8. Dresdner Probabilistik-Workshop
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Response surface based robust design optimization on the example of a high pressure turbine blade

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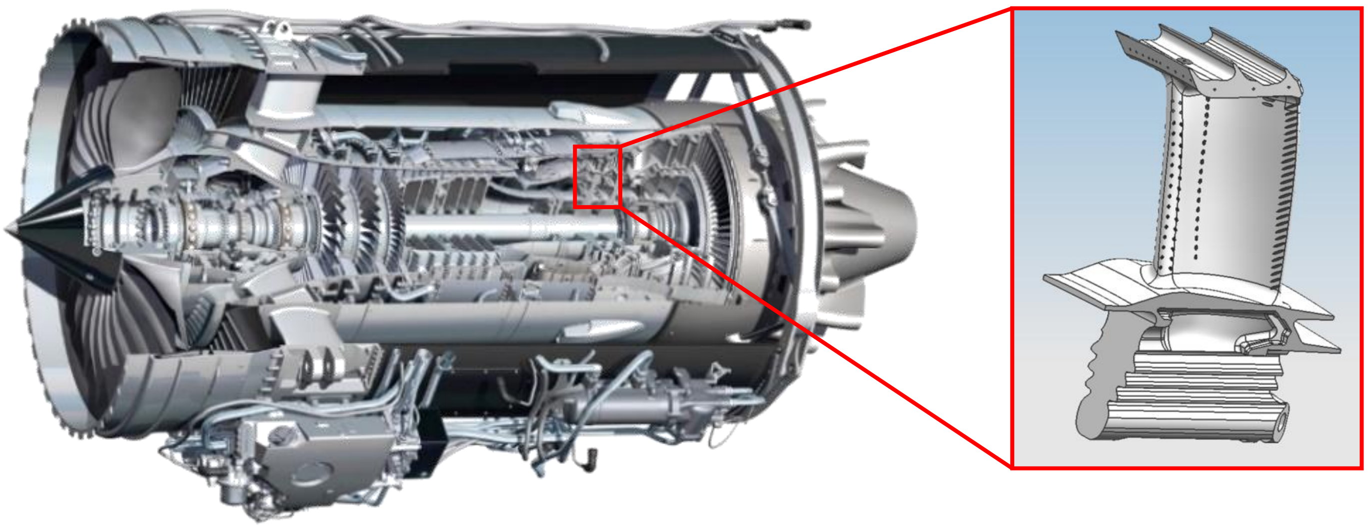
- Manufacturing uncertainties influence component properties, which can result in invalid components
- Robust design addresses this problem in an early design stage
- Challenge: new methods and strong increase in the number of simulations



Focus of this work:

- Go through a robust design workflow for a real world turbine blade
- To ensure the physical integrity a deep look into the methods and an extensive validation are necessary

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Toolbox: basic functionality

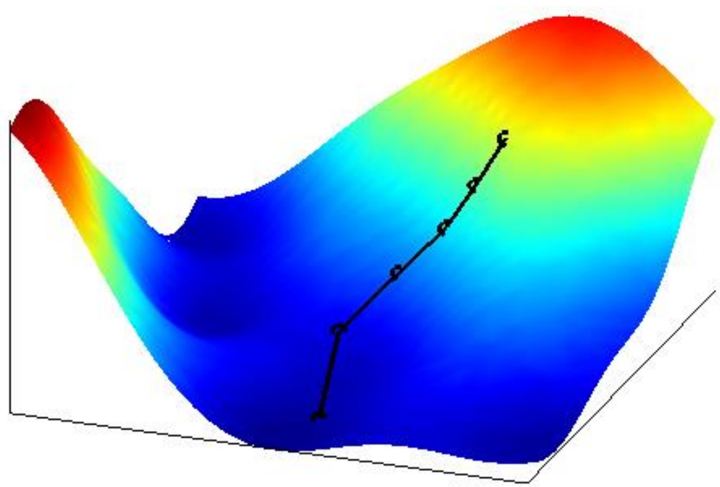
sample point generation → calculation of “real“ values → generation of response surface → optimization

sample point generation
- monte-carlo-simulation
- latin hypercube sampling
- optimal latin hypercube sampling

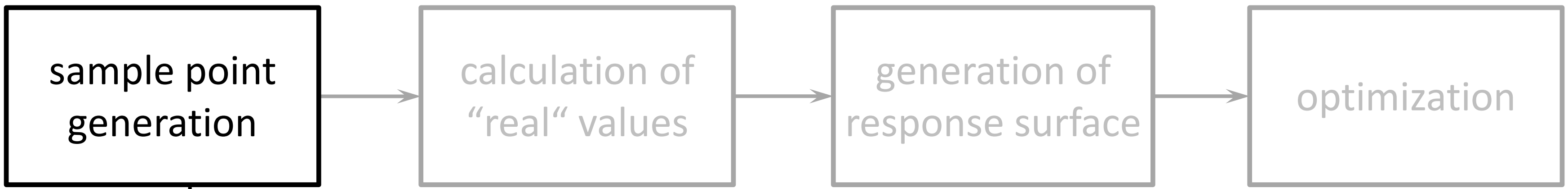
calculation of “real“ values
- usage of typical test functions for optimization problems
- later: real world problem of HP turbine blade

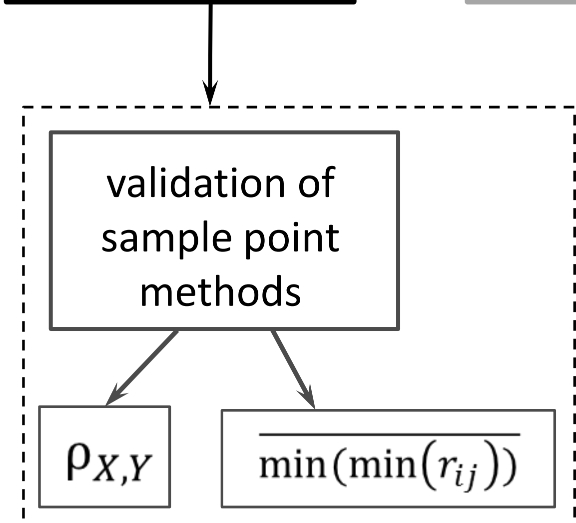
generation of response surface
- linear regression (LR)
- radial basis functions (RBF)
- combination of LR und RBF
- kriging method

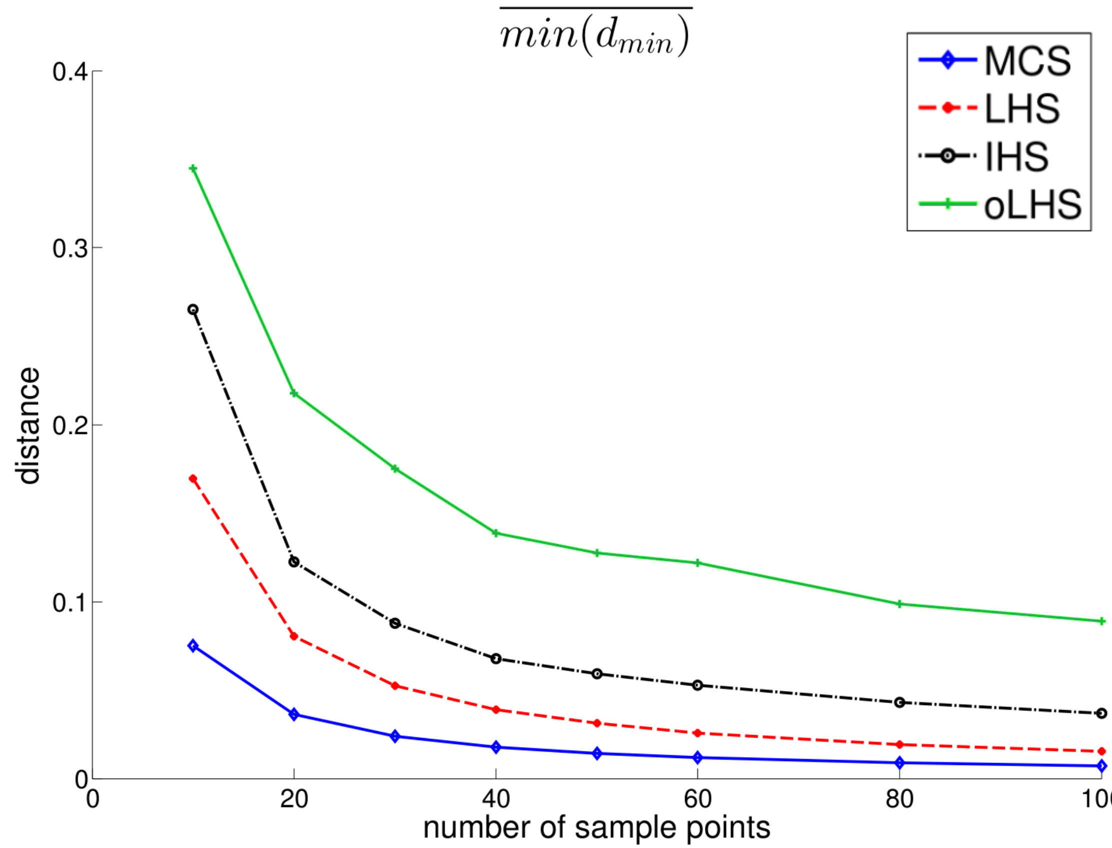
optimization
- Simplex
- CMA-ES
- NSGA-II



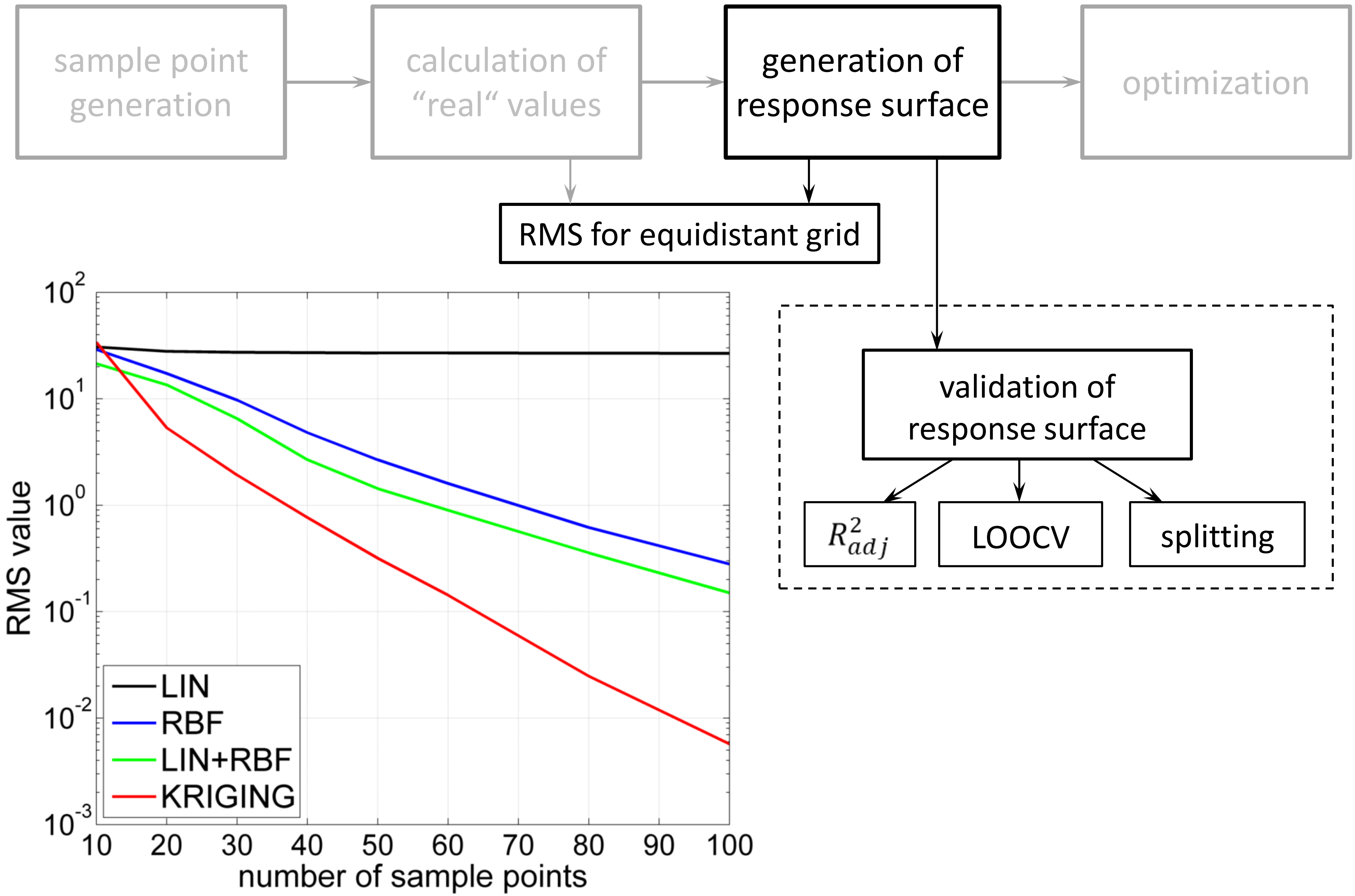
Toolbox: validation – sample point generation







Toolbox: validation – generation of response surface



Case: input and output parameters

Geometry → 16 Parameters

- Lean, skew and axial shift for 5 sections
- Lean, skew and axial shift for platform
- Scaling factor for wall thickness of PS and SS

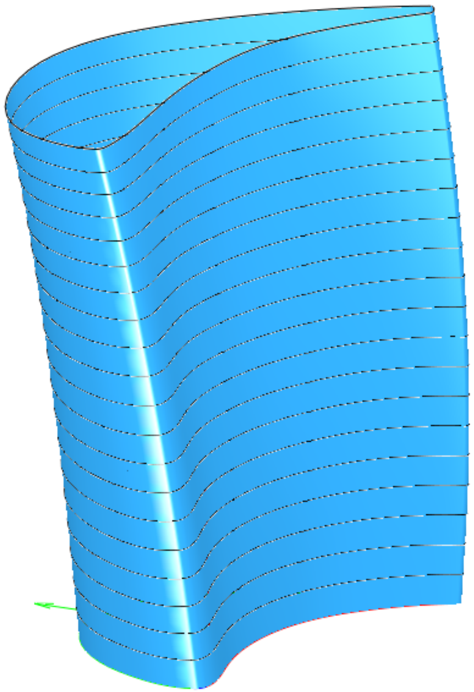
Boundary conditions → 1 Parameter

- Scaling factor for temperature field

Material → 1 Parameter

- Crystal angle

⇨ uncorrelated 18 dimensional normal distribution



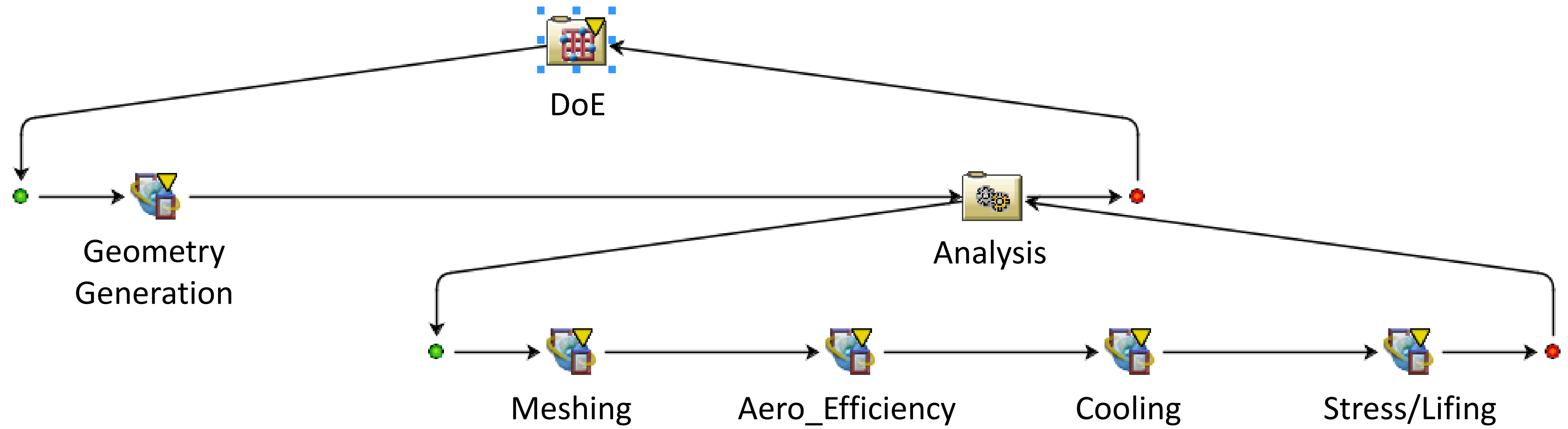
Main objective

- external combined life of LCF and Creep on the aerofoil

Further objectives

- internal combined life (core)
- mass of the blade
- aero efficiency

Case: workflow and execution



Execution:

- Generate 2 sets of sample points: 300 with oLHS- and 130 with MCS-sampling
- Distributed calculation (~3-4h per sample point) over different workstations
- Create response surface for every output parameter
- Run various optimizations

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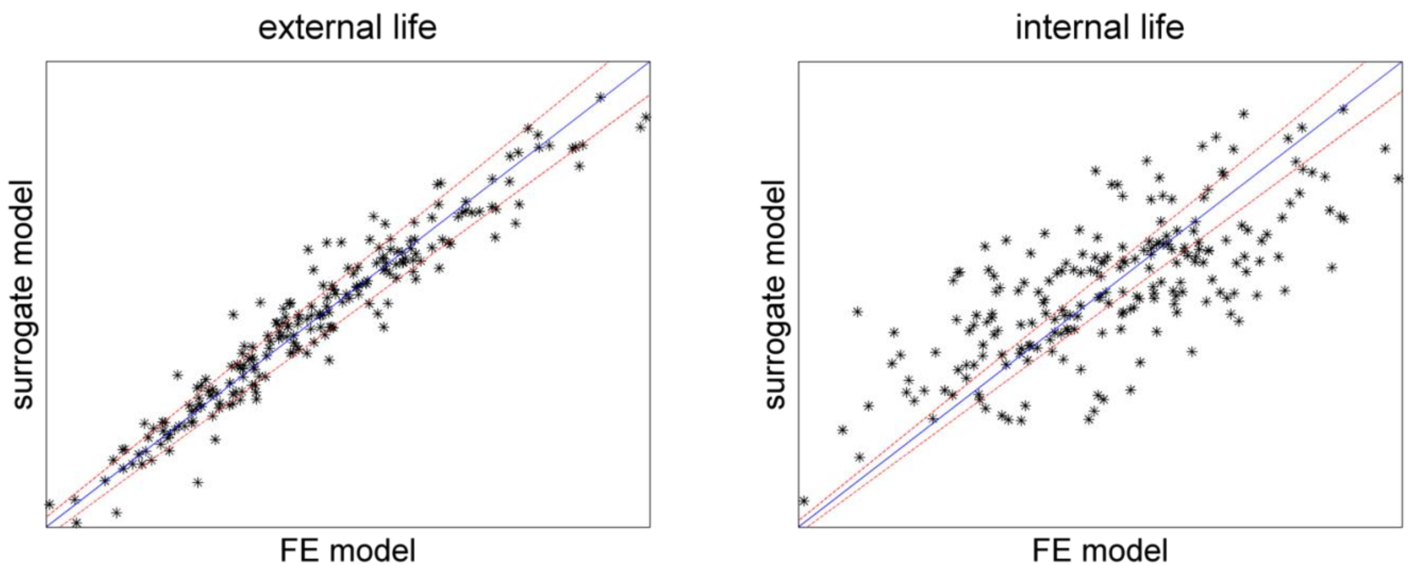
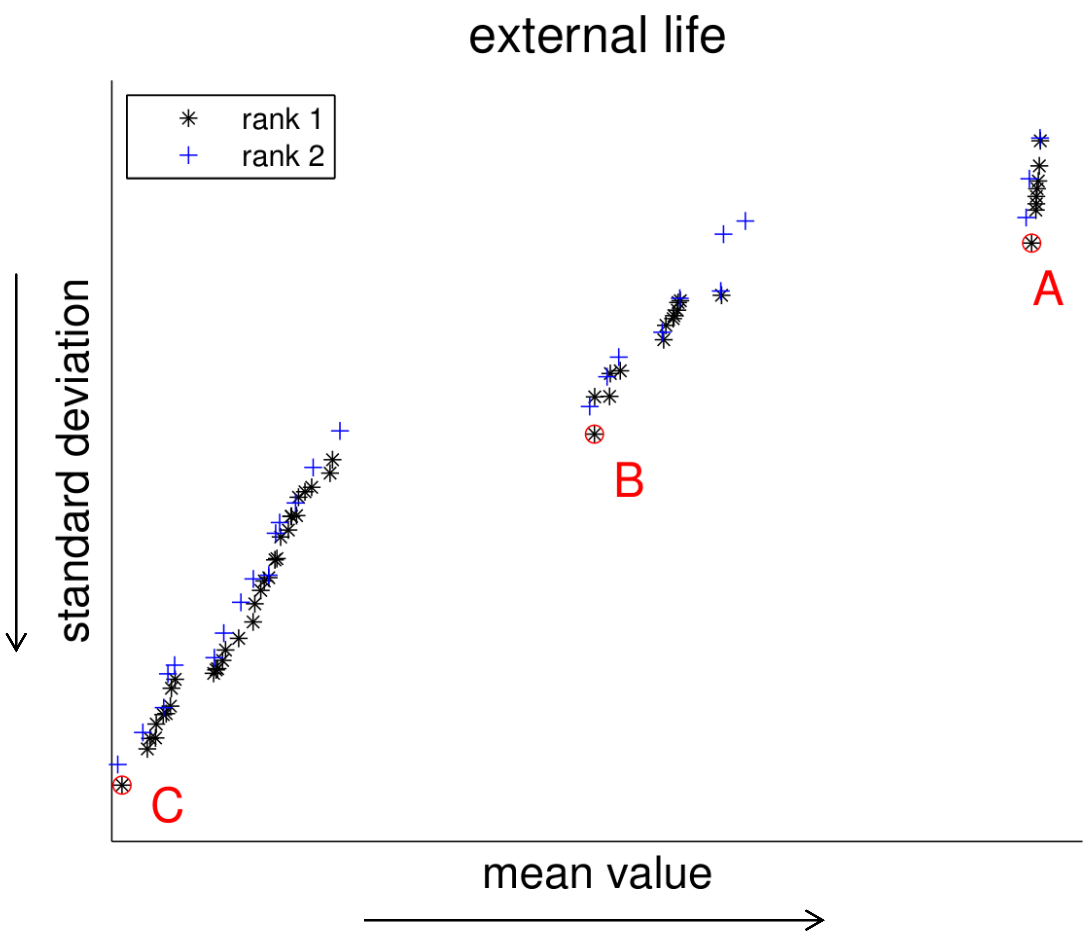
Results: generation and validation of response surfaces

	mass	external	internal	efficiency
LR	0.749	0.749	0.348	0.988
RBF	0.931	0.896	0.216	0.991
Kriging	0.976	0.965	0.715	0.999

LOOCV with correlation coefficient after Pearson

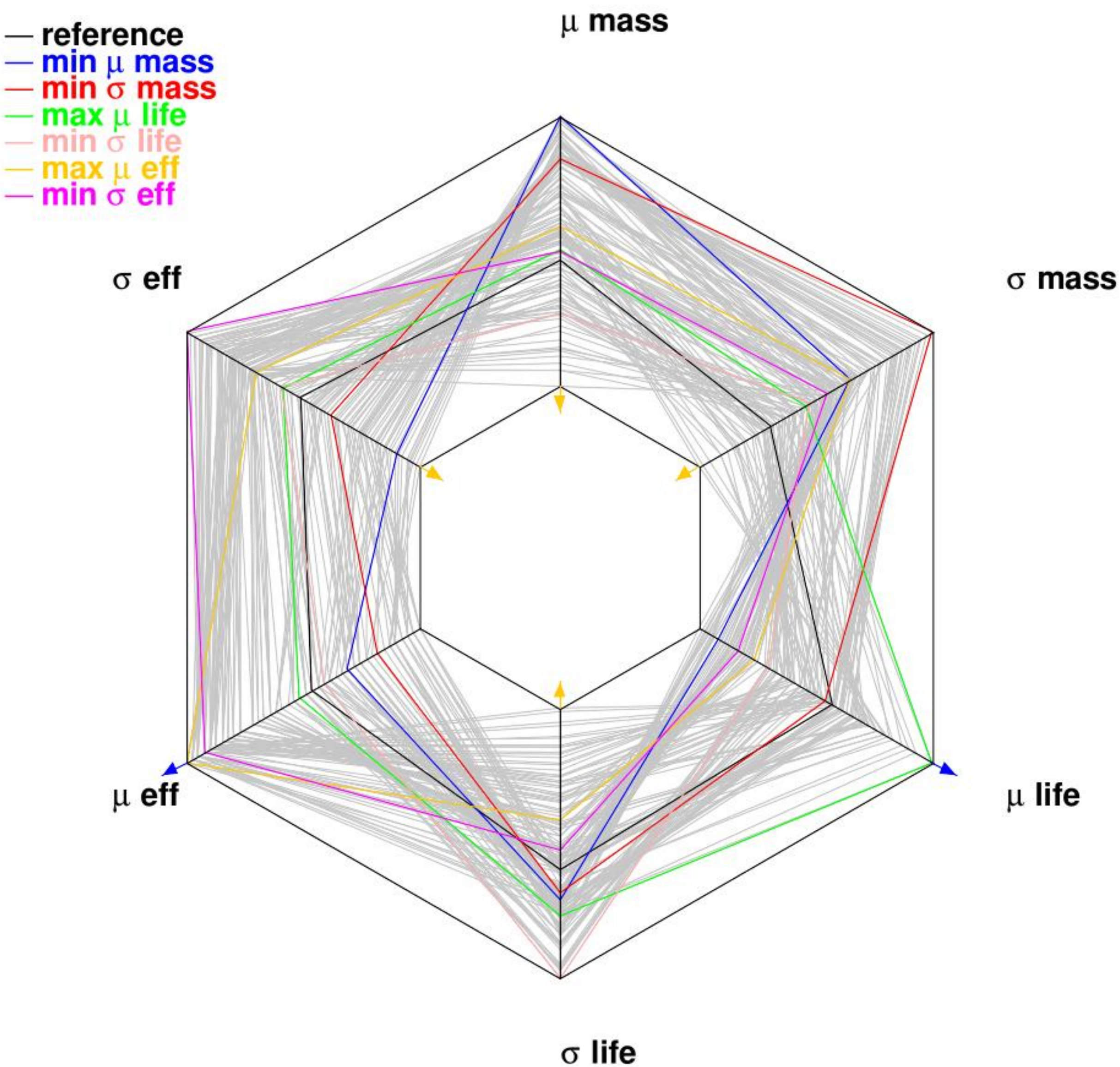


Results: robust design optimization for external life



Optimizer
- NSGA-II - 80 individuals - 100 generations - 500 evaluations

Results: multi objective and robust design optimization



Optimizer

- NSGA-II
- 150 individuals
- 300 generations
- 500 evaluations

➔ 22.5 million evaluations

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Achievements

- Created a toolbox containing most important methods for sample point and response surface generation, a lot of generic test function and various optimization algorithms

- First demonstration of a full multi-objective and robust design optimization for a real world turbine blade with the help of response surfaces at RRD

Research outlook

- Use correlated set of input parameter with more realistic distributions for the robust statement and reduce the number of evaluations for robustness with more advanced methods

Thank you for your attention!

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