

Automatic simulation platform to support product design and optimization

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Kai Katajamäki

Outline

- Background
- Automatic calculation system in optimisation
- Case studies
- Conclusions

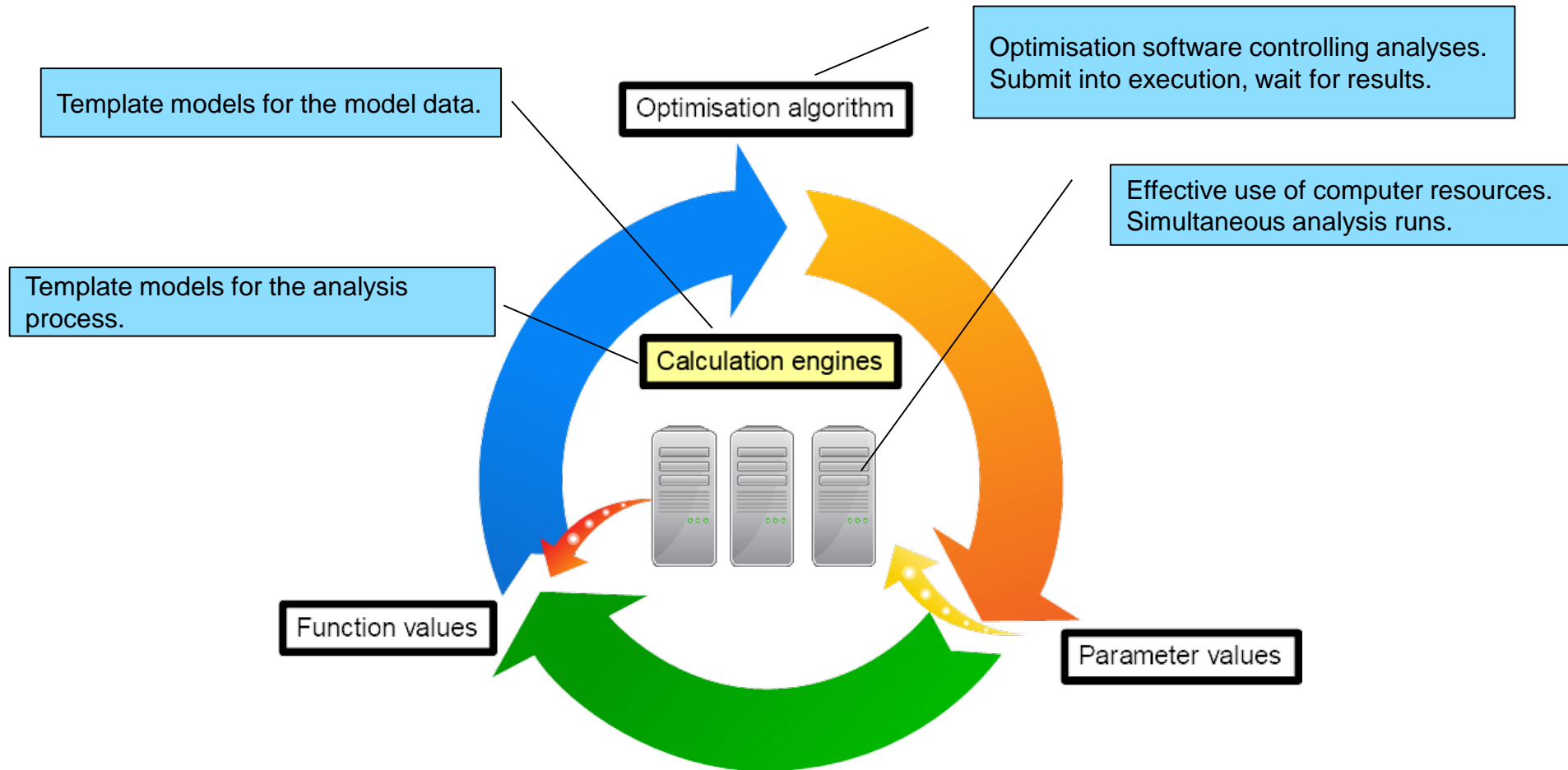
Why automatization and optimisation

- Benefits of automatization:
 - Analysis time reduction, cost savings
 - Reliability increases, avoidance of human errors, traceability
 - Automatic model and results documentation and reporting
- Use of optimisation methods
 - Increases understanding on the effect of input variables to responses, parameter variation studies, sensitivity studies
 - Control of uncertainty, lack of knowledge, statistical variability
 - To find optimal solutions to design problems
- Optimisation in supporting product design
 - Effective use requires effective analysis system, calculation engine

Targets of the work

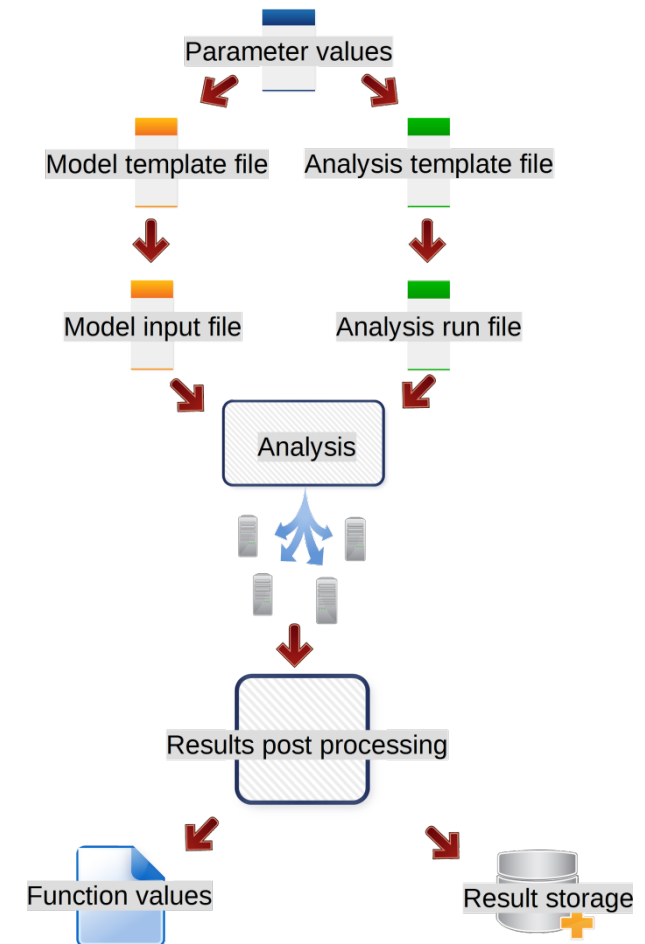
- To combine complicated structural analysis process with optimisation:
 - Simple and clear interface between optimisation and analysis
 - Modular analysis process enabling different analysis needs
 - Analysis process supporting different analysis software
- Support for typical design variables
 - Continuous, discrete
 - Plate thicknesses, main dimensions, ...
 - Categorical variables
 - Binary, part existing/non-existing (1/0), element sets
 - Qualitative variables, possible sub-parts, for example turbo-charger
- Possibility to open/in-house software
 - Small and medium-sized enterprises (SMEs)
 - Customising for own needs

Combining analysis and optimisation



Calculation engine

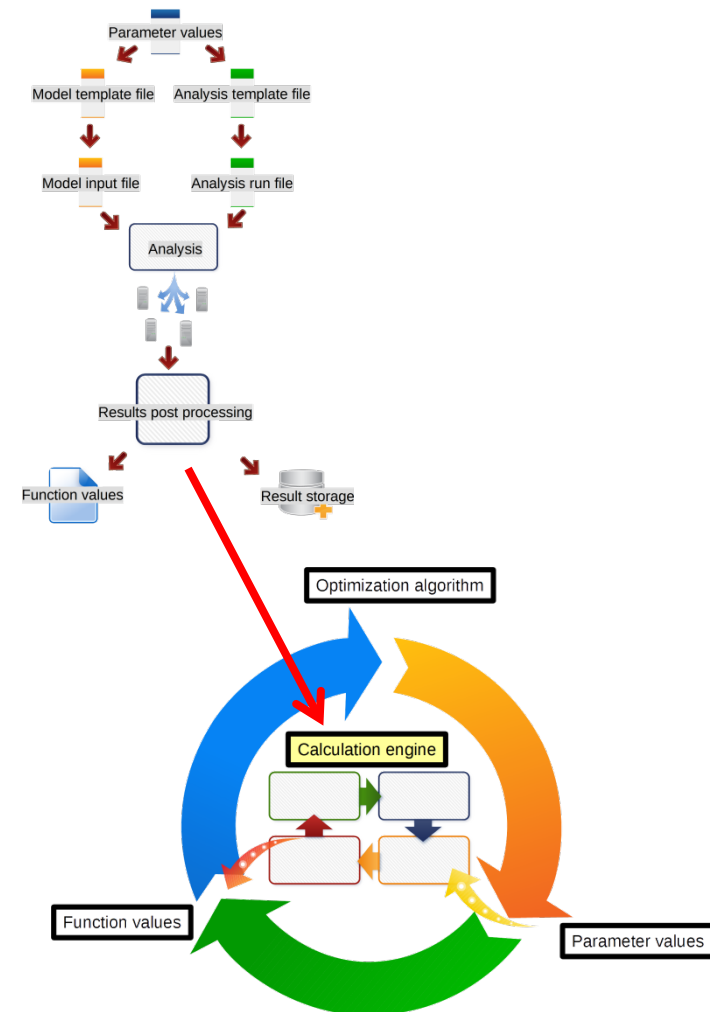
- Based on templates for both model and analysis
- Vibration analysis
 - Free vibration analysis
 - Forced vibration analysis
- Automatic vibration results post-processing
 1. Reporting of natural modes & vibration spectra
 2. Automatic natural mode identification
 3. Search for maximum responses
- Programmed with Python 2.7 & NumPy
 - Abaqus
 - Matlab, gnuplot
 - Abt. 3000 lines of code
 - Windows, Linux, Cluster
- Can operate stand-alone, parameter studies



Calculation engine connected to Dakota (<https://dakota.sandia.gov/>) optimization software

1. Get parameters from Dakota
 - Text file
2. Modal analysis
3. Forced response analysis
4. Mode identification
5. Forced vibration results post-processing
6. Return of required frequencies and maximum response values to Dakota
 - Text file

Interface with shell script or bat file



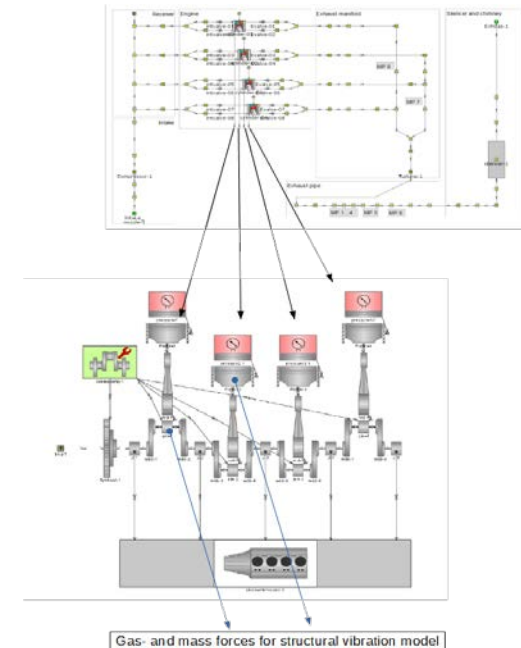
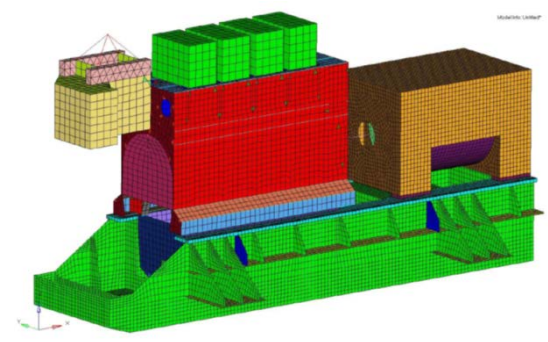
Studied case

VTT's test diesel generating set

The generating set is of type Wärtsilä Vasa 4R32 and it is located at VTT's engine laboratory in Otaniemi, Espoo, Finland. The generating set consists of the diesel engine driving a generator which is of type by ABB ALPC560 D8. Both are mounted at a common base frame. The base frame is a welded steel plate structure and it is mounted on a concrete block via flexible air springs. The engine is an inline four cylinder diesel engine operating at a constant speed of 750 rpm and producing 1640 kW of power.

Studied case

VTT's test diesel generating set



Previously prepared Abaqus FEM model was used in the analysis. The calculation model is composed of 44528 elements and 47164 nodes. The number of degrees of freedom is 240627. Engine excitation forces from previous studies conducted with GT-Power. Calculation model verified/calibrated using measured modes.

Case 1. Target: remove strong resonance at running speed

Objective of the optimisation: minimize the total mass

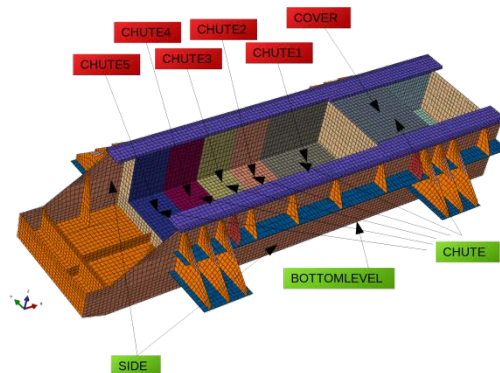
Constraints: Limit vibration levels at five locations

$$\min_{\mathbf{x} \in D} \{m(\mathbf{x})\}$$

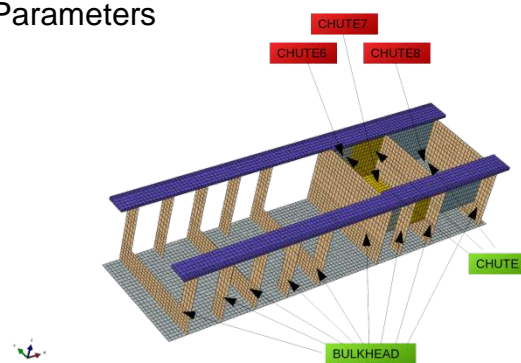
$$LB \leq g_a(\mathbf{x}) \leq UB$$

Parameters in common base frame:

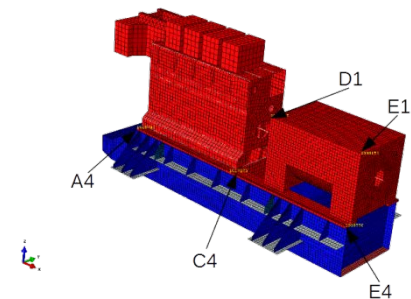
- Plate thicknesses
- Height, width
- Some plates as binary categorical variable: exist/non-exist



Parameters

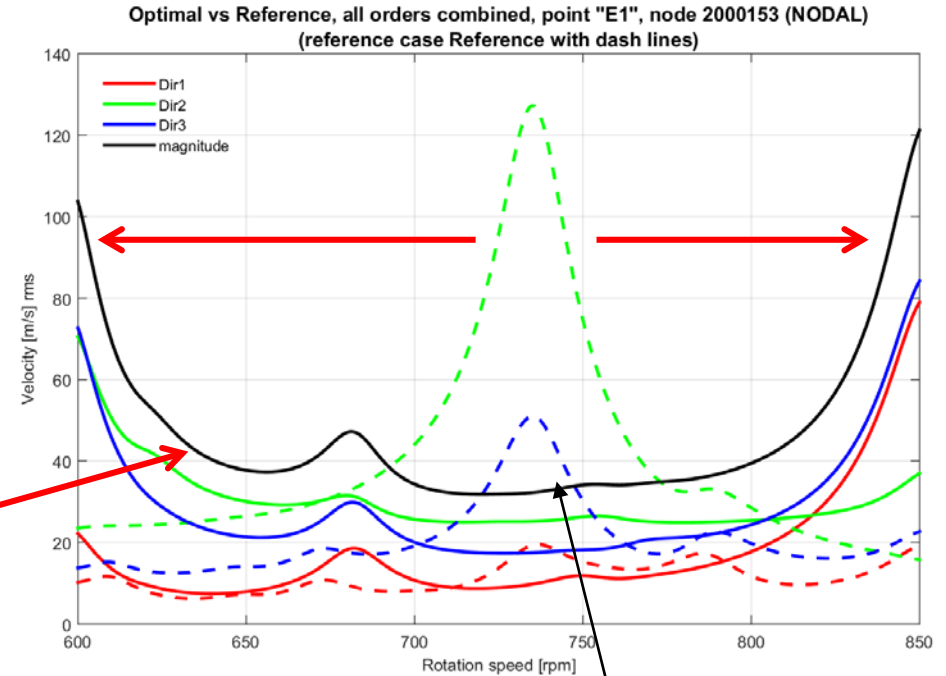
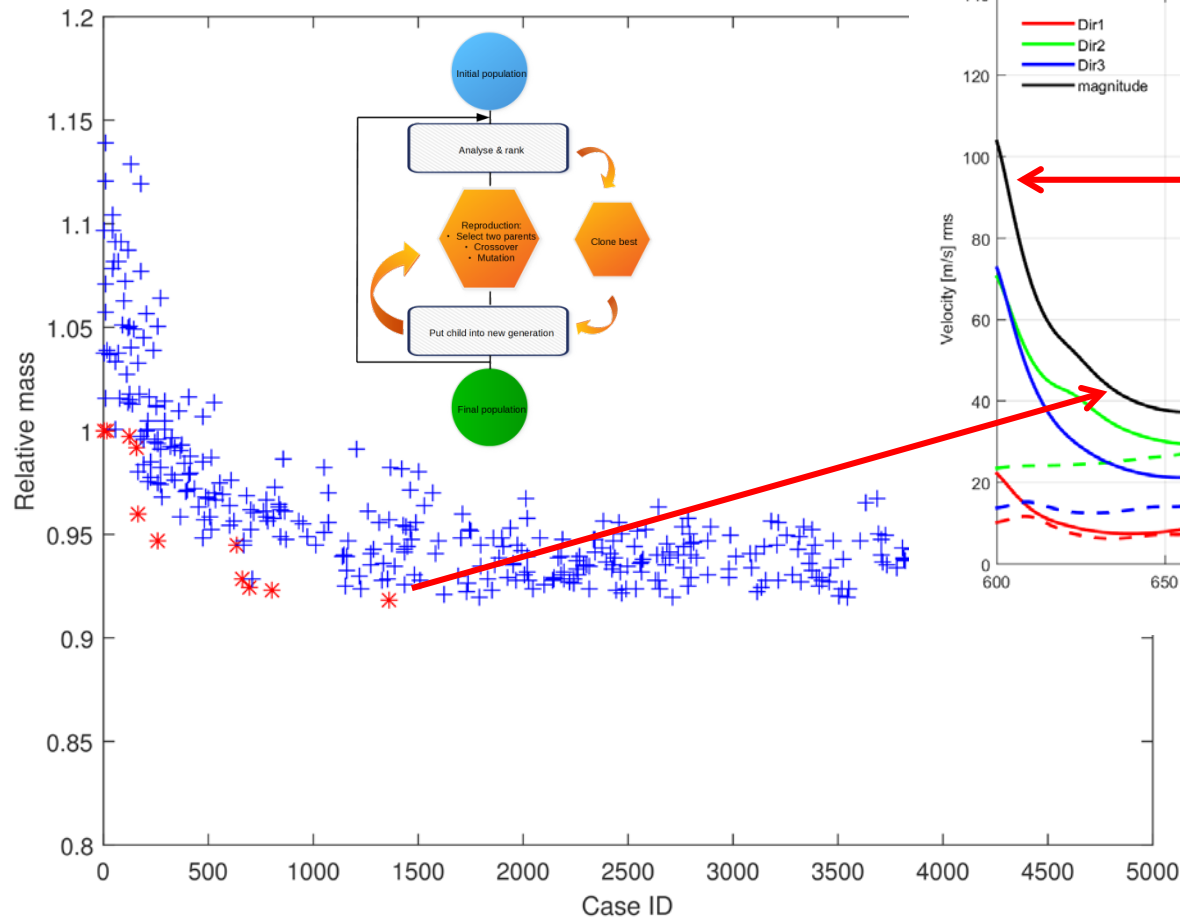


Constraints at these locations



Results obtained with evolutionary algorithm

Mass minimized



Resonance removed from running speed range

ID	SID	BLH	CHU	BOT	BOTH	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	Cover
Orig	30	10	10	15	-1770	OFF	ON	OFF	ON	OFF	ON	ON	ON	OFF
Evo	10	10	12	10	-1610	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF

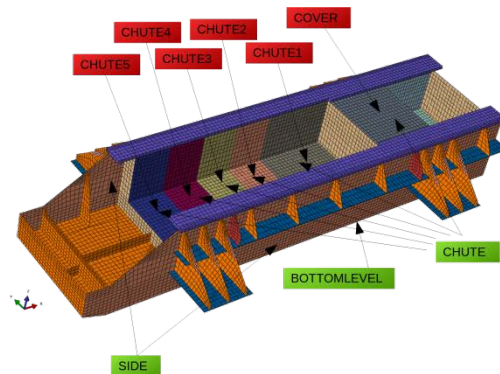
Case 2. Target: Find most important parameters and/or down choose worthless/poor

Parameter study: find correlations between responses & variables

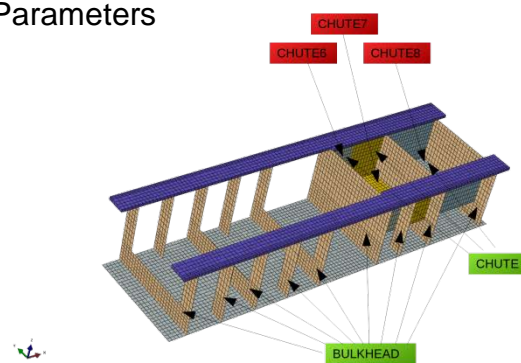
Statistical analysis with R, a language and environment for statistical computing and graphics (<https://www.r-project.org/>)

Parameters in common base frame:

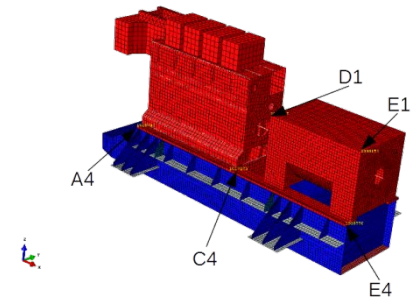
- Plate thicknesses
- Height, width
- Some plates as binary categorical variable: exist/non-exist
- Generator type as categorical variable



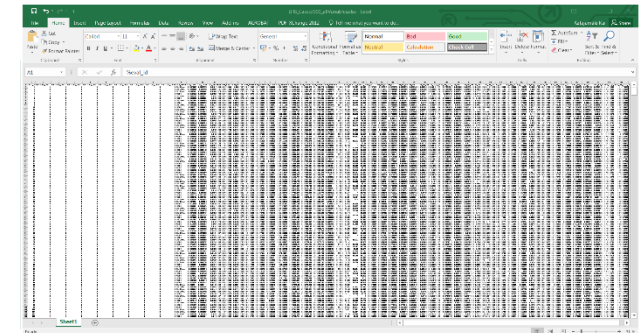
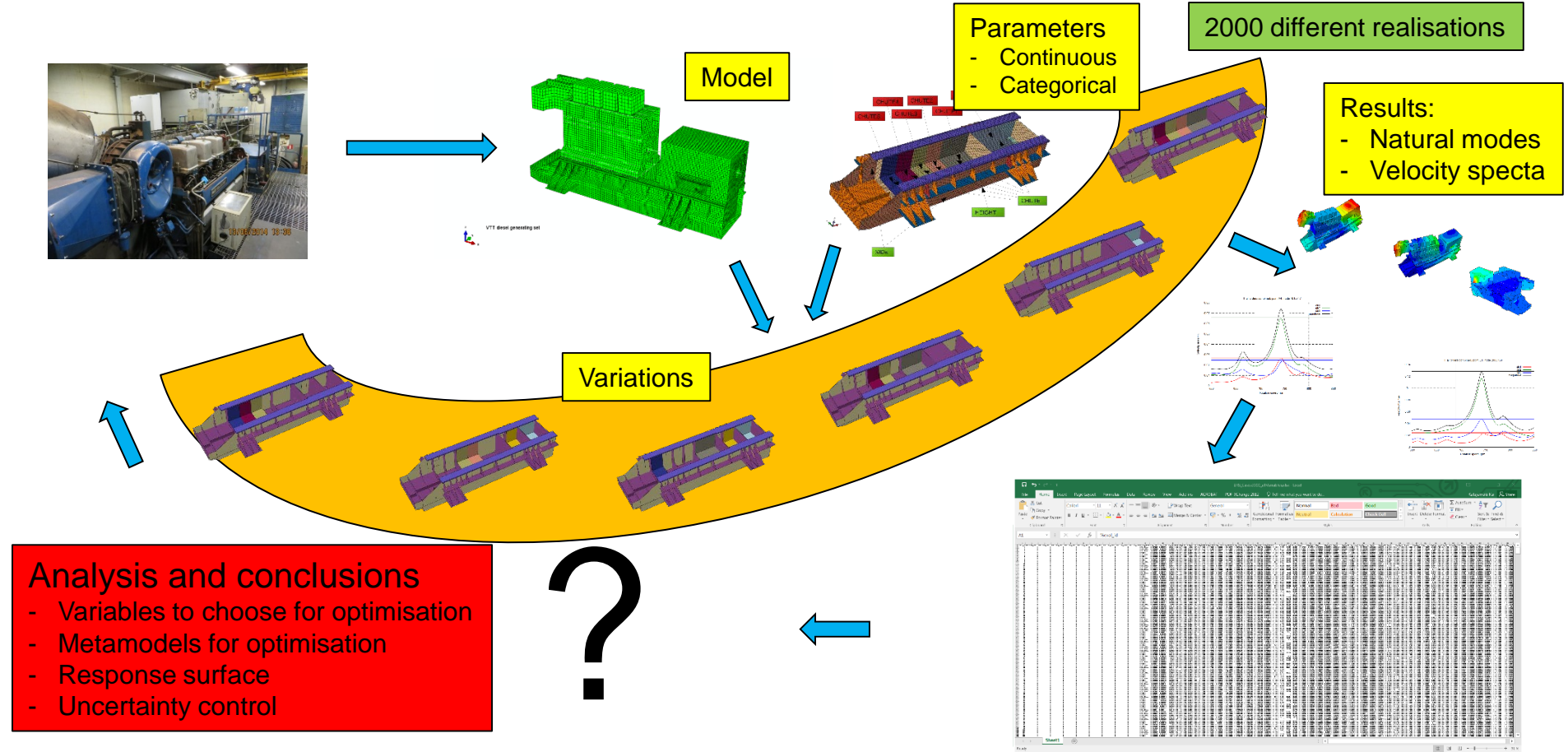
Parameters



Responses at these locations



Parameter study – statistical analysis (R)



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	%eval id	:SET:CBF_CHUTE1	:SET:CBF_CHUTE2	:SET:CBF_CHUTE3	:SET:CBF_CHUTE4	:SET:CBF_CHUTE5	:SET:CBF_CHUTE6	:SET:CBF_CHUTE7	:SET:CBF_CHUTE8	:SET:CBF_COVER	GEN_MODEL	CBF_SIDE	CBF_COVER
2	1	1	1	1	1	0	1	0	0	1	ORIGINAL	0.01578073	0.019777956
3	2	0	0	0	0	0	0	1	1	1	ORIGINAL	0.01810935	0.0164496
4	3	1	0	1	1	0	0	0	0	1	ORIGINAL	0.0105281	0.01346283
5	4	1	0	0	0	1	0	1	1	0	MODIF	0.01624579	0.01847534

Parameter study – statistical analysis (R)

Partial correlation matrix between variables and responses

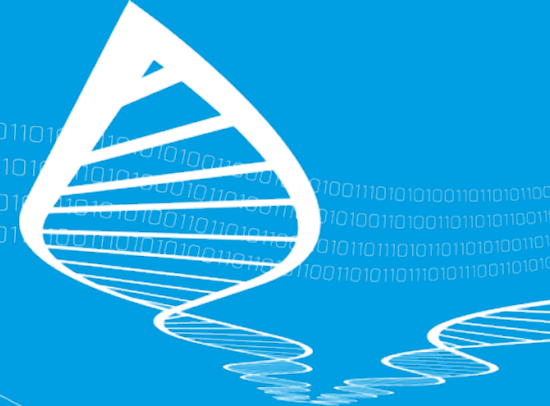
Not good parameters for optimisation

	Mass	Mode_11	Mode_12	Mode_13	A4_V1	A4_V2	A4_V3	E1_V1	E1_V2	E1_V3	E1.b_V1	E1.b_V2	E1.b_V3
E	0.00	-0.01	0.00	-0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01
PLTH_15	0.89	0.92	0.75	0.75	-0.98	-0.97	-0.97	0.25	-0.99	-0.96	-0.79	-0.99	-0.96
PLTH_20	0.34	0.28	-0.37	0.00	-0.07	-0.03	-0.08	-0.10	0.08	-0.15	-0.16	0.08	-0.11
PLTH_30	0.00	-0.01	0.00	0.01	0.01	0.00	0.00	0.04	0.01	0.01	-0.01	0.01	0.00
PLTH_35	0.27	-0.10	-0.30	-0.06	-0.15	-0.16	0.01	-0.16	0.02	-0.13	-0.45	0.02	-0.16
DENSITY	0.15	-0.07	-0.29	-0.07	-0.04	-0.06	-0.06	-0.09	0.01	-0.05	-0.27	0.01	-0.08
SPRING1	0.01	0.00	0.02	-0.01	0.00	0.00	0.00	-0.02	-0.01	0.00	0.01	-0.01	0.00
SPRING2	-0.01	-0.01	0.03	0.01	0.02	0.02	0.03	0.02	0.02	0.02	0.04	0.02	0.02
SPRING3	-0.01	0.00	0.02	-0.01	0.01	0.01	0.00	-0.02	0.01	0.01	0.01	0.01	0.01

Poor correlation => find better variables

Conclusions

- Automatic analysis system can reduce time drastically and at the same time increase quality, traceability, reliability, ...
- Modern scripting languages combined with wide range of different software available make it possible to develop such systems effectively
- Effective use of optimisation software requires effective calculation engines
- Enables the use of statistical methods, uncertainty and reliability analysis



TECHNOLOGY «FOR» BUSINESS

