Optimization in a nutshell – Introducing *optiSLang* to Master's students

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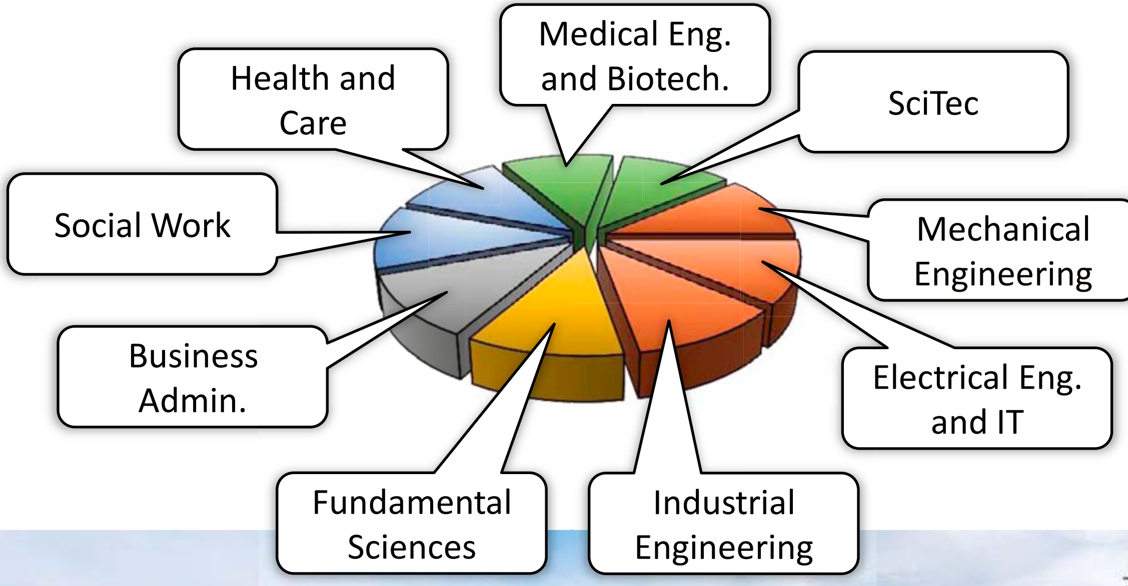
Ernst-Abbe-Hochschule Jena
University of Applied Sciences

Welcome to our university!

Ernst-Abbe-Hochschule Jena
University of Applied Sciences

4’700 Students
400 employees
125 professors



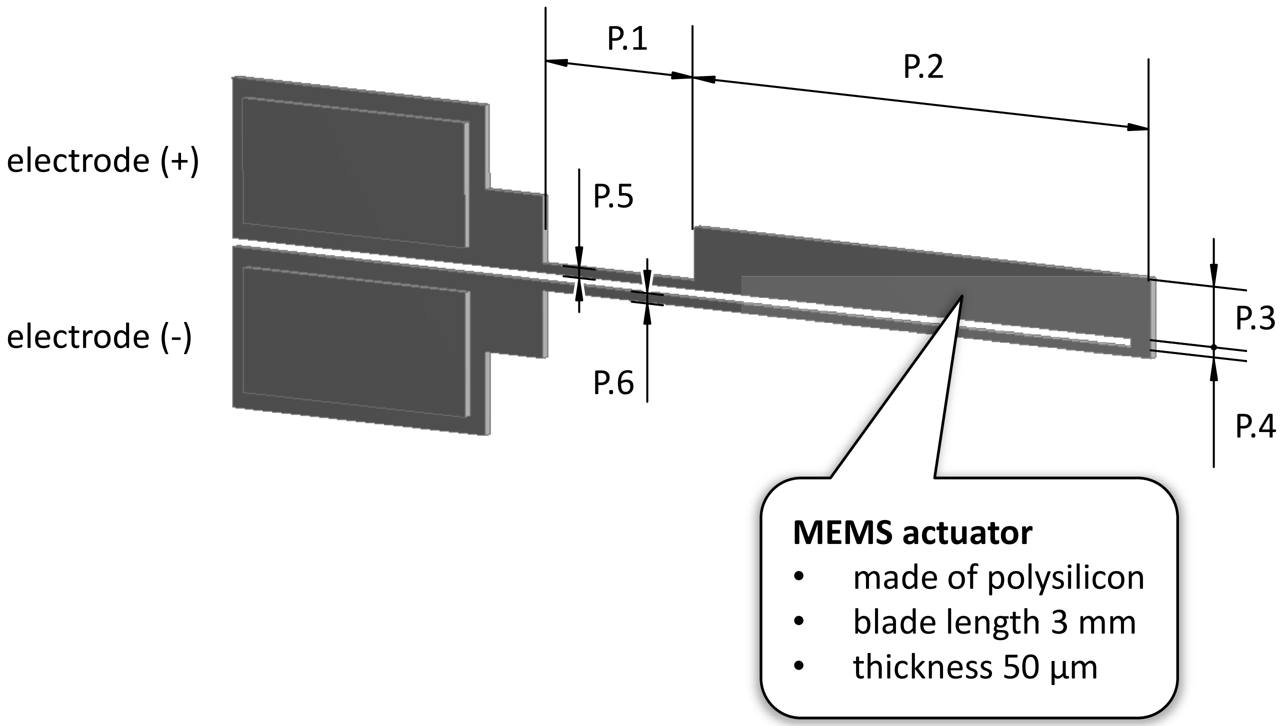
source: EAH Jena

My customers

Master's Course "Scientific Instrumentation"

Typical Challenge

Improve the design!

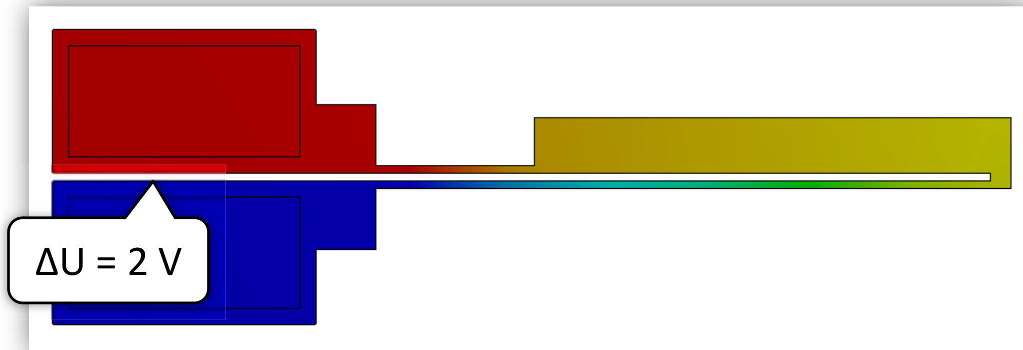


source:
Ansys WB 14.5
tutorial

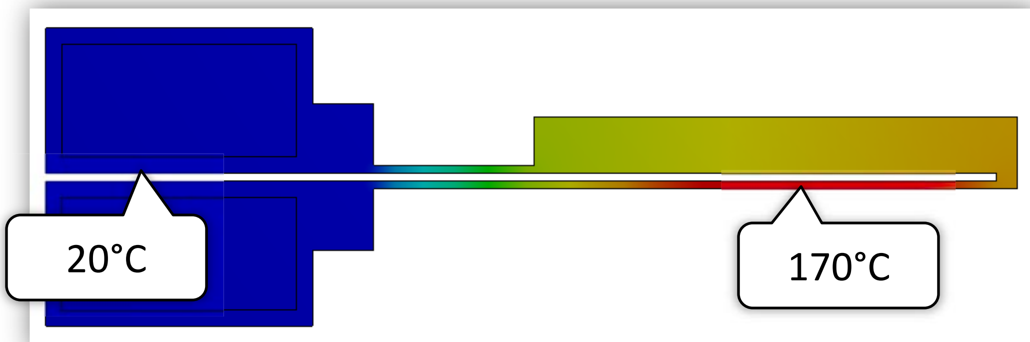
Typical Challenge

Improve the design!

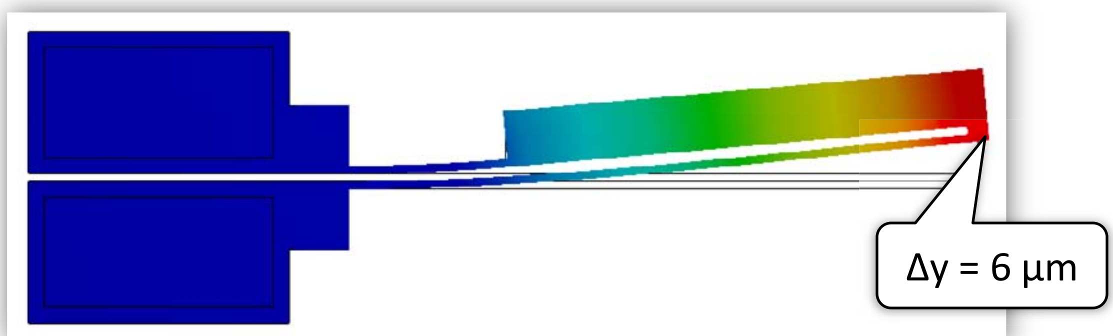
Electrical Potential



Temperature Field

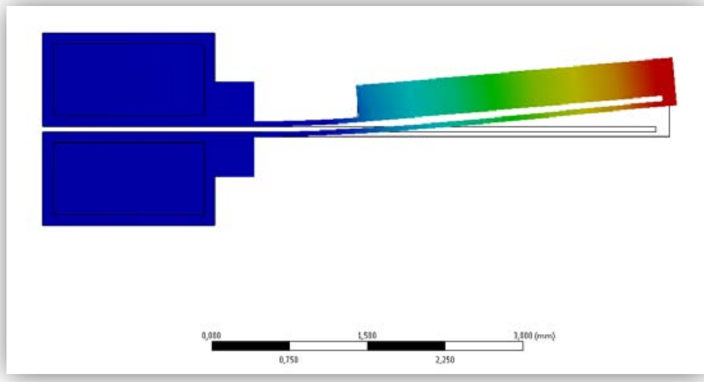


Displacement Field



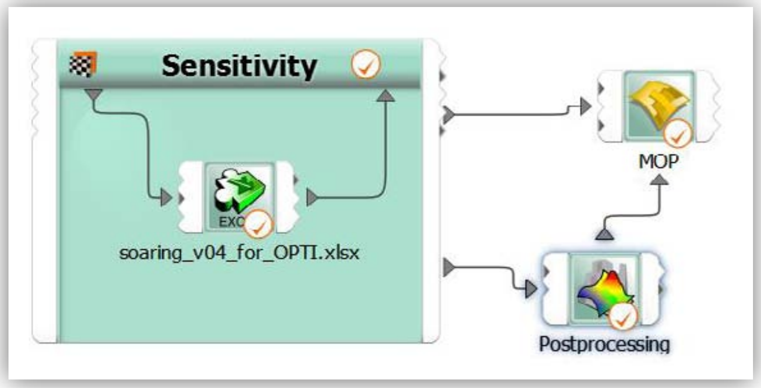
Typical Challenge
Improve the design!

Plan A:
"making in up as you go along"



1. setup experiment and begin exploring a somewhat "defined" design space
2. realise: applying the "typical" full factorial DoE sampling restricts the number of parameters to be explored
3. conclude a rather limited "optimisation"

Plan B:
"best practice"



1. develop a parametric model of the problem; define design space, objective and constraints
2. setup experiment and interface with optimisation tool
3. explore and optimise the design in true 21th century fashion

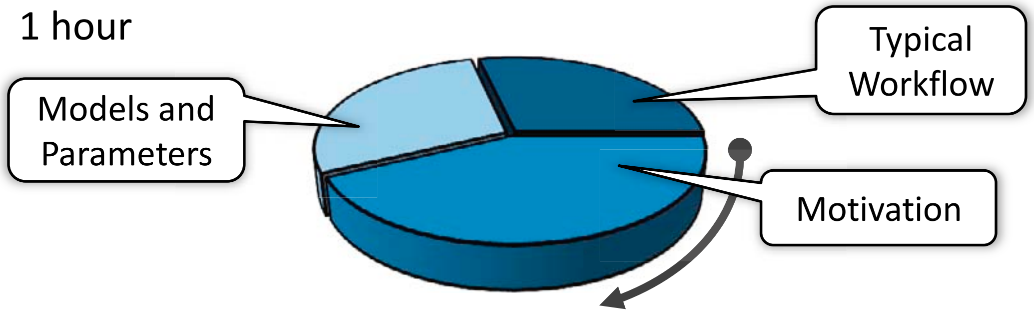
conclusion: **I need a bare-essentials optimisation course for my students!**

Course Outline

Part 1 - Lecture

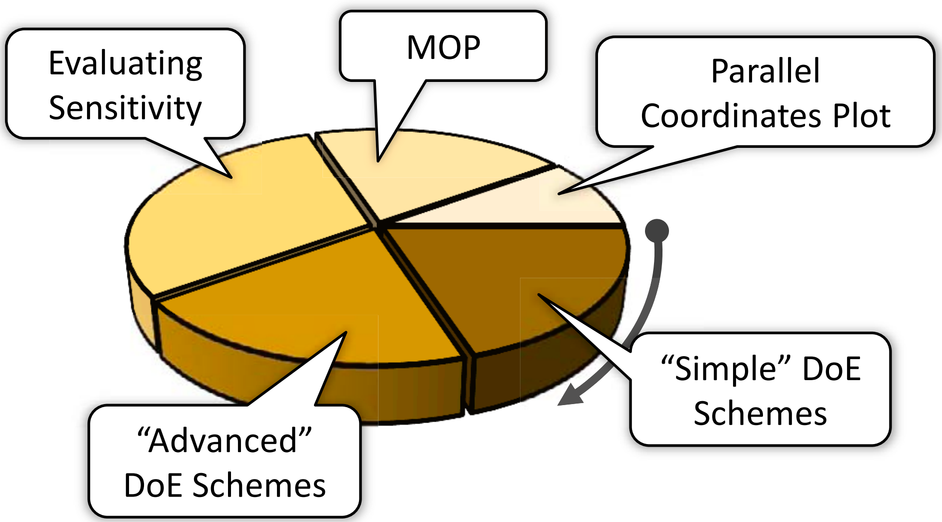
Introduction

1 hour



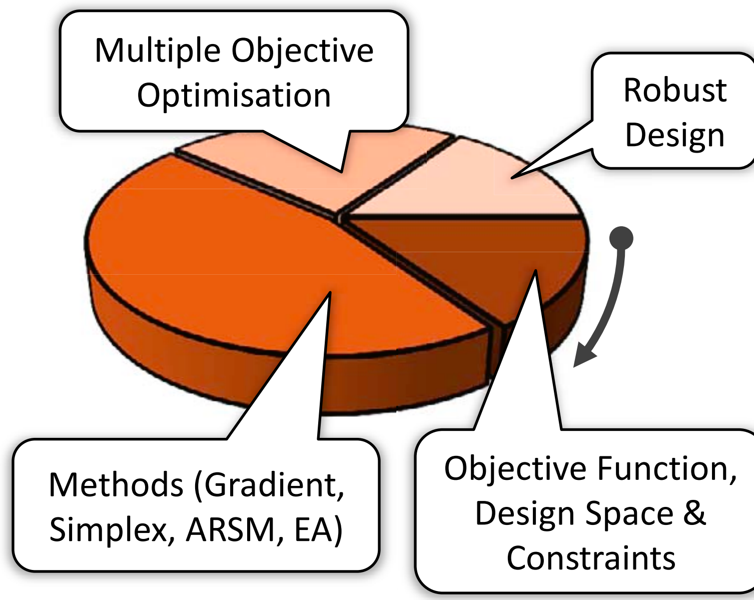
Sensitivity Analysis

2 hours



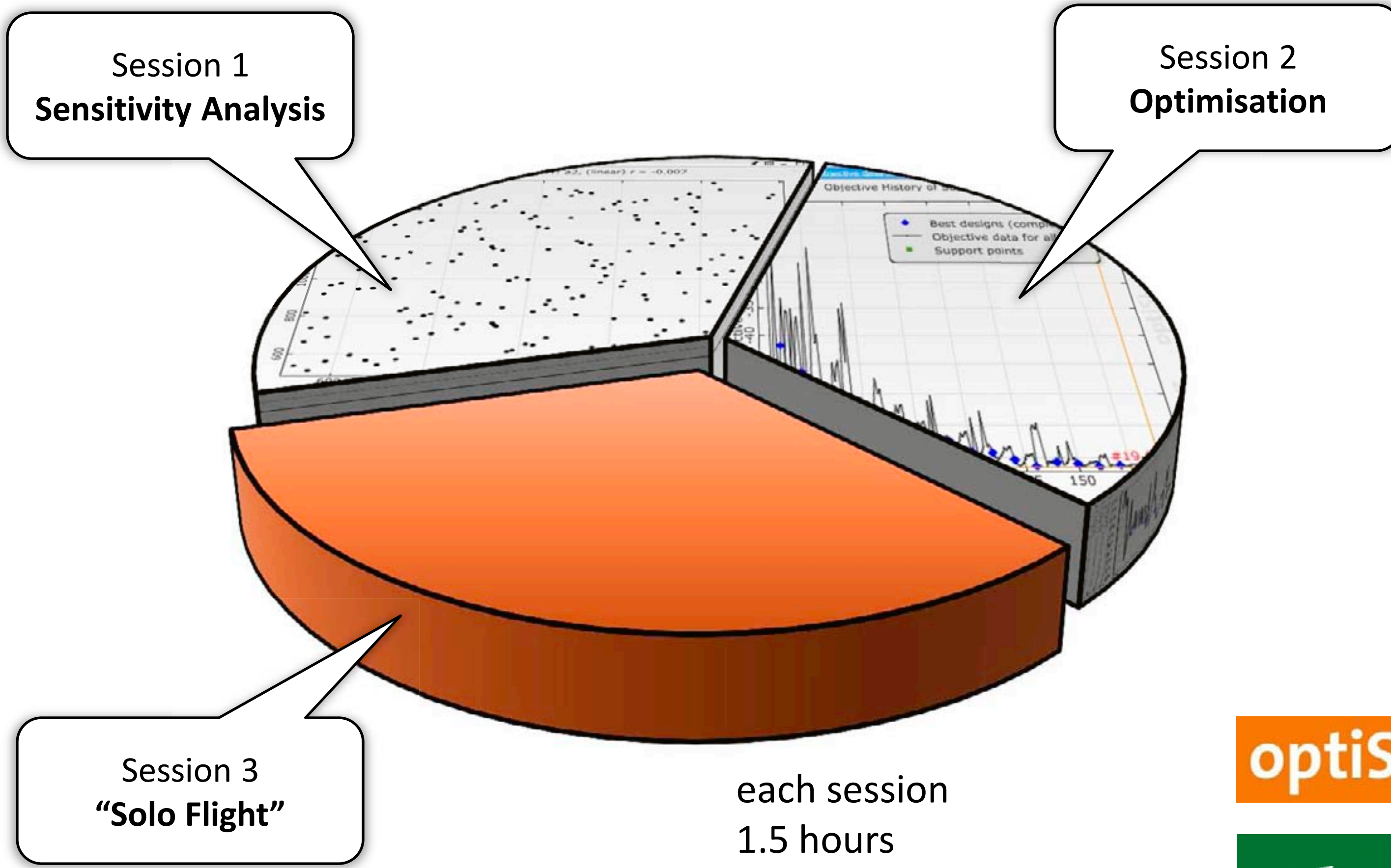
Optimisation

1.5 hours



Course Outline

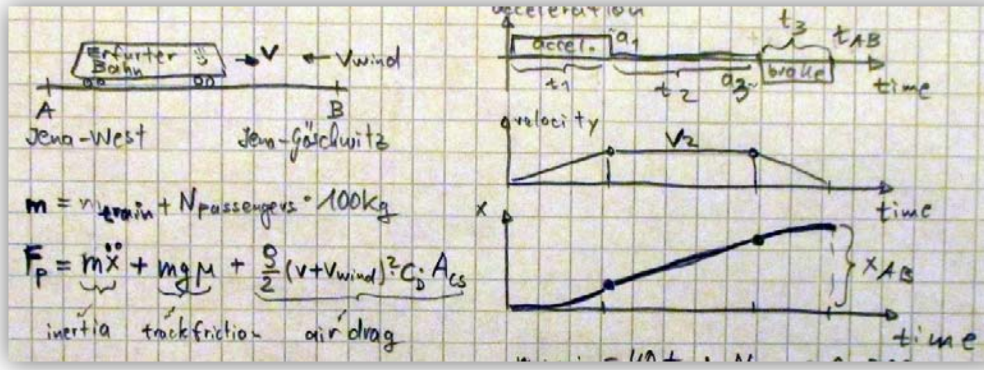
Part 2 – Computer Lab



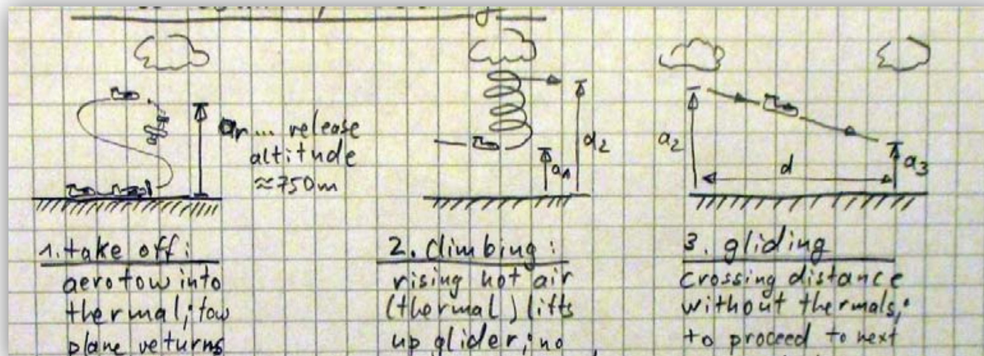
each session
1.5 hours

Part 2 – Computer Lab – The “Solo Flight”

Railway Fuel Efficiency

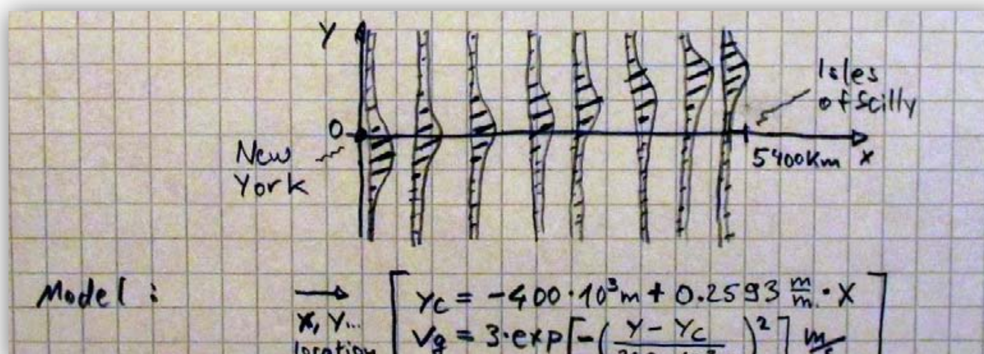


Cross Country Soaring



Blue Riband of the Atlantic


source: Wikipedia.de
RMS Queen Mary



Course Outline

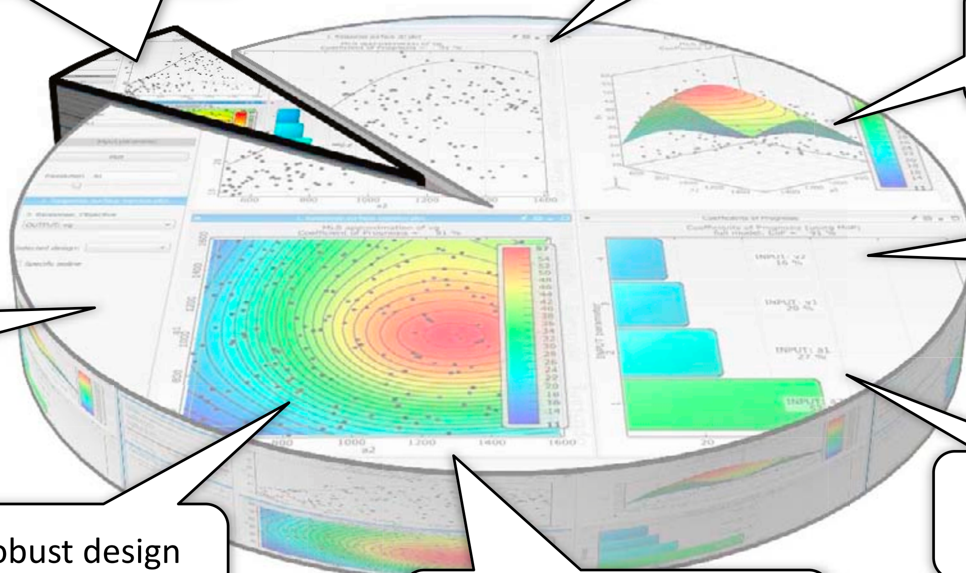
Topics we can't explore ... for now!

the contents of our *bare-essentials* course:

- a few parameters
- deterministic, continuous
- single objective optimisation
- solver: MS Excel

stochastic and discrete parameters

developing a good parametric model



direct vs. model based optimisation

and many other topics ...

loads of parameters

robust design optimisation

interfacing with ANSYS, Matlab, SimulationX etc

Computational Landscape

The model and the optimisation problem

model:

$$z(x,y) = \sum_{i=1}^{5} c_i \cdot \exp\left[-\frac{(x-a_i)^2}{\pi} - \frac{(y-b_i)^2}{\pi}\right] \cdot \cos\left[\pi(x-a_i)^2 + \pi(y-b_i)^2\right]$$

$$a = [3,5,2,1,7],\; b = [5,2,1,4,9],\; c = [1,2,5,3,3]$$

design space:

$3.0 \le x \le 4.0$ longitude

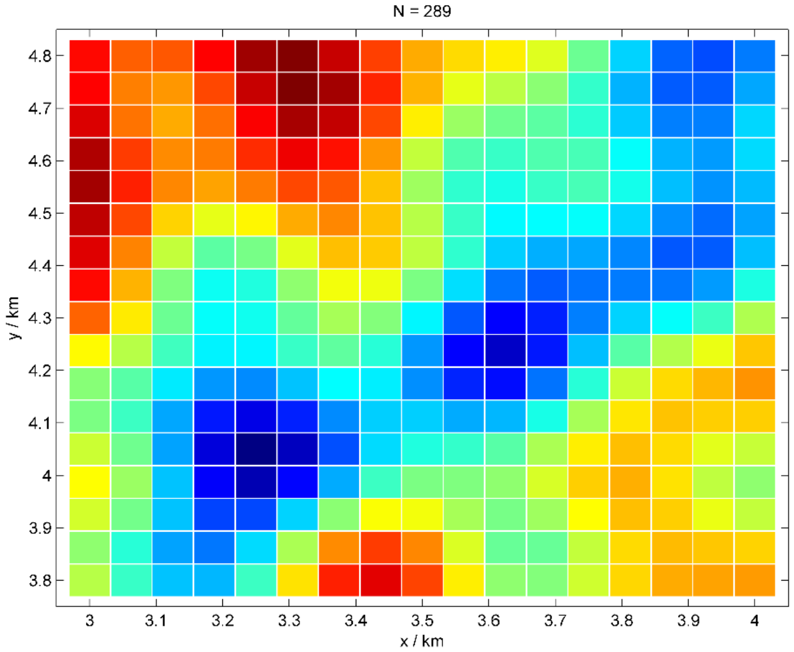
$3.8 \le y \le 4.8$ latitude

objective: $z \rightarrow \min!$ **"locate the deepest valley!"**

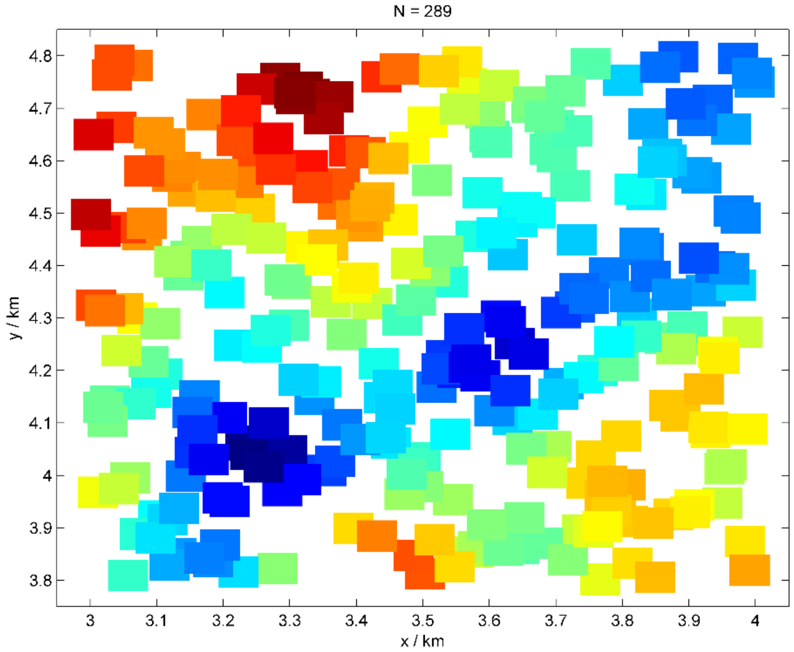
source:
Test functions for optimization needs
MARCIN MOLGA, CZESŁAW SMUTNICKI,
2005

Computational Landscape
Probing the Unknown: N = 9, 25, 81, 289

DoE scheme
Full Factorial

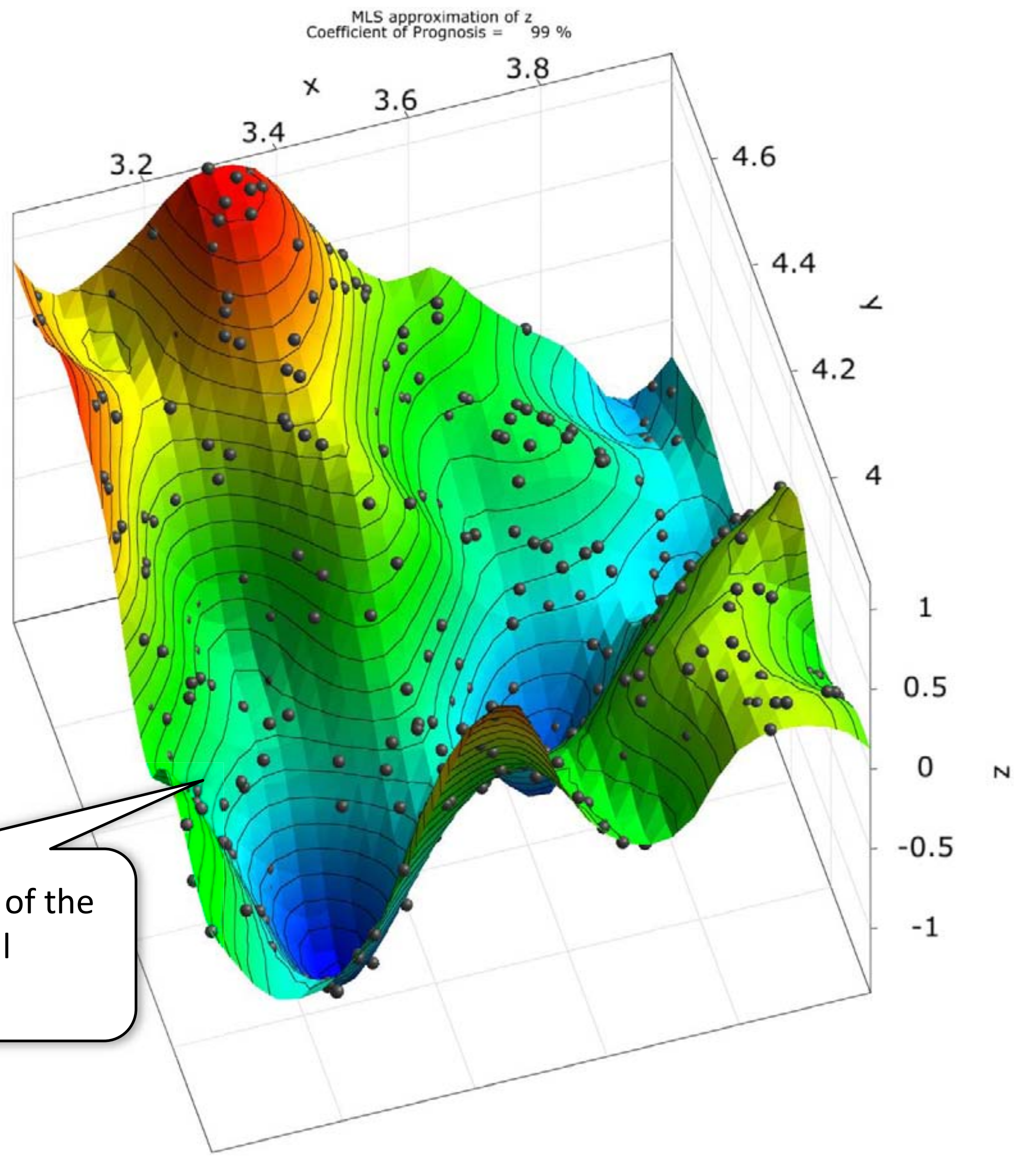


DoE scheme
Adv. Latin Hypercube Sampling



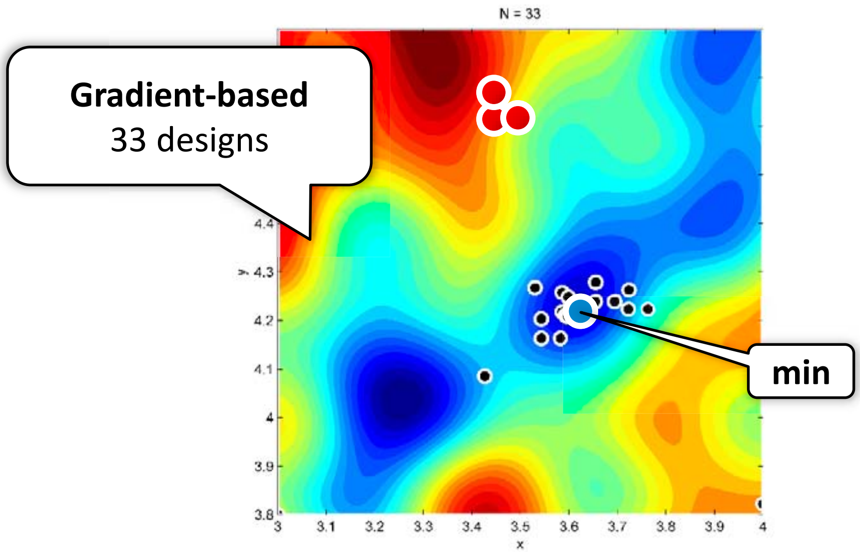
Computational Landscape

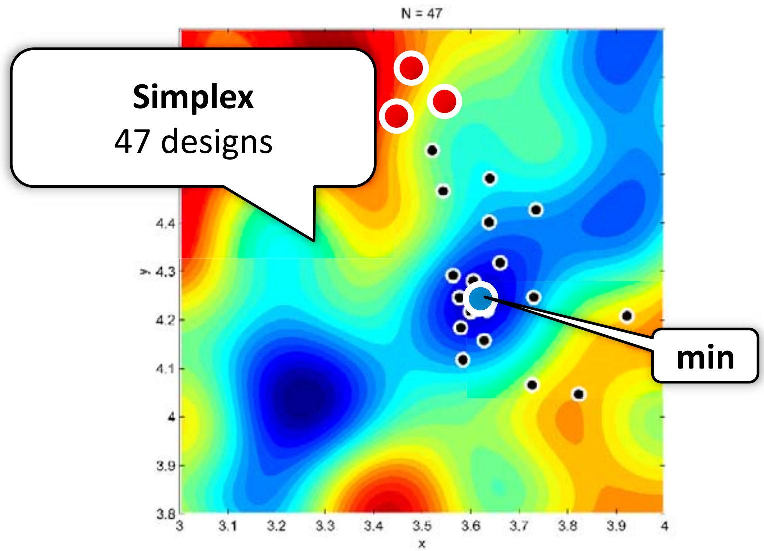
Above the tree tops – The M.O.P.

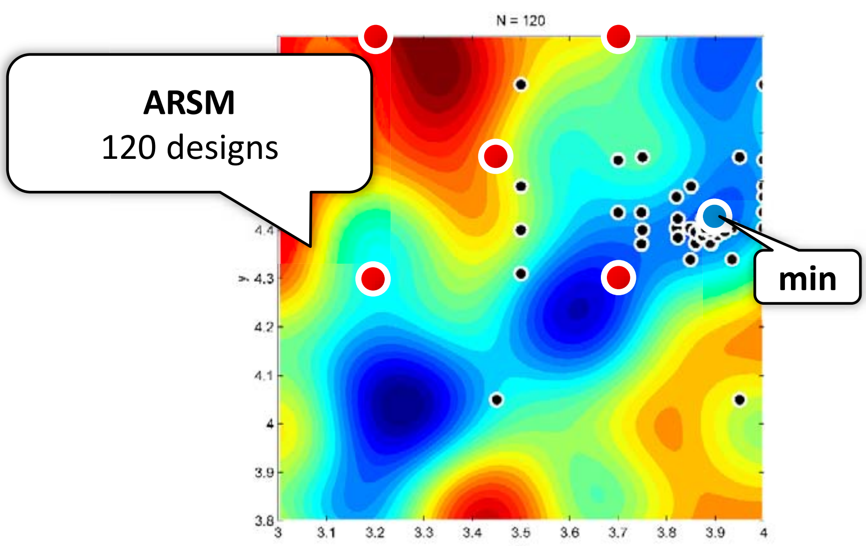


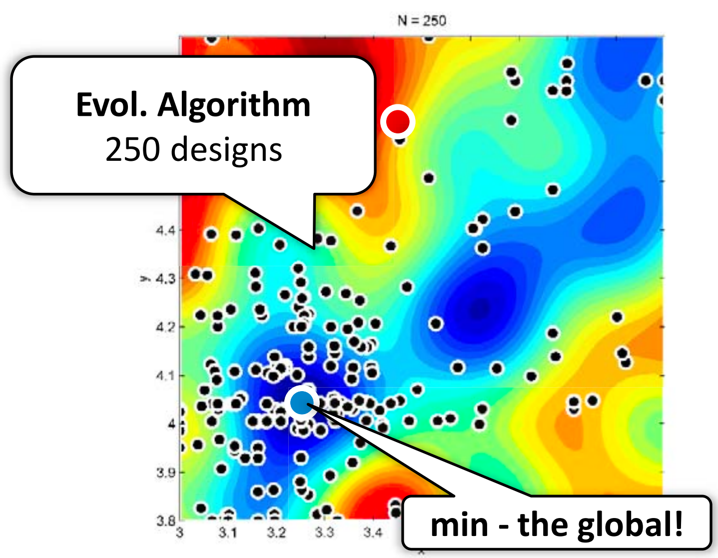
optiSLang visualisation of the Meta-Model of Optimal Prognosis (MOP)

Computational Landscape
The optimisation methods visualised









Cycling Time Trial

The model and the optimisation problem

model:

$$F_d = m \cdot g \cdot \sin\alpha$$ downward force

$$F_f = \mu \cdot m \cdot g \cdot \cos\alpha$$ road friction

$$F_a = k_1 \cdot v^2$$ air drag

$$F_p = F_d + F_f + F_a$$ propulsion force

$$P_r = \begin{cases} F_p \geq 0: & = F_p \cdot v \\ F_p < 0: & = 0 \end{cases}$$ required human power

$$rf = C_1 + C_2 \cdot {P_r}^3$$ rate of fatigue

$$f = rf \cdot t$$ fatigue

objective:

$$v_{avg} \rightarrow max!$$

"maximise average velocity!"

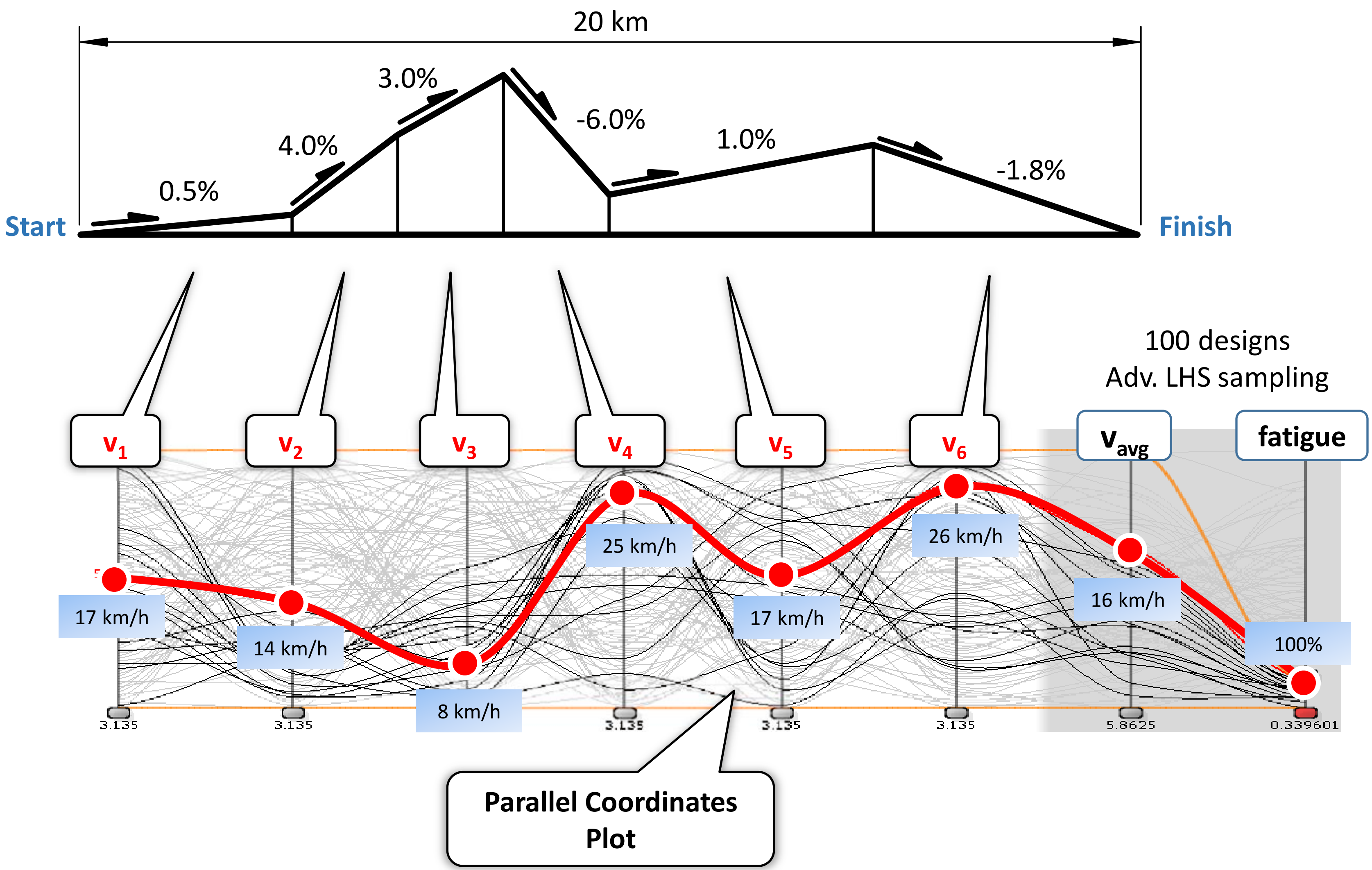
constraint:

$$f_{AB} = \sum_{i=1}^{N_{sec}} f_i \leq 100\%$$

"total fatigue accumulated over all track sections less than 100%!"

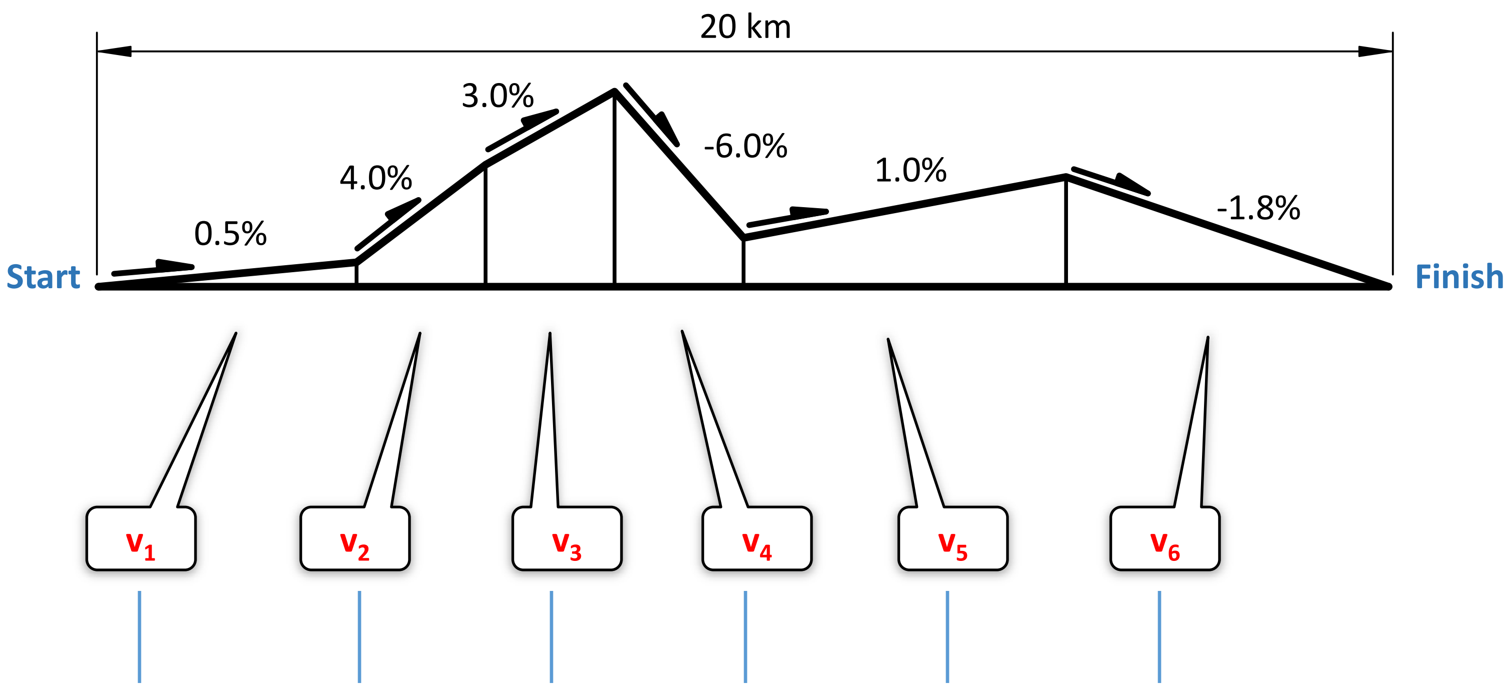
Cycling Time Trial

Making sense of the design parameters



Cycling Time Trial

Making sense of the design parameters



Importance of Parameters regarding ***“average velocity”***

23%	**3%**	**5%**	**6%**	**32%**	**27%**

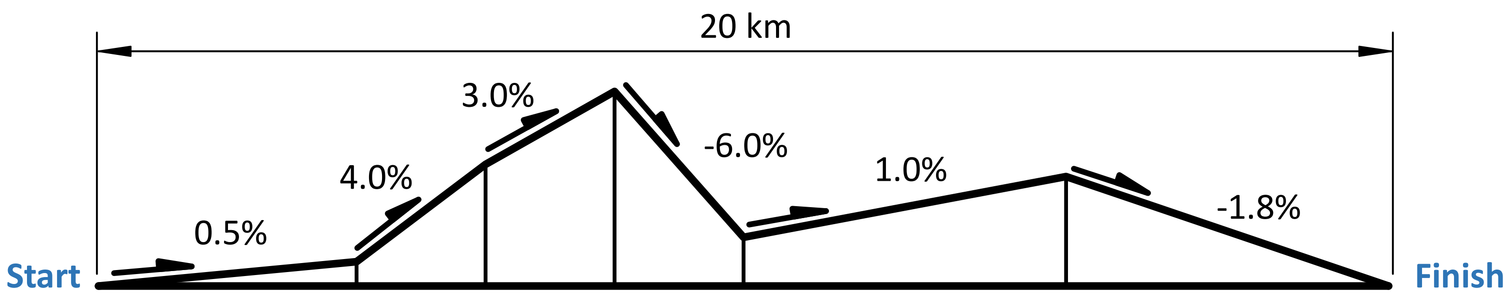
Importance of Parameters regarding ***“fatigue”***

-	**76%**	**20%**	**-**	**-**	**-**

based on MOP

Cycling Time Trial

The optimal race strategy



v_1	v_2	v_3	v_4	v_5	v_6	v_{avg}	fatigue
24.5	**9.7**	**12.2**	**40.0**	**21.1**	**40.0**	**21.2**	**100%**
22.5	**8.4**	**10.6**	**40.0**	**19.1**	**40.0**	**19.3**	**75%**
19.9	**6.8**	**8.6**	**40.0**	**16.5**	**40.0**	**16.6**	**50%**

velocity in "km/h"

by the way: **40 km/h** is the limit of my comfort zone

Farewell

Get in touch. We do love optimisation!

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