Automate engineering processes at scale

pSeven
overview

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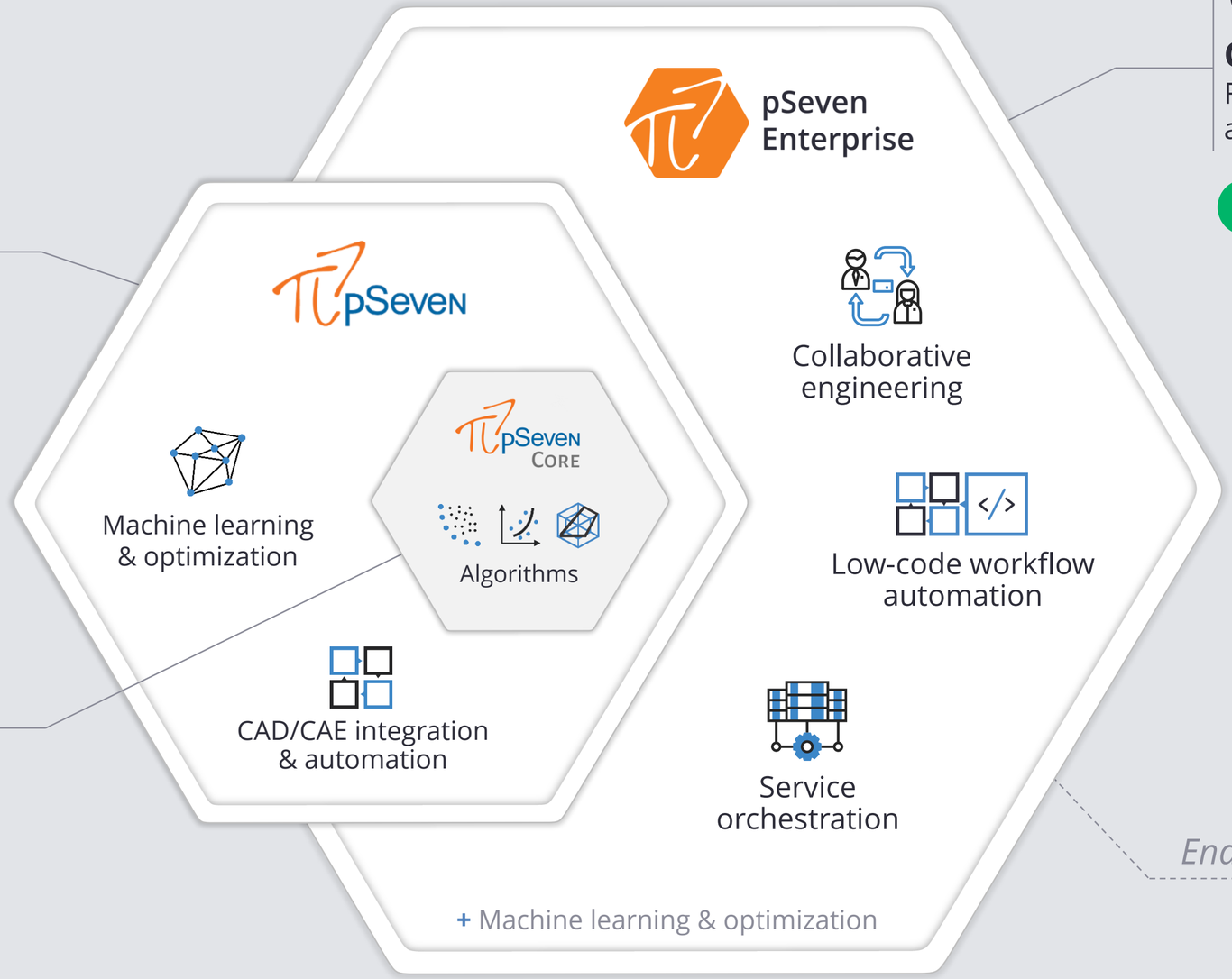
pSeven product line

Desktop application
For local engineering tasks
& product development

10% design lead time reduction

Python library
For scientific research
& software development



Cloud-native platform
For engineering automation
at enterprise level

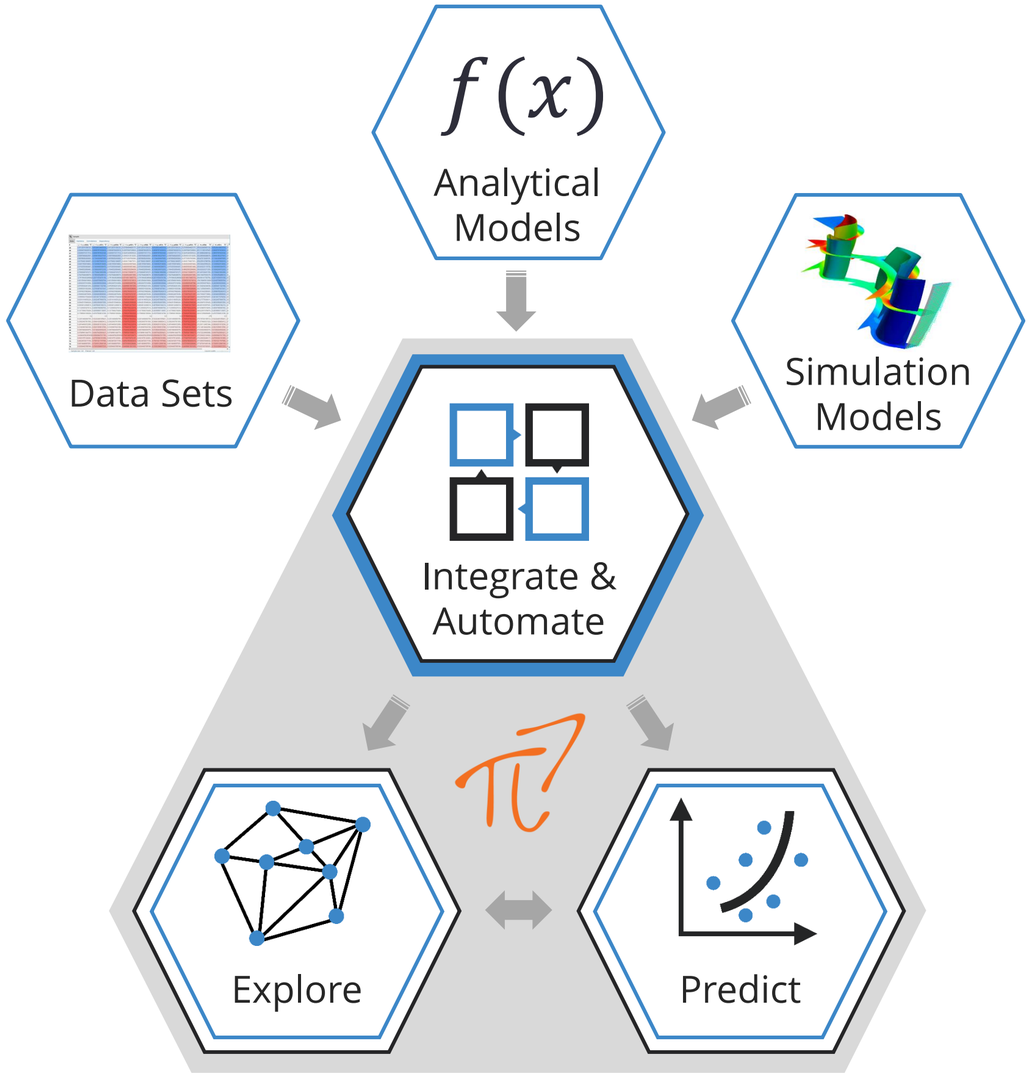
Up to 3x productivity gain

Enable

Digital Twins

Integrate, Explore & Predict

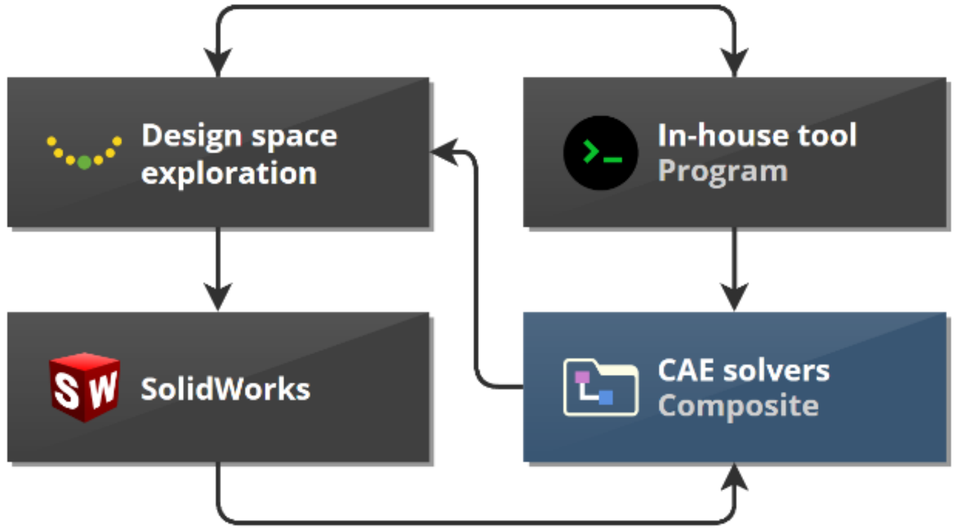
- pSeven is developed to:
  - Automate complex product design processes and integrate all external software and data into a single workflow
  - Solve engineering problems with a complete toolset for Design Exploration and Predictive Modeling



Process automation in pSeven

- Design process in pSeven is represented as a sequence of computations with defined execution order. This is called a workflow.

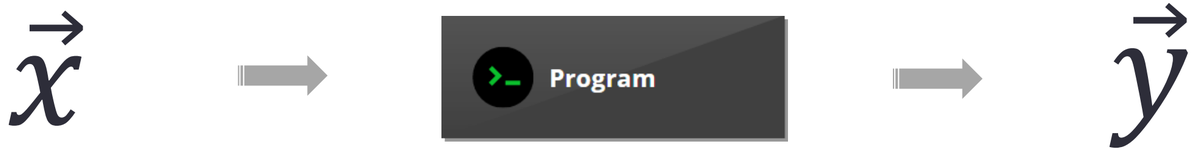
- Workflow consists of blocks, connections and parameters that provide:
  - Intuitive and visual definition of complex computations
  - Implementation of logic operations and nested loops
  - Parallel and remote execution
  - Data reuse and caching



External software integration

- pSeven is a vendor-neutral platform and allows engineers to integrate any CAD/CAE software packages their company uses into a single workflow.

- pSeven workflow includes two kinds of integration blocks:
  - Direct integration blocks — program-specific blocks, easy to configure.
  - Generic integration blocks — allow integration using any program's command line interface. Provide greater flexibility than direct integration blocks, but often require some scripting or manual command input.



Provide input parameters

Run external software

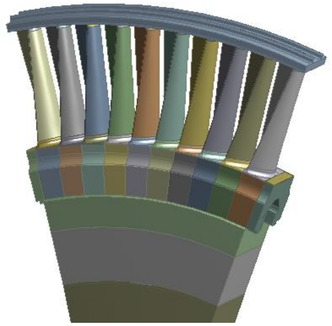
Get output parameters

Design Exploration in pSeven

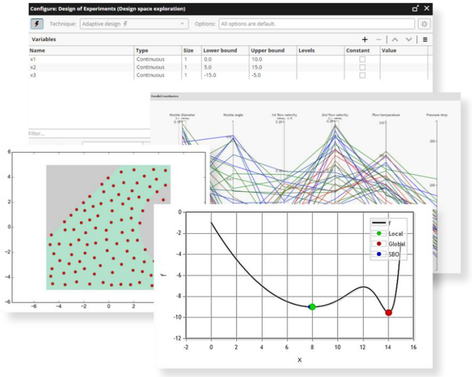
- Design Exploration allows engineers to:
  - Develop trust in their models
  - Explore design alternatives
  - Perform trade-off studies
  - Discover bottlenecks
  - Identify models
  - Set goals

"Design Space Exploration is both a class of quantitative methods and a category of software tools for systematically and automatically exploring very large numbers of design alternatives and identifying optimal performance parameters."

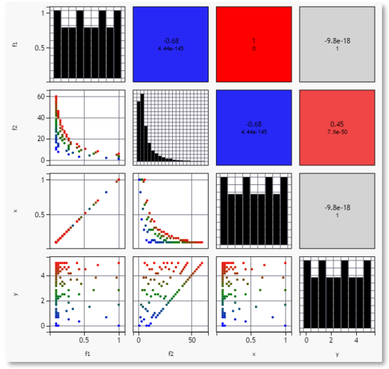
- B. Jenkins, Ora Research



Create model



Apply Design Exploration tools

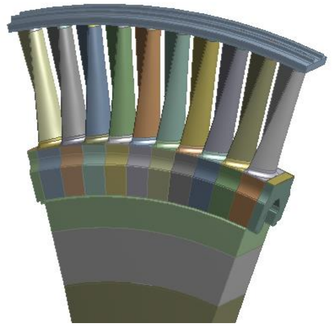


Make decisions based on numbers

What is Design Optimization?

- Manual design optimization appeared at the same time as the product design itself. Design Exploration provide ways for automated optimization while developing trust in its results.

- Design Optimization helps engineers answer the following questions:
  - Which product design parameters are the best?
  - How to improve product characteristics?
  - How to decrease effect of parameters variability on overall product behavior?

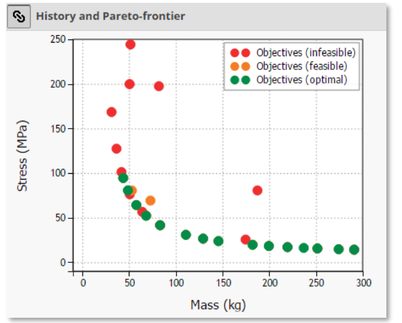


Create model

$\vec{x}$

$\uparrow \vec{f}$

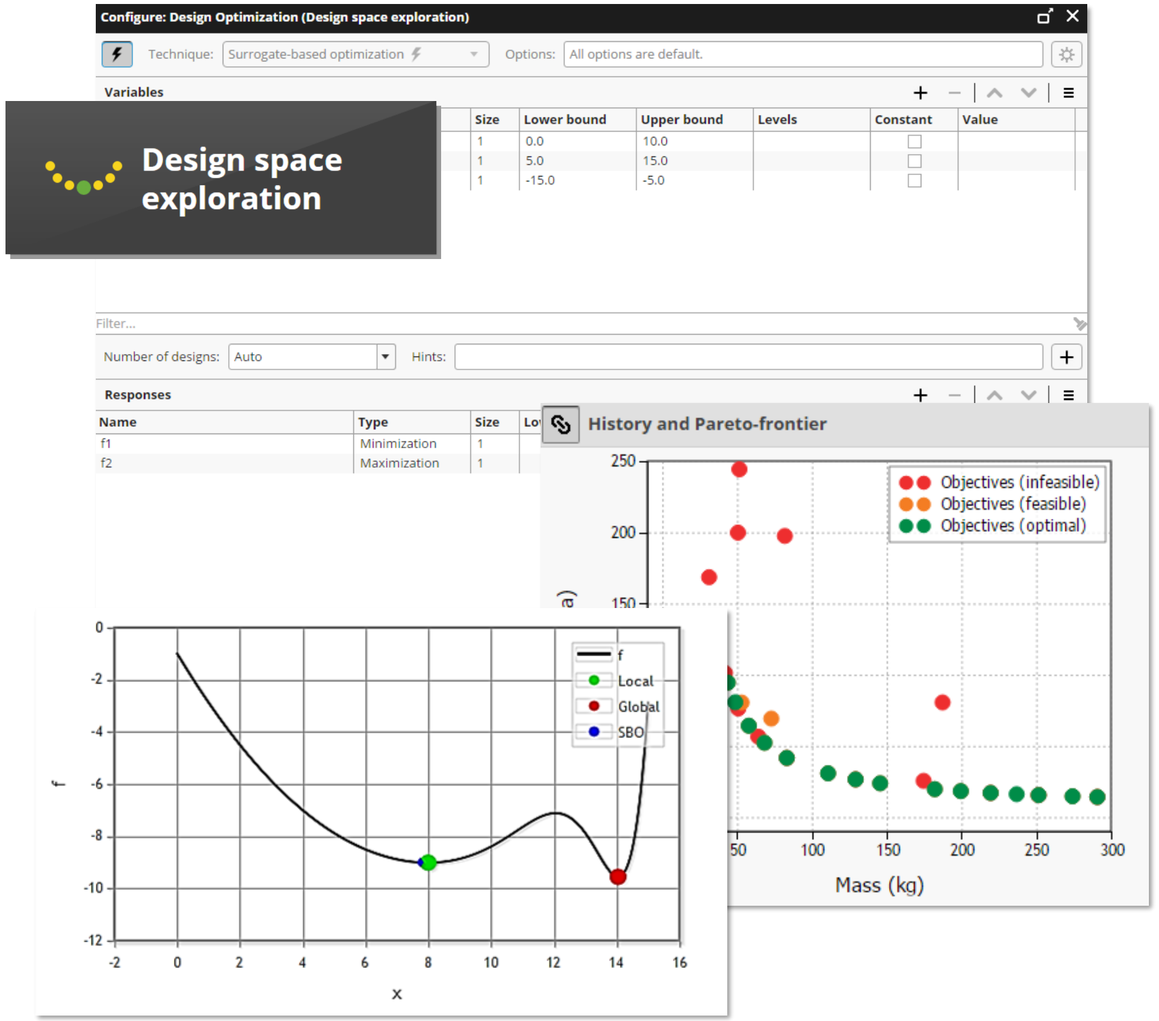
Define variables and goals



Run optimization

Design Optimization in pSeven

- pSeven provides easy and effective solution for most of industry optimization problems:
  - Single- or multi-objective, robust optimization
  - Large dimensionality*
  - Long model evaluation time**
  - Continuous and discrete input variables
  - Nonlinear, multimodal or noisy objective functions and constraints
  - Presence of implicit constraints and domains of undefined behavior



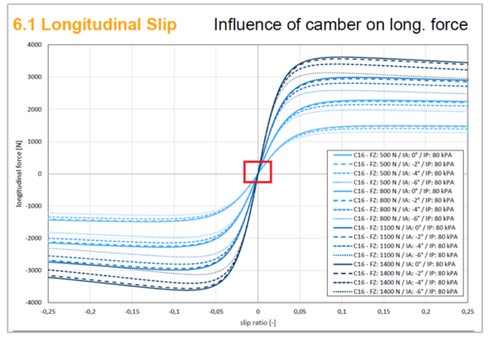
SmartSelection chooses the optimization algorithms automatically and adaptively!

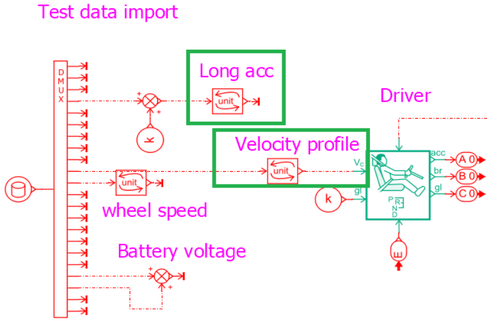
* - Up to 100 design variables for nonlinear time-consuming models

** - For example, any CAE model

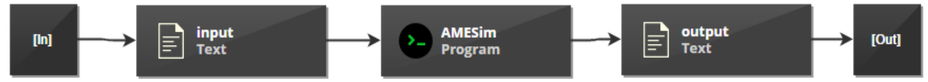
Tire dynamics model identification

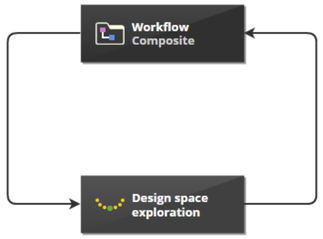
- Objective:
  - Identifying the scale factors for calibration of the tire model of racing bolide.
- Challenges:
  - Mathematical model (Pacejka's "Magic Formula") describing the behavior of tires at given small forces in the contact patch is in a narrow range => it is very difficult to catch the change in force and bind this change to a specific scale factor.
- Solution:
  - Amesim simulation model was integrated into pSeven workflow.
  - Using Gradient-Based Optimization the problem of single-criteria optimization with 6 variables was solved.
- Results:
  - Calibration accuracy **increased by 1.36%** compared to previously used approach.
  - The total identification time for the scale factors was 300 seconds (5 min).

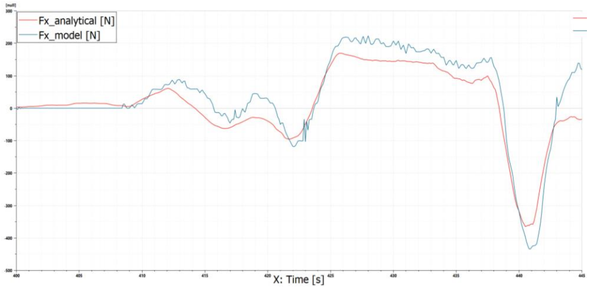




Amesim model

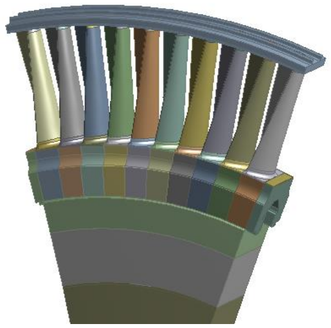






Design of Experiments in pSeven

- Design of Experiments (DoE) is a selection of model input variables (x) at which responses (f) are measured to achieve specific goals:
  - Explore design space using as small number of observations as possible
  - Get as much information as possible about the model behavior
  - Measure output sensitivity, variability and other characteristics
  - Enable reliable surrogate-based optimization
  - Generate a training sample for building an accurate predictive model

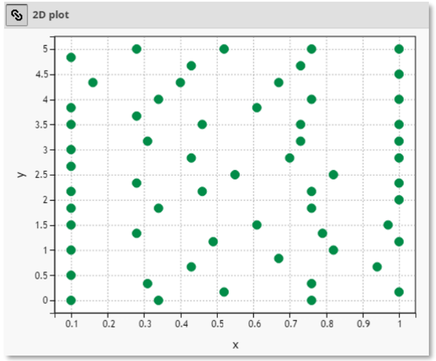


Create model

$\vec{x}$

$\vec{f}$

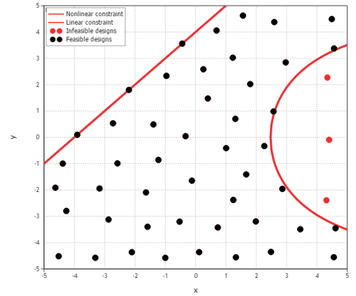
Define variables and responses



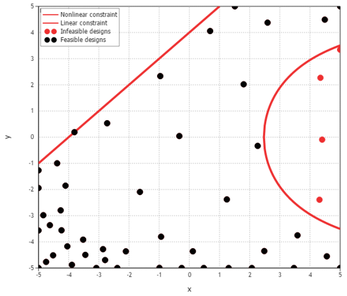
Run a series of model evaluations

Adaptive design technique for DoE

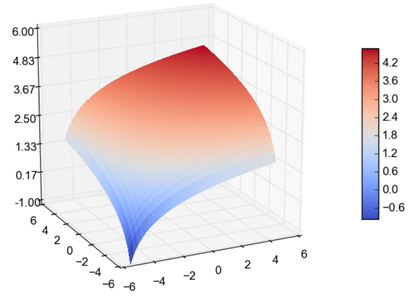
- Adaptive Design technique supports 3 scenarios:
  - Uniform - feasible domain sampling:
    - Setup: variables and bounds, linear and non-linear constraints
    - Result: uniform sample in feasible domain
  - Explore - response surface improvement:
    - Setup: variables and bounds, linear and non-linear constraints, objective function
    - Result: sample in feasible domain for better objective function approximation
  - Contour - search for designs with given objective function value:
    - Setup: variables and bounds, linear and non-linear constraints, objective function and its required value
    - Result: sample in feasible domain with given value of objective function



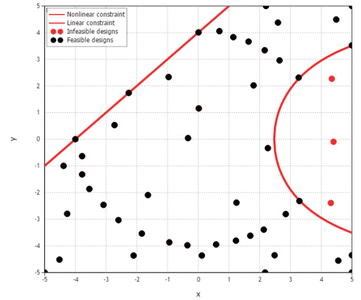
Uniform



Explore



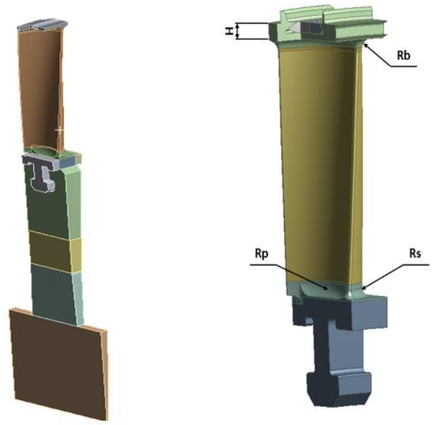
Objective function



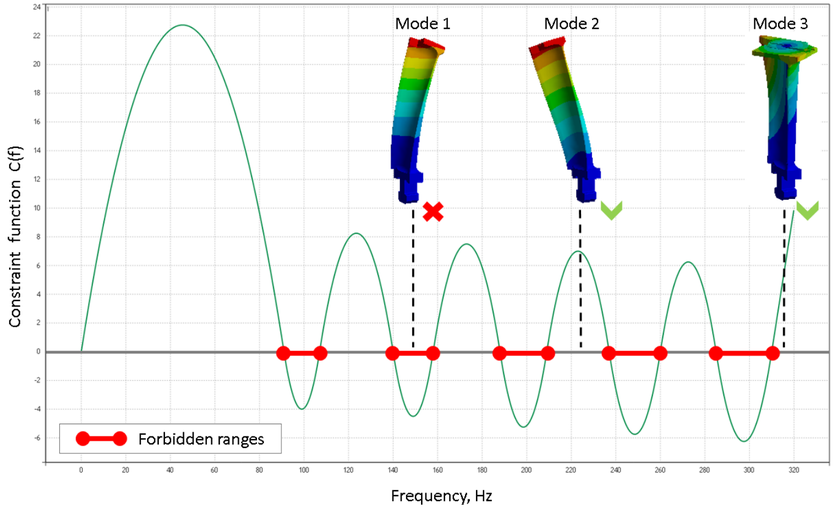
Contour

Turbine blades automatic detuning from resonance modes

- Objective:
  - Automate the selection of steam turbine blades geometry parameters.
  - Detune bucket exciting frequency from resonance modes in the operational regimes.
- Challenges:
  - Complex blade geometry with a significant number of elements.
  - No off-the-shelf methodology of frequency and modes evaluation and separation.
- Solution:
  - Meshing and strength analysis performed in Ansys Mechanical.
  - Integration workflow with special scripts to define the logic of computations was created in pSeven.
  - The algorithm of Adaptive Design of Experiments (ADoE) was applied to find the geometry. AdoE allows to generate uniform and non-uniform samples with respect to all constraints, while saving computational budget.
- Results:
  - The module of bucket exciting frequency from resonance modes was developed within the **Integrated Computational Platform (ICP)**, which enables to design turbine blades automatically complying with the number of requirements



Full model assembly | Geometry parameters



What is a predictive model?

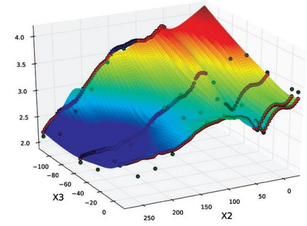
- Predictive model* is a substitution (“black box”) of existing data, analytical model or simulation built with approximation techniques.
- Predictive modeling makes it possible to:
  - Predict response function values for new designs
  - Accelerate computation of complex simulations by many orders of magnitude
  - Use fast and accurate predictive models in parametric and optimization studies
  - Capture essential knowledge from vast amounts of data
  - Easily and safely exchange models between partners preserving IP rights

* - Predictive models are also often called regression models, approximation models, response surface models (RSM), surrogate modes, metamodels etc.

Data set

$f(x)$

Analytical model

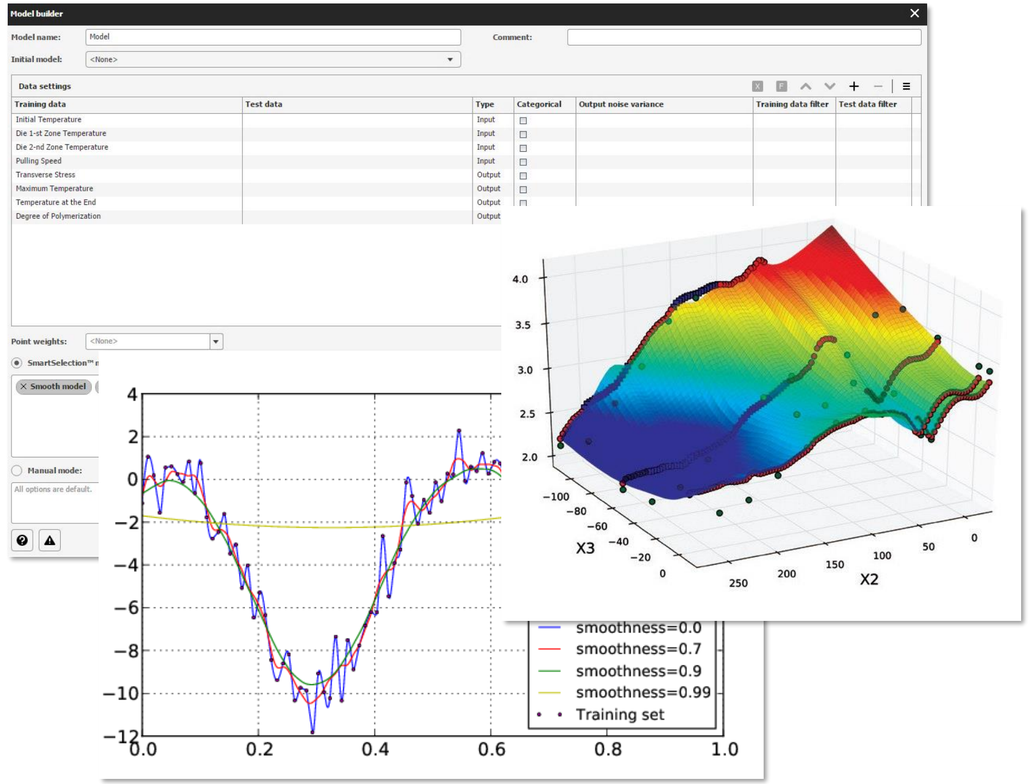


Predictive model

Simulation model

Building predictive models

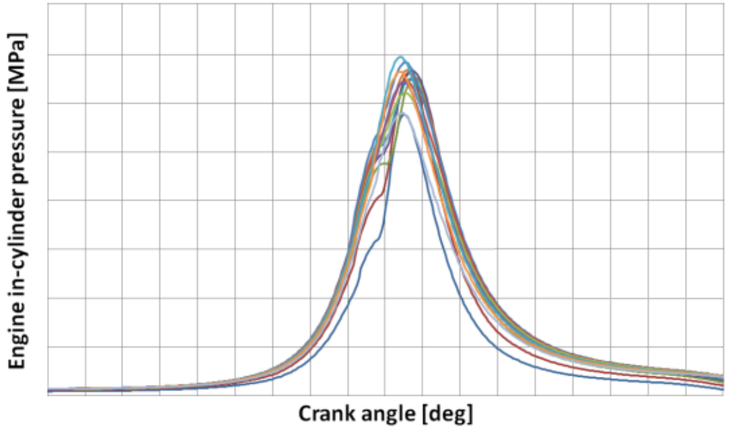
- pSeven provides unbeatable capabilities and flexibility for building predictive models:
  - Variety of industry-proven approximation techniques
  - Full control of the model building time
  - Accuracy and error estimation
  - Dealing with oscillations and model smoothing
  - Logarithm of outputs and exact fit
  - Handling anisotropic data, discontinuities and inhomogeneous data, multi-fidelity data
  - Updating existing models with new data and combining of the models

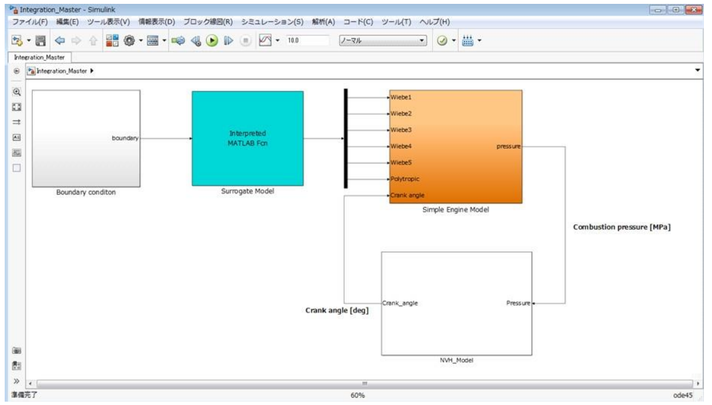


SmartSelection selects the most efficient technique for a given problem and data automatically!

Fitting and predicting of combustion model parameters

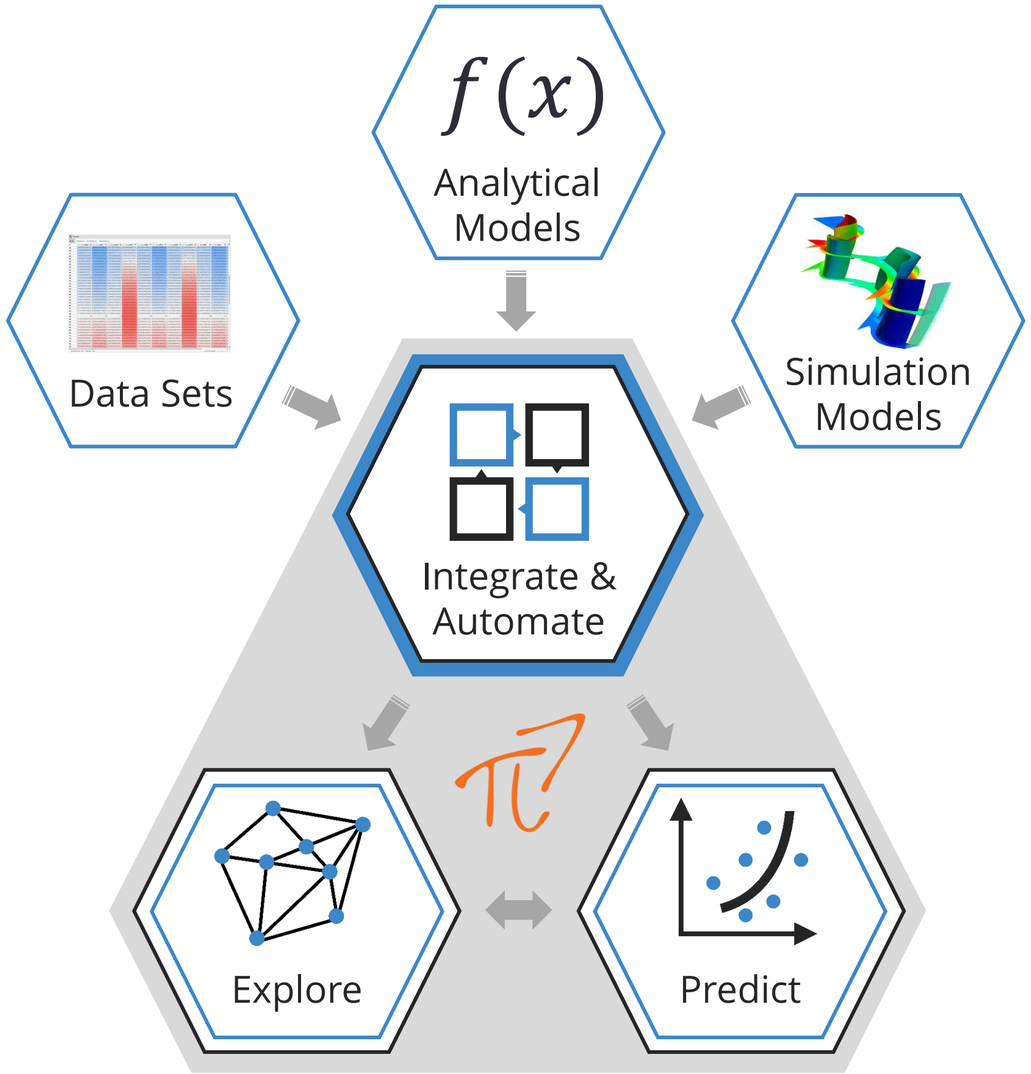
- Objective:
  - Accurate engine modeling requires to know combustion model parameters at arbitrary operation regimes:
    - Wiebe function (5 parameters)
    - Specific heat ratio
- Challenges:
  - Fixed number of experimental data available.
  - High accuracy of predictions is required.
- Solution:
  - **1 stage:** Fitting combustion model parameters to existing experimental in-cylinder pressure vs. crank angle curves using optimization of residuals.
  - **2 stage:** Creating approximation model to predict combustion model parameters at an arbitrary regime using known values, like intake and exhaust manifold pressure, fuel consumption, injection timing, RPM etc.
- Results:
  - Fast and accurate approximation model was created that can be used in further 1D engine simulations via export to FMI.





Integrate, Explore & Predict

- pSeven allows to:
  - Capture and automate engineering process in the form of a workflow with the aid of integration blocks
  - Explore your model with tools for Design Exploration
  - Predict responses for new designs or operational regimes of the product with Predictive Modeling



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