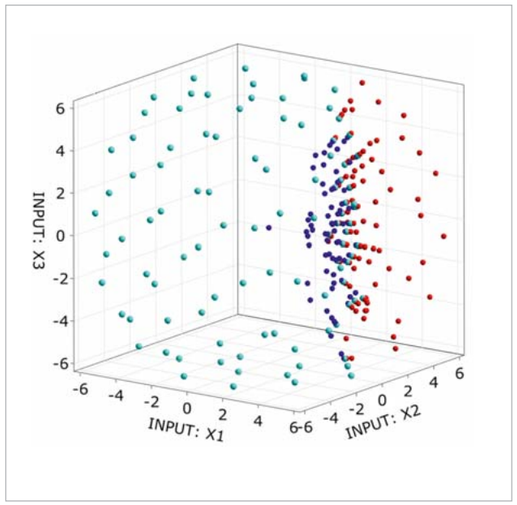
Scan the Robustness Space
- Creation and calculation of a small set (100) of possible design scenarios by using LHS
  - First estimation of probabilities by using the histogram

Verification of probabilities
Verification of the estimation of rare event probabilities by using appropriate reliability analysis

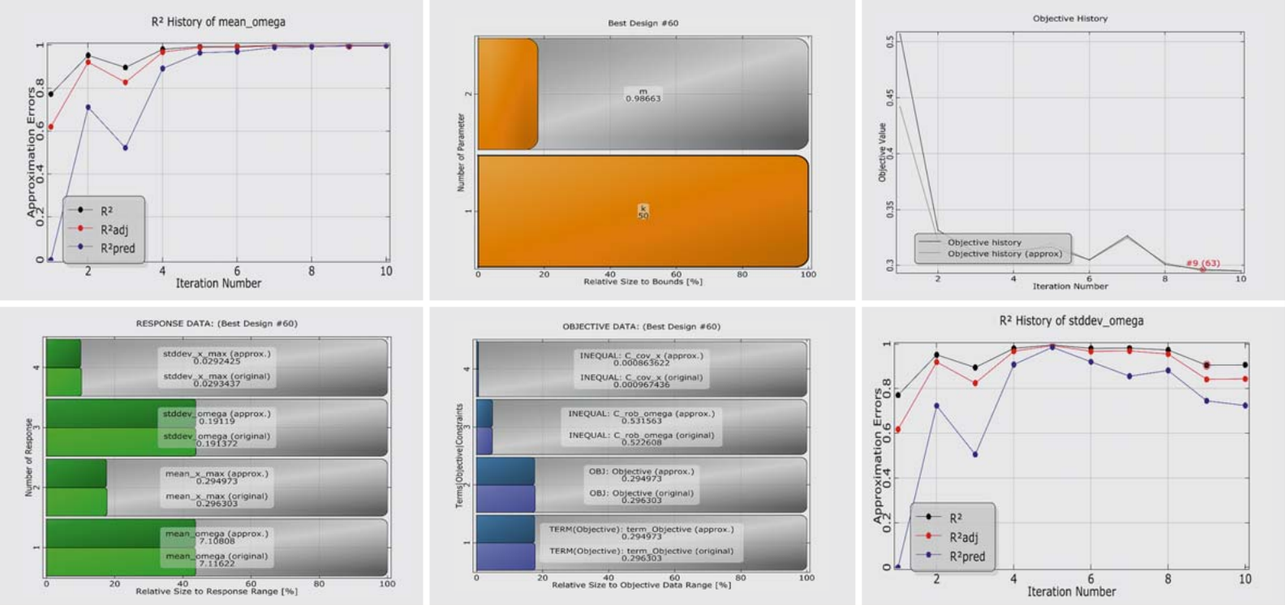
Verification of responses variation
- Identification of the causes of responses variations and the related scattering of in/out variables
- Identification of the best strategy to improve robustness



Reliability analysis using Adaptive Response Surface Method



Application of directional sampling procedure



ROBUST DESIGN OPTIMIZATION (RDO)

The Robust Design Optimization (RDO) combines CAE-based optimization with robustness evaluation and allows a product optimization with a synchronized assurance of robustness. optiSLang provides iterative as well as simultaneous methods for variance-based and reliability-based RDO including tasks conforming to Design For Six Sigma (DFSS).

Practical Application

The main idea behind RDO is the consideration of uncertainties in the design process. There are different sources of uncertainties like loading conditions, tolerances of geometrical dimensions or material properties caused by production or deterioration. Some can have a significant impact to the design performance which has to be considered in the design optimization procedure. This can be done by an iterative RDO. It combines deterministic optimization with variance or probability based robustness analysis at certain points during the optimization process. If necessary safety distances vary strongly in the design space, a simultaneous RDO has to be run. In this case, the robustness measures of every design on the optimization loop have to be estimated by using a stochastic analysis.

Best Practice

- Definition of the design space of optimization variables as well as the robustness space of all scattering variables
- Initial sensitivity analysis within the design space as well as initial robustness evaluation within the space of scattering variables in order to identify important parameters, optimization potential, initial violation probabilities and safety margins
- Variance-based RDO for tasks with low sigma level
- Reliability-based RDO for tasks with high sigma level
- Simultaneous RDO in case of sharply varying safety margins
- Sequential RDO with deterministic optimization and stepwise adjusted safety factors as best practice method in the majority of cases
- Recommendation of final reliability proof for tasks with a sigma level higher than three

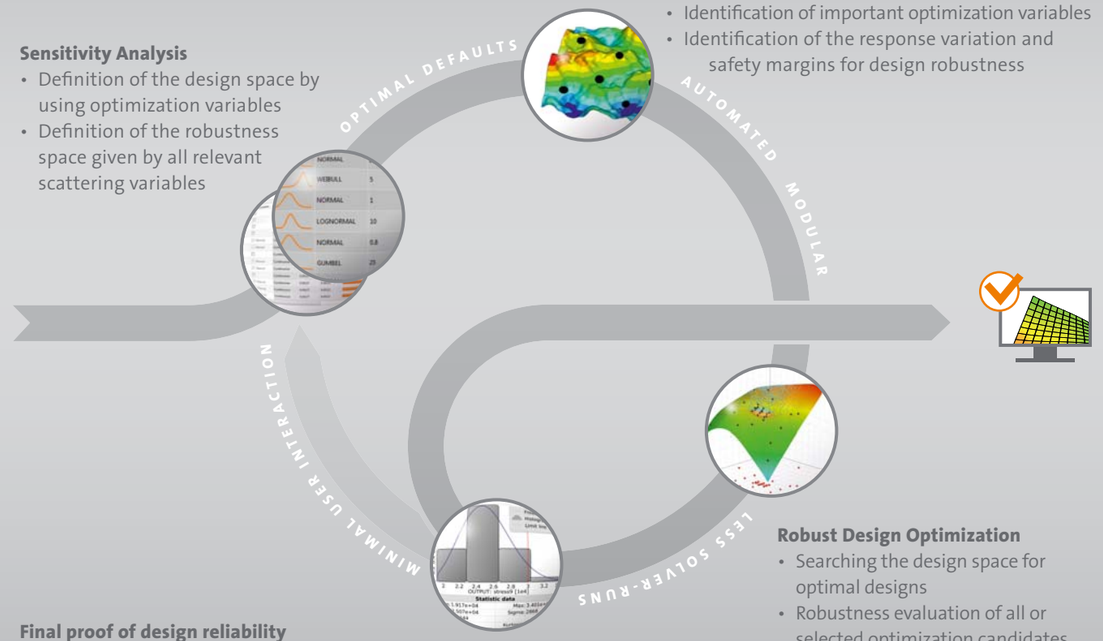
Methods

Variance-based RDO

- Evolutionary Algorithm (EA), Genetic Algorithms, ARSM
- EA combined with robustness evaluation
- Adaptive response surfaces in combination with robustness evaluation

Reliability-based RDO

- Evolutionary algorithm, genetic algorithms, ARSM
- Evolutionary algorithm combined with First Order Reliability Method (FORM)
- Adaptive response surfaces for optimization and reliability analysis



Scan of the design and robustness space

- Identification of important optimization variables
- Identification of the response variation and safety margins for design robustness

Sensitivity Analysis

- Definition of the design space by using optimization variables
- Definition of the robustness space given by all relevant scattering variables

Robust Design Optimization

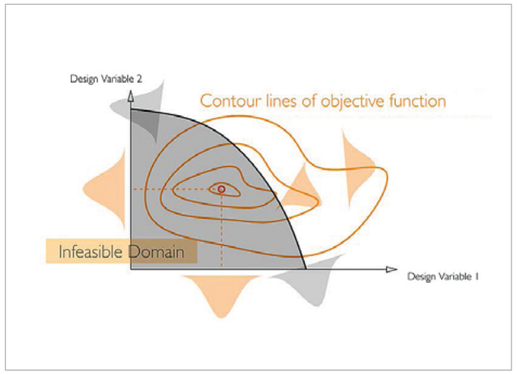
- Searching the design space for optimal designs
- Robustness evaluation of all or selected optimization candidates by using sequential or simultaneous RDO strategies

Final proof of design reliability

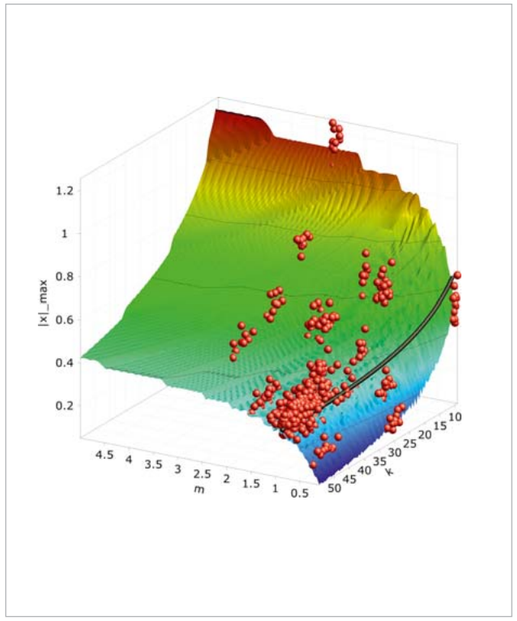
Prove of the design reliability in terms of sigma levels or probabilities of violation by using a reliability analysis

Postprocessing & Visualization

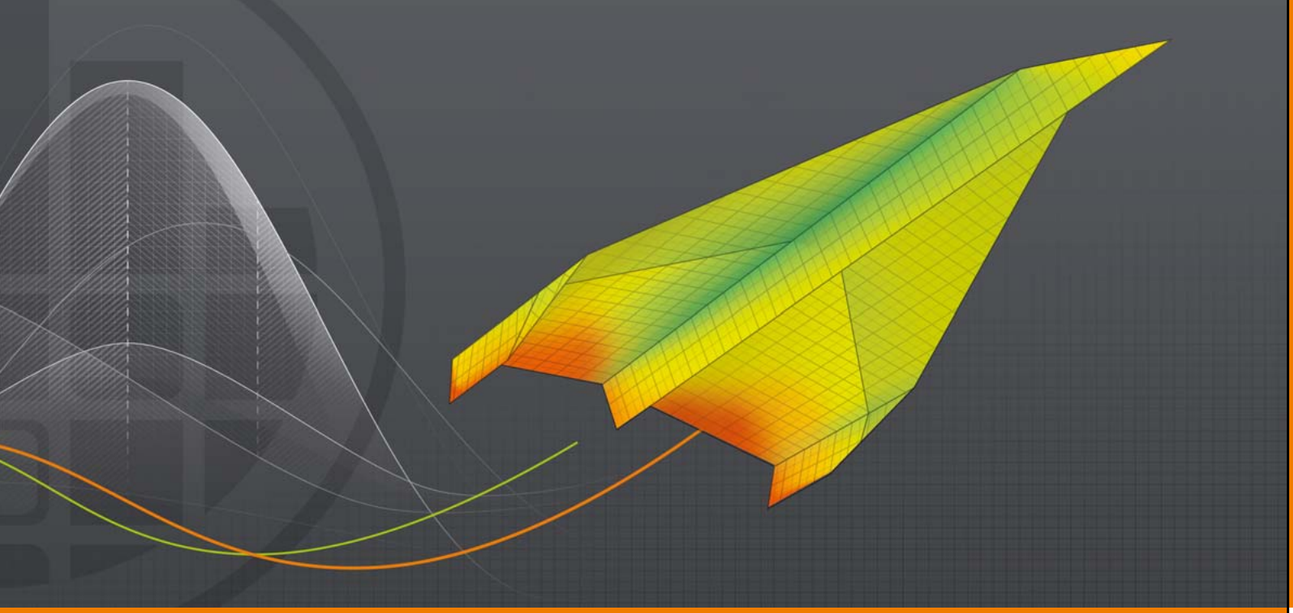
- Histograms
- Anthill plots to visualize deterministic response values
- Additional illustration of statistical evaluation of the robustness measures
- Violation probabilities and sensitivity indices of robustness measures



Varying location of the optima and contour lines of constraints as a consequence of uncertainties



Variance-based Robust Design Optimization samples using ARSM in combination with Advanced Latin Hypercube Sampling



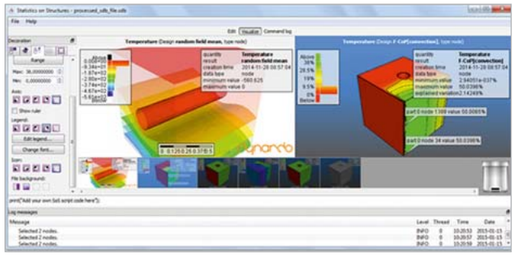
STATISTICS ON STRUCTURES

The software solution for the analysis and simulation of data being distributed in space or time. Statistics on Structures (SoS) provides you with pre- and post- processing tools for spatially distributed 3D data and can be applied to sensitivity analysis, optimization, robustness evaluation and RDO.

Background

SoS enhances optiSLang's capabilities of parametric studies to field data. Examples of field data are

- Time histories (e.g. signal processing, parameter calibration, loading curves)
- Geometric deviations (e.g. geometric boundary, shell thickness, thickness of composite layers)
- Material properties (e.g. distribution of mortar and admixtures in concrete, porosity in ceramics, friction parameters on surfaces)
- Damages (e.g. distribution of cracks, residual strains after forming), pre-stress distribution and loading conditions



Extensive GUI for MOP-Postprocessing

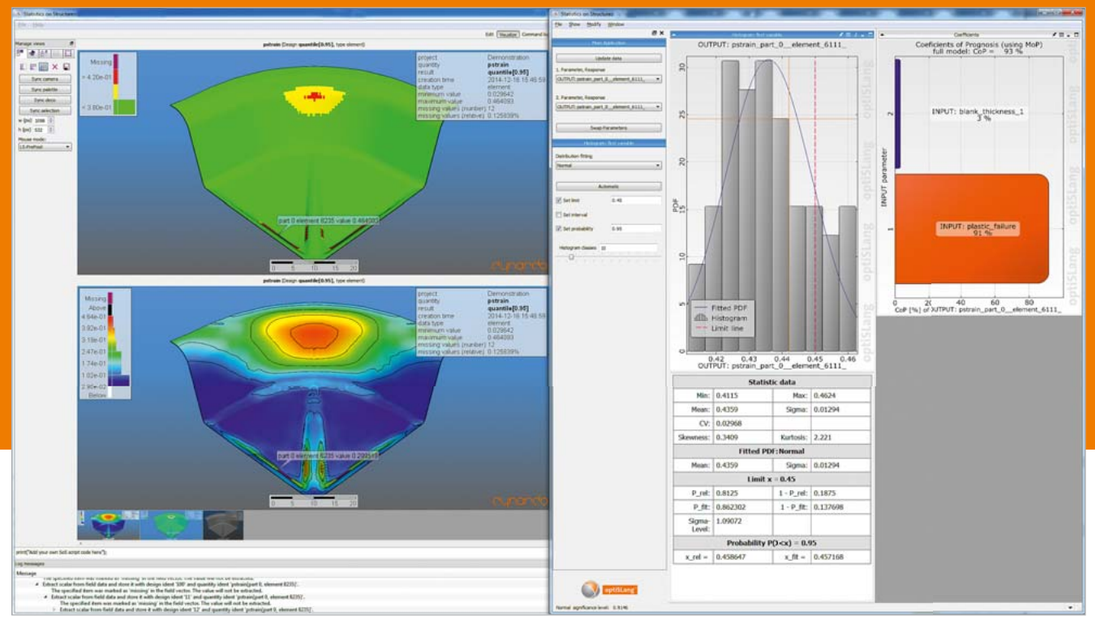
One major difficulty when analyzing field data is that positions of maxima and minima may change in space or time. By taking the whole field variation into account, the identification of hot spots can be simplified, leading to increased accuracy of numerical results in robustness evaluations, meta-modeling and sensitivity analyses.

The 3D visualization provides further confidence in statistical results of FEM data and helps to understand variations in numerical CAE models. Random field models allow a parameterization of field data through scatter shapes. Thus, SoS is also able to generate imperfect designs, allowing the consideration of spatially and temporally distributed perturbations as inputs in robustness studies.

Highlights

Visualization of statistical properties on FEM meshes

- Intuitive GUI with many statistical functions
- Extensive 3D data visualization
- Easy integration into custom CAE processes



Hot spot detection example: In a deep drawing simulation (metal forming production process) the plastic strain must not exceed a certain threshold by a given probability. On the left: Visualization of critical zones (in yellow and red) for the non-exceedance probability of the threshold on the FEM mesh and statistical identification of the most likely failure point. Right: Detailed robustness evaluation at the hot spot in optiSLang: Distribution fitting, evaluation of thresholds and sensitivity analysis with variable ranking.

Hot spot detection

- Reliable and simple detection of hot spots, e.g. potential failure locations by statistical measures
- Reduction of numerical complexity by separation of location and response, increases accuracy of further analysis

Correlation analysis of variations

- Identification and ranking of input parameters that influence the variation of the model response
- Spatially local sensitivity analysis at hot spots using optiSLang's Metamodel of Optimal Prognosis (MOP) to identify and rank important input parameters
- Spatially global sensitivity analysis using spatial correlations and noise pre-filtering (F-MOP) to visualize the influence of individual input parameters on the FEM mesh
- Improved accuracy for small number of design evaluations

Random field models

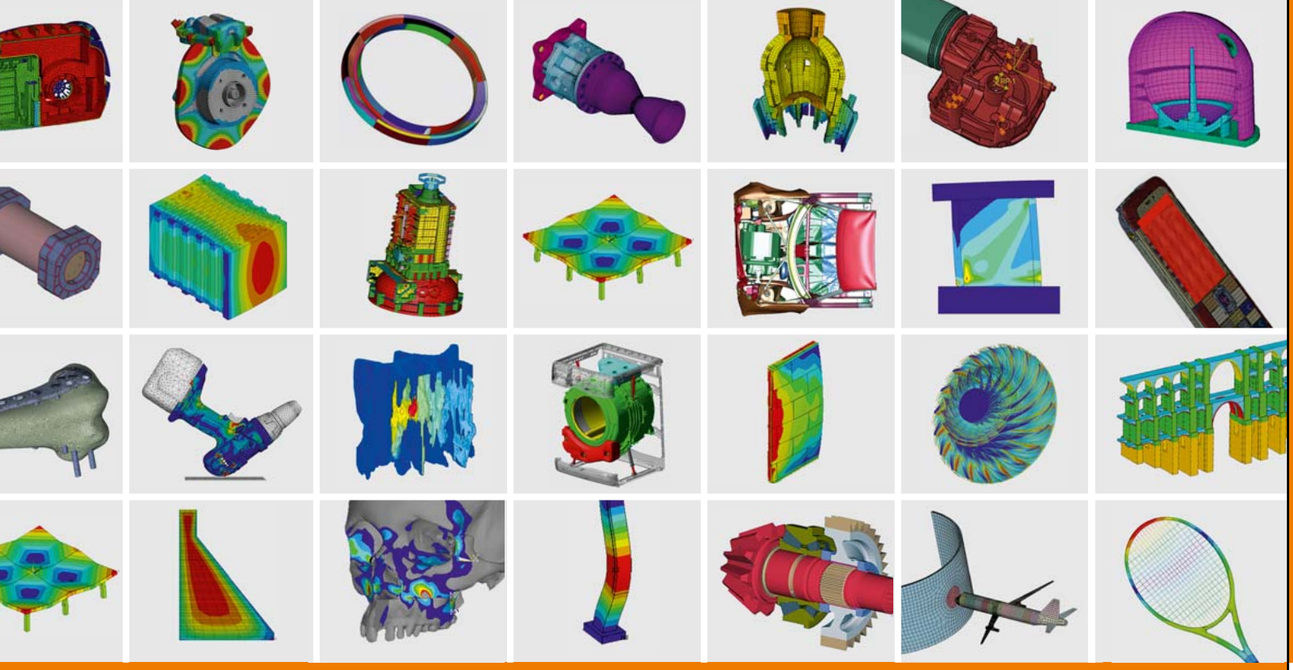
- Simulation of imperfect designs (e.g. random geometries, pre-damage, time signals ...)
- Predict variation of field data using nonlinear field meta models (F-MOP) in optimization
- Identification of coupled mechanisms through scatter shapes (e.g. buckling)

Benefits

- Realistic description of random effects on FE structures
- Detection of hot spots and potential failure locations
- Analysis of causes and effects of production tolerances and natural scatter
- Supporting the mitigation of quality problems
- Application of robust design optimizations

Extension of optiSLang to signals and spatially distributed data using SoS

	optiSLang	SoS
Optimization		
Hot spot detection	signals	3D field
Sensitivity analysis	scalar	3D field, signals
Optimization on meta model	scalar	3D field, signals
Robustness evaluation		
Generation of random designs	scalar	3D field, signals
Compute robustness measures	scalar, signals	3D field
Hot spot detection	signals	3D field
Sensitivity analysis	scalar	3D field, signals



CUSTOMIZATION & PILOT PROJECTS

Dynardo provides computational services and customized solutions for your FE analyses and CAE optimization tasks in virtual product development of all engineering disciplines. Due to the company's combination of being a CAE service provider and software developer, Dynardo is your competent and flexible partner for complex tasks in the CAE field.

Pilot Projects

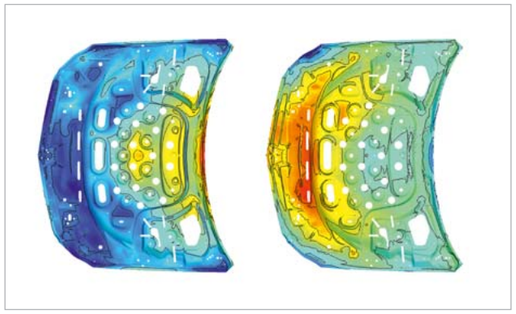
Especially for the introduction of CAE-based Robust Design Optimization in product development processes, a pilot project as an initial cooperation based on the customer's product knowledge and our consulting experience would be a perfect start. Dynardo has expertise in various industrial fields and will help you to conduct realistic safety and reliability analysis, proper assessment of material behavior, prediction of failure evolution, design optimization or simulation of FEM based limit load analysis.

Customization

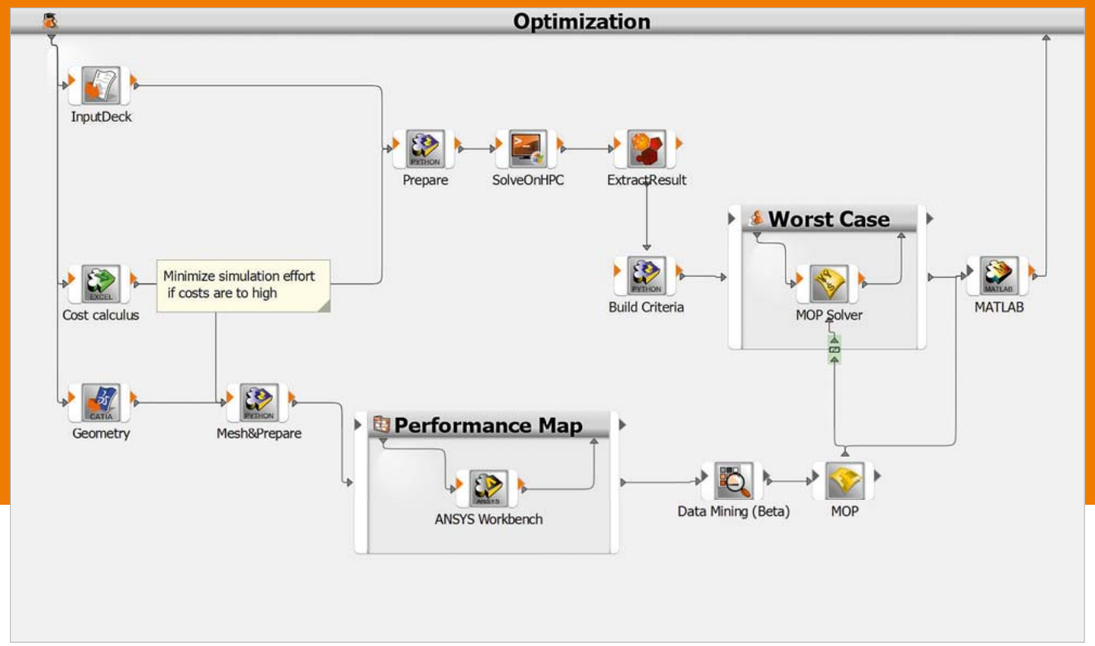
You want to make your virtual product development more efficient? Dynardo develops customized solutions based on optiSLang and SoS. We integrate your in-house software into optiSLang or make optiSLang be a part of your company SPDM (Simulation Process & Data Management) solution. Even fully automatized RDO workflows can be generated. We help you to establish a company-wide standard workflow and make your products benefit from consistent and efficient CAE processes.

RDO Consulting Service

In cases, customers would like to investigate the potentials of CAE-based optimization for their product lines but have not implemented a CAE-based development process yet, we offer to generate and verify a virtual model of a product and conduct a CAE-based optimization. The final result will show possible optimized product configuration and how input variation affects the design responses using the MOP/CoP methodology.



Detection of geometric deviations between two incompatible meshes of a car cowling (copyright/courtesy of DAIMLER AG)



Fully automatized optimization workflow in optiSLang considering structural costs and metric of performance map, running several solvers and using HPC

BOSCH

In the uncomplicated and flexible cooperation with Dynardo, it is a great advantage that the company is not only a software developer but also an engineering service provider. Direct communication with the programers and individual license agreements ensure a rapid adaptation and extension of the software optiSLang to specific technical requirements of Robert Bosch GmbH.

Roland Schirrmacher (Robert Bosch GmbH)
Corporate Sector Research and Advance Engineering
Future Mechanical and Fluid Components (CR/ARF1)

NOKIA

For high end consumer goods, the robustness is a key function. In 2008, Nokia implemented sensitivity analyses into the virtual prototyping to identify critical drop directions of load cases as well as robustness evaluations of the drop test regarding production tolerances and material scatter. With the help of optiSLang, the robust product performance of mobile phones could be increased concerning critical drop conditions.

DAIMLER

In the framework of the virtual product development process of the Daimler AG, parametric CAE-models are employed for the evaluation and optimization of different functional requirements like driving comfort or crashworthiness behavior. Robust dimensioning means to design a vehicle which is as insensitive as possible in regard to existing scatter in material or production properties. In order to ensure robustness within the virtual prototyping, in 2002, Daimler started implementing optiSLang for NVH analysis of driving comfort. Since then, applications have been extended to crashworthiness, brake squeal load cases as well as forming simulation.

SUPPORT & TRAININGS

In training courses for beginners, advanced users or experts, we provide information about our software products and the methods of CAE-based Robust Design Optimization as well as practical applications in various industries.

Support

The main interest of our support team is a successful customer. We provide technical support by phone, e-mail or online. All requests regarding our software products optiSLang, multiPlas, SoS and ETK will be processed thoroughly and answered immediately. Our support team will also help you to implement efficient RDO applications and its various methods to solve CAE-challenges in your particular field of business.

Info days and webinars

During our info days and webinars, you will receive an introduction to performing complex, non-linear FE-calculations using optiSLang, multiPlas, SoS and ETK. At regular webinars, you can easily get information about all relevant issues of CAE-based optimization and stochastic analysis. During an information day, you will additionally have the opportunity to discuss your specific optimization task with our experts and develop first approaches to solutions.

Trainings

For a competent and customized introduction to our software products, visit our basic or expert trainings clearly explaining theory and application of a sensitivity analysis, multidisciplinary optimization and robustness evaluation. The trainings are not only for engineers, but are also perfectly suited for decision makers in the CAE-based simulation field. For all trainings there is a discount of 50% for students and 30% for university members/PHDs. You can find an overview of the current training program at our homepage www.dynardo.de.

Internet Library

Our internet library is the perfect source for your research on CAE-topics and applications of CAE-based RDO. There you will find practical references and state-of-the-art case studies matched to the different fields of methods and applications.

Infos

www.dynardo.de/en/consulting
www.dynardo.de/en/trainings
www.dynardo.de/en/library

ANNUAL WEIMAR OPTIMIZATION AND STOCHASTIC DAYS

Your conference for CAE-based parametric optimization, stochastic analysis and Robust Design Optimization in virtual product development.

The annual conference aims at promoting successful applications of parametric optimization and CAE-based stochastic analysis in virtual product design. The conference offers focused information and training in practical seminars and interdisciplinary lectures. Users can talk about their experiences in parametric optimization, service providers present their new developments and scientific research institutions inform about state-of-the-art RDO methodology.

Take the opportunity to obtain and exchange knowledge with recognized experts from science and industry.

You will find more information and current dates at: **www.dynardo.de/en/wost**.

We are looking forward to welcoming you at the next Weimar Optimization and Stochastic Days.

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