Experiment Planning for Simulation based Verification

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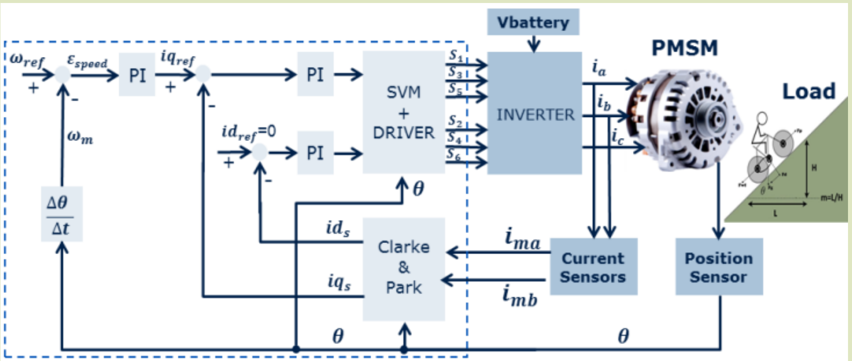
Overview

- Motivation
- Experiment Planning
- Example: eBike application
- Summary

Products must be robust in their application



- Systems must function under full range of conditions and applications

⇒ highly-dimensional, continuous verification space

⇒ requirements on verification:
  - Product robustness
  - Quality assurance (coverage, automation)

Source of variation	***Example factors***	***Performances***
Operating conditions	Temperature, supply voltage/current	*Static*: power consumption *Dynamic:* current ripple *Pass/Fail*: reset outputs *Class*: failure mode
Design parameters	*Discrete*: ADC resolution, Amplifier gain *Continuous*: Power switches ON-Resistance, Amplifier offset	
External components	Load, supply circuitry	
Component tolerances	R, C, …	
Process variations	Technology-dependent (Poly resistor, Vth …)	
Noise sources	Noise on ADC input, Process noise	

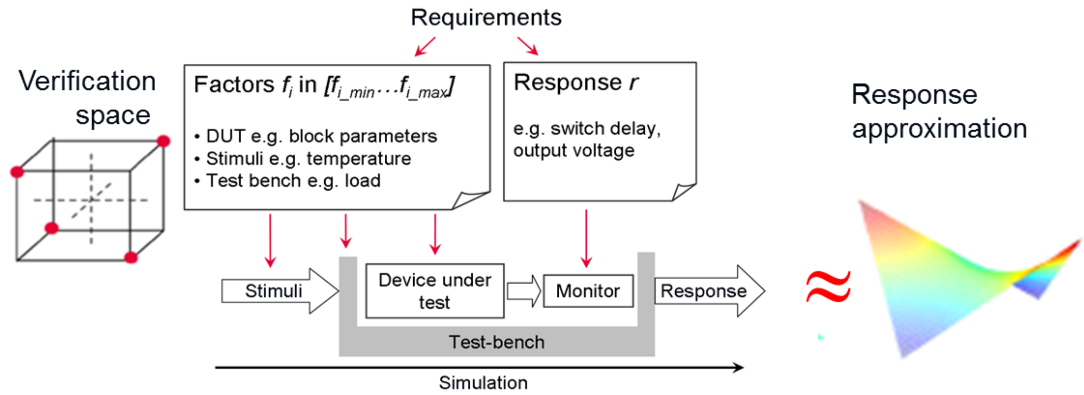
Design of experiments

Design of experiments (DoE) is a set of methods to plan and analyze experiments, which apply changes to the input variables of a system (factors) to identify with minimum resources the reasons for changes in the output, referred to as response.

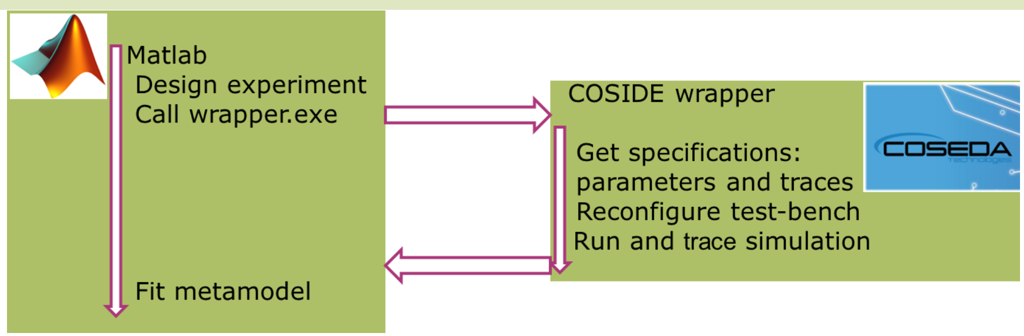
Method objectives:

- Screening: Identify factors with significant impact on the response
- Sensitivity analysis: Find effects of factors on the response
- Worst-case analysis: Find factors for worst-case response
- Optimization: find factors which optimize specific outputs

Experiment Planning and Analysis for Simulation based Product Verification:



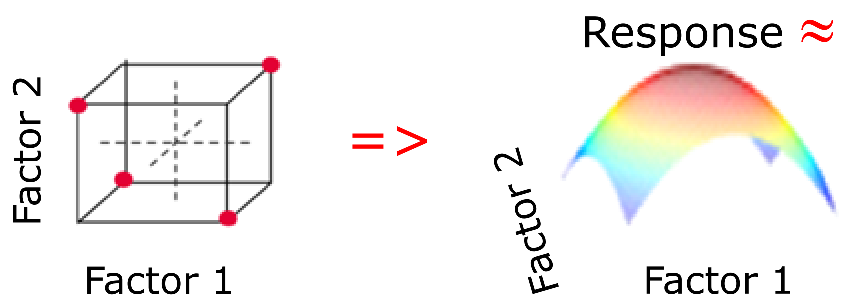
Environments



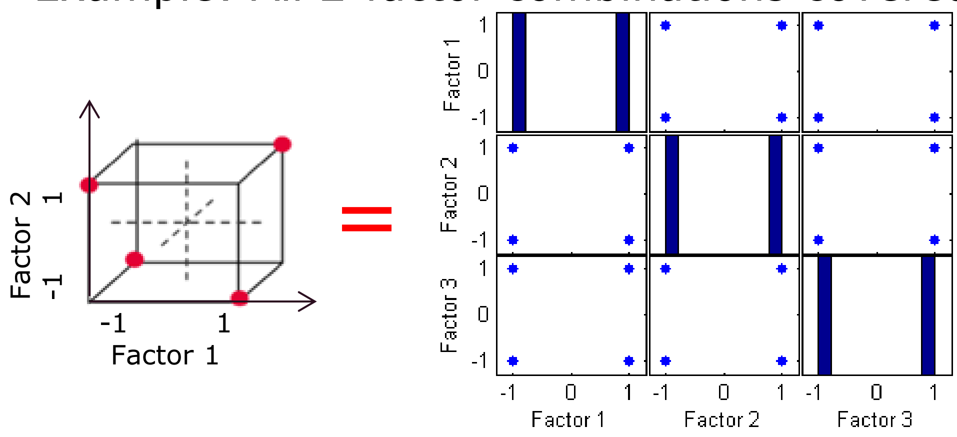
Experiment planning goals

- Prediction between samples
  - Metamodels explain variability of test parameters by effects of factors
- Coverage
  - Problems arise from up to 3 factors, mostly in corners
- Uniformity & de-correlation
  - Equal importance between factors and combinations
- Redundancy
  - Combinations occur more times

Example: Quadratic metamodel

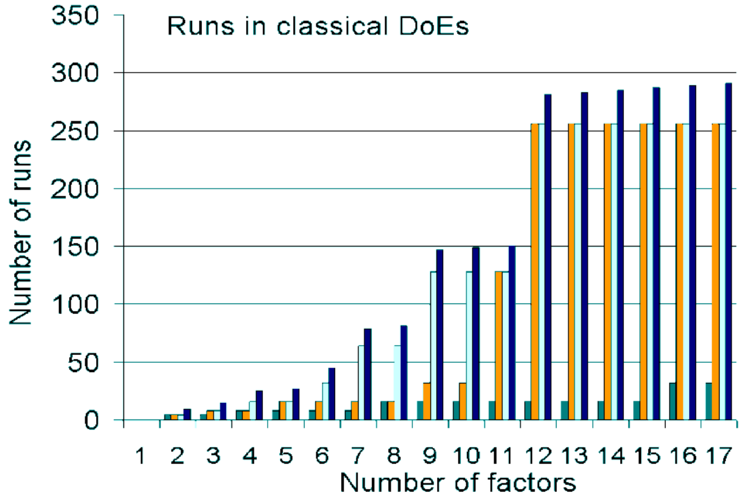


Example: All 2-factor combinations covered

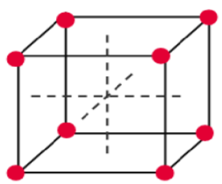


Classical Design of Experiments

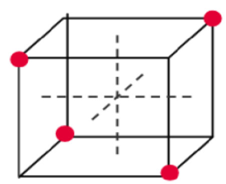
› Polynomial metamodels: $R(f) = c_0 + \sum_{o=1}^{2} \sum_{i=1}^{n} c_i^{(o)} \cdot f_i^o + \sum_{j=1}^{n-1} \sum_{k=j+1}^{n} c_{jk} \cdot f_j \cdot f_k$



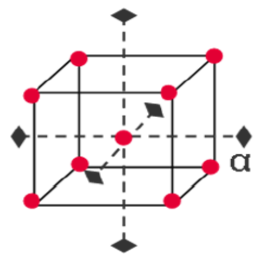
- 1st order without interactions
- 1st order with some interactions
- 1st order with interactions
- 2nd order with interactions



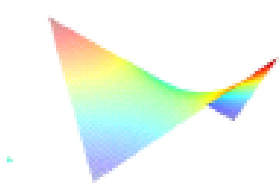
⇒1st order model with interactions

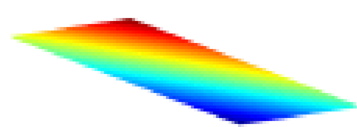


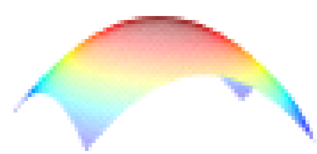
⇒1st order model without interactions

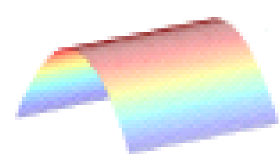


⇒2nd order model









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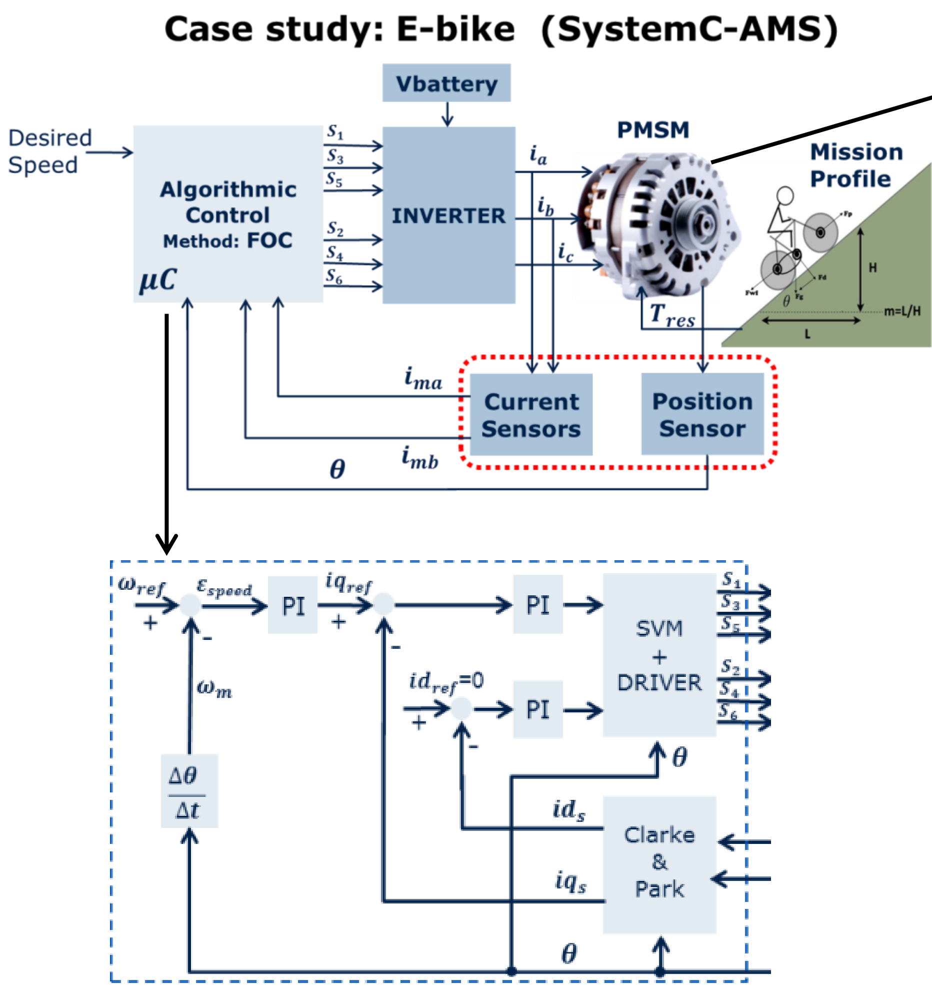
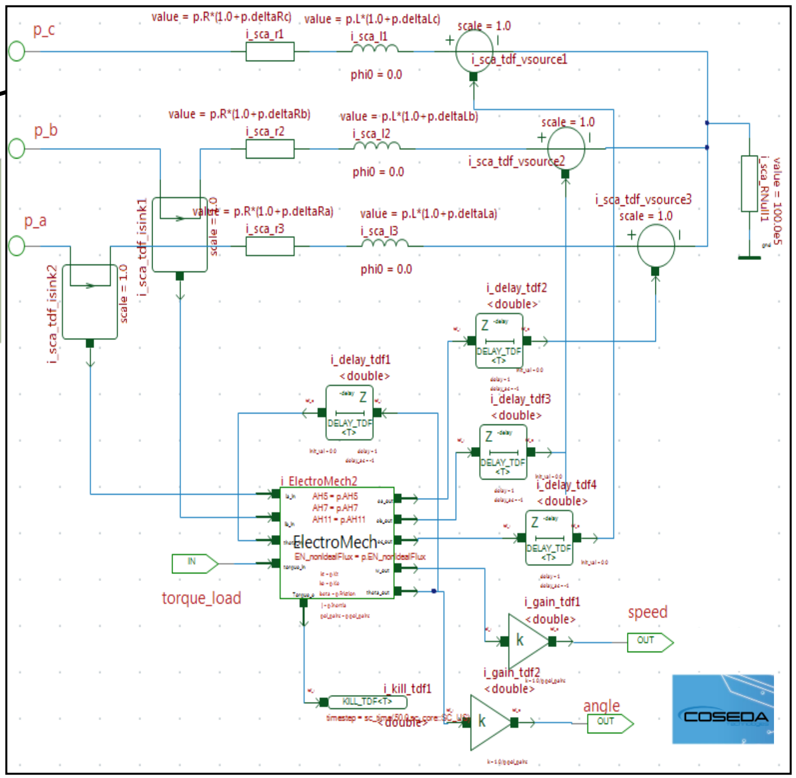
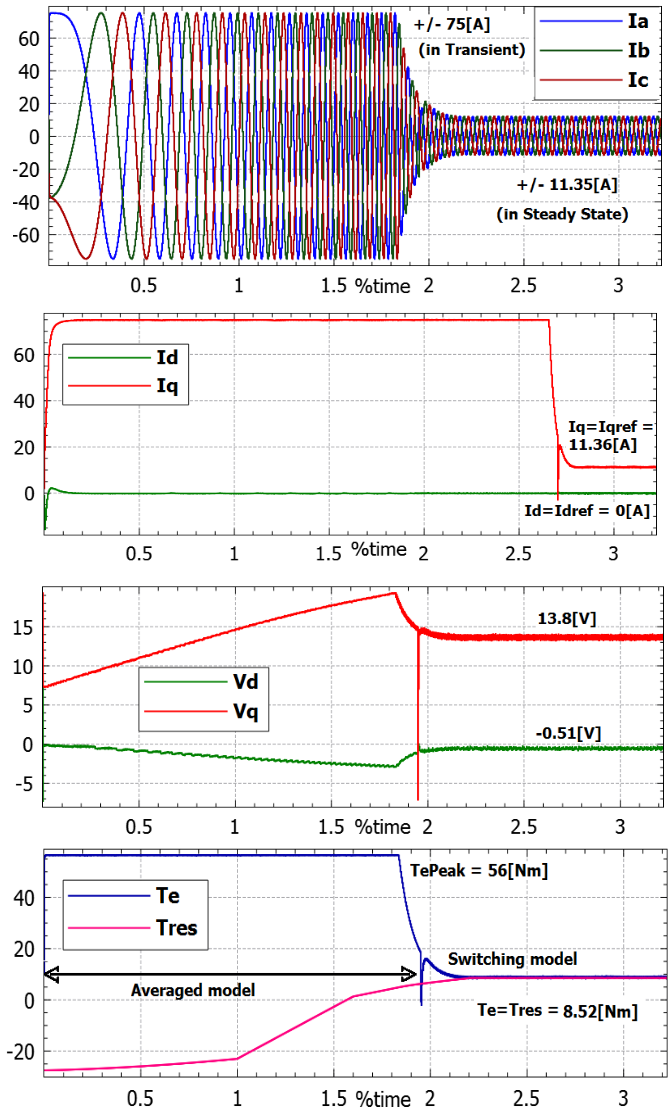
System Model Description





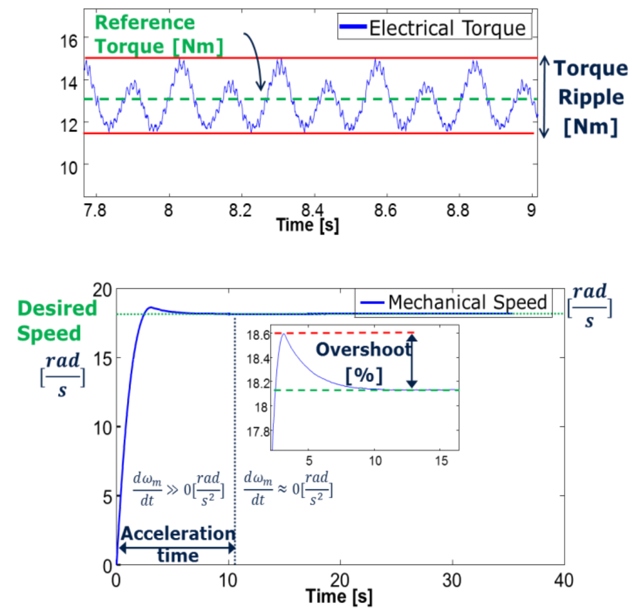
Simulation results

- Startup phase: Currents and Torque critical for the steady state phase



- The effect of control, sensors, and load, on the speed and torque are investigated in steady state:

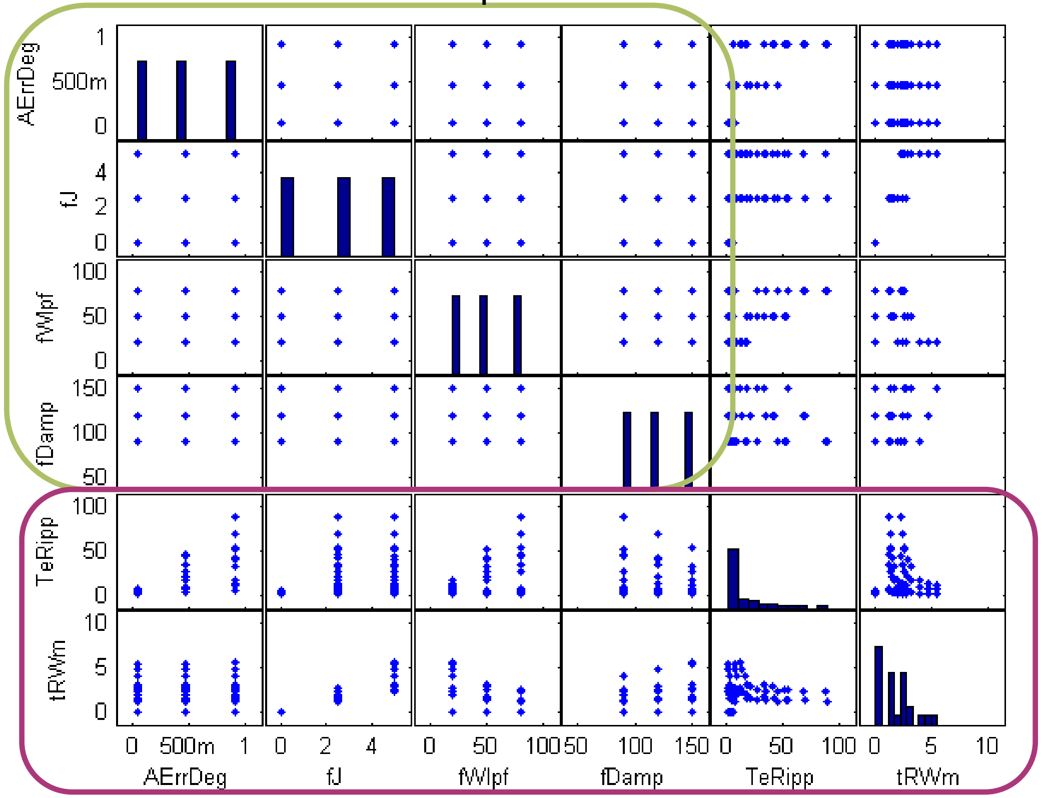
System Responses



Experiment results

Varia bles	Source	Name
Factor s	Component features	Angle sensor error AErrDeg
	Controllable	PI controller parameters: fWlpf, fDamp
	Uncontrollable (environment, application, components)	Load inertia fJ
Respo nses	Properties of electrical and mechanical responses	Ripple electrical torque TeRipp, Time in speed response tRWm

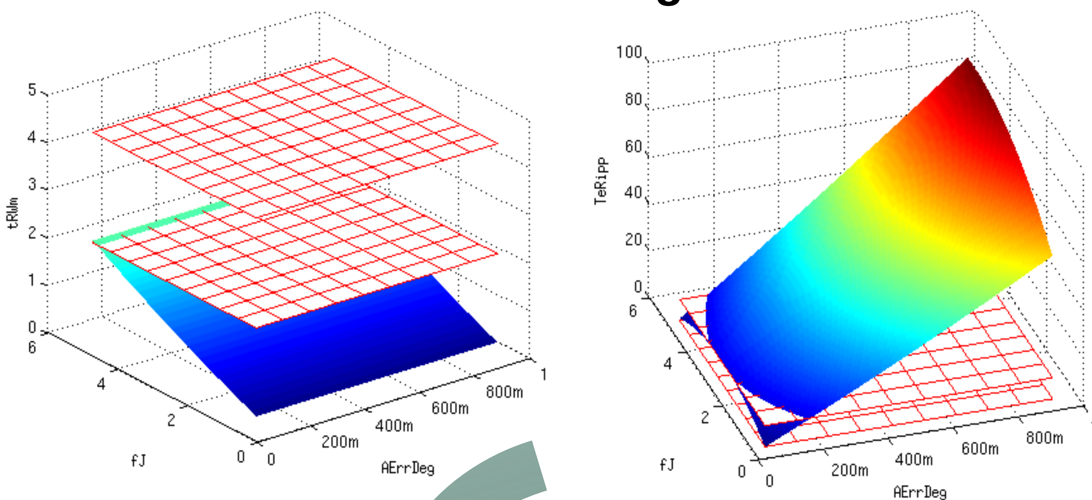
- 2-level factorial experiment



- Effects responses
  - vs. factors
  - vs. responses

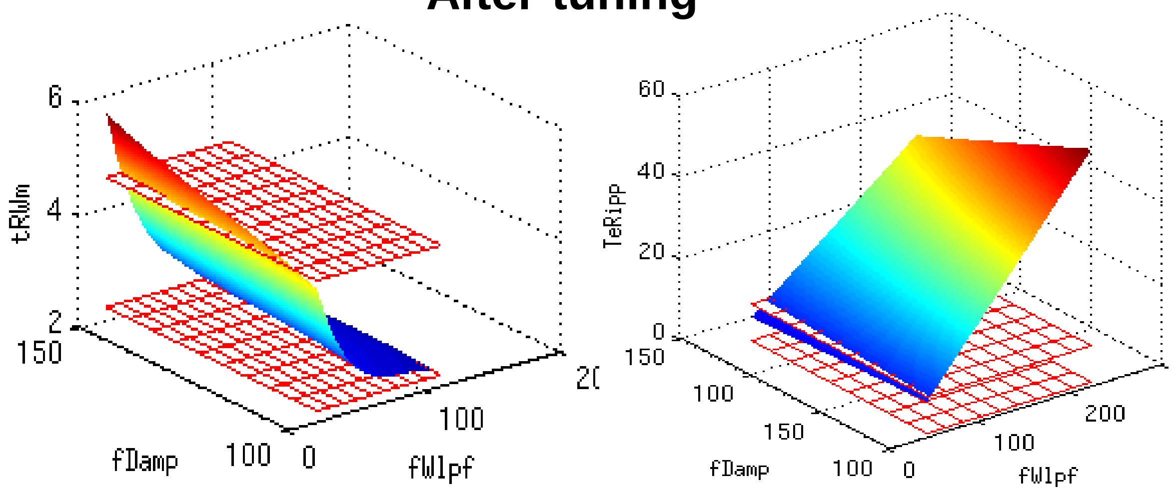
Trade-Offs between System Performances and Optimizations

Before tuning



Control Factors:
$fWlpf = 100$
$fDamp = 110$

After tuning



Control Factors:
$fWlpf = 25$
$fDamp = 130$

Summary

- SystemC-AMS experiment planning is a systematic solution to investigations on fitness of components in target application
- Experiment planning is a systematic solution to an in-depth analysis of the impact on components on performances
- Based on metamodels, application parameters can be optimized, with respect to the impact of the undesired variations
- This was applied for tuning the control for eBike application optimization

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