Hybrid Electric Vehicle FMI-Based Design Optimization

NAFEMS americas events

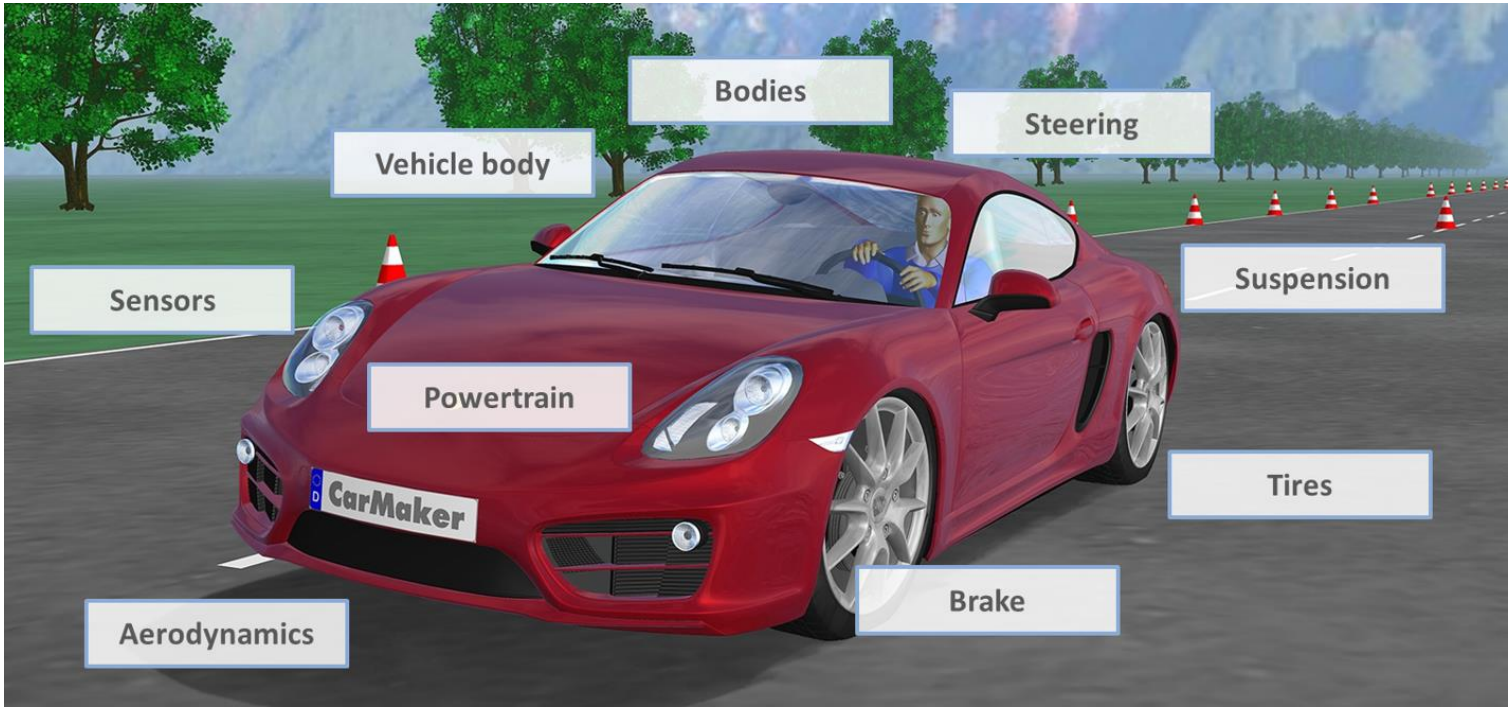
C. Schwarz[1], A. Froidmont[2]
[1]ISKO engineers AG
[2]Noesis Solutions

Powertrain electrification

- How can this be engineered efficiently ?
  - Minimize fuel consumption
  - Avoid limited range autonomy
  - Increase vehicle dynamics

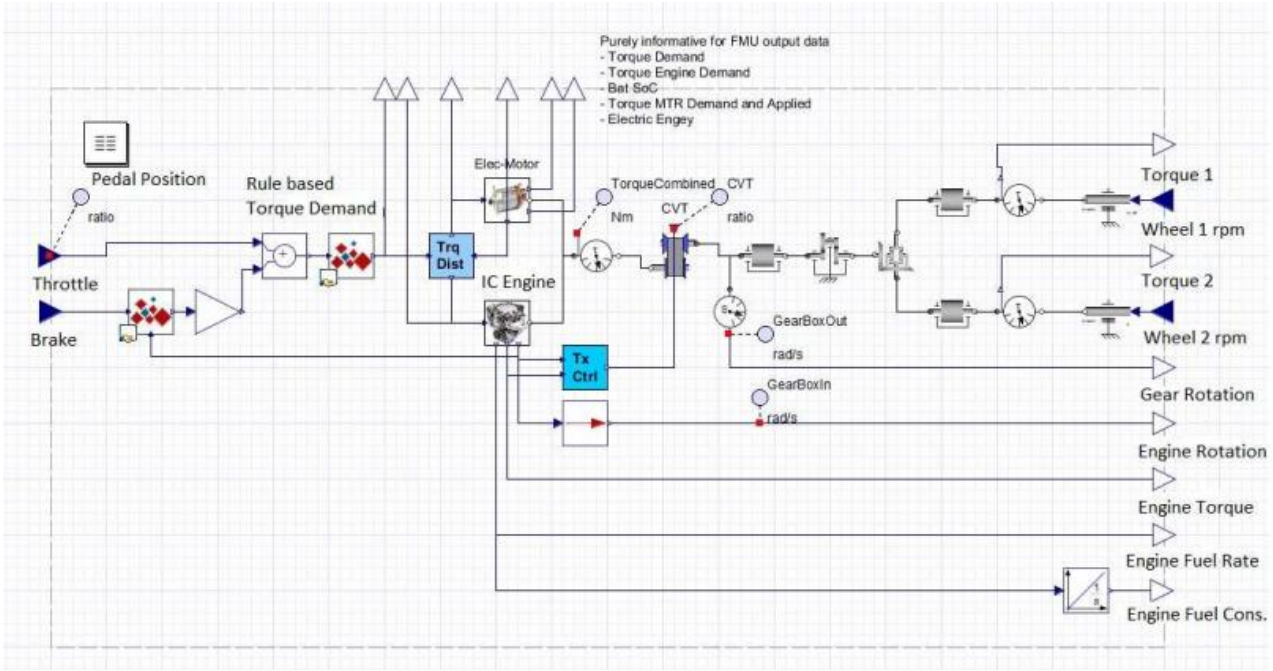
Carmaker

- Simulates the car behavior in real situations



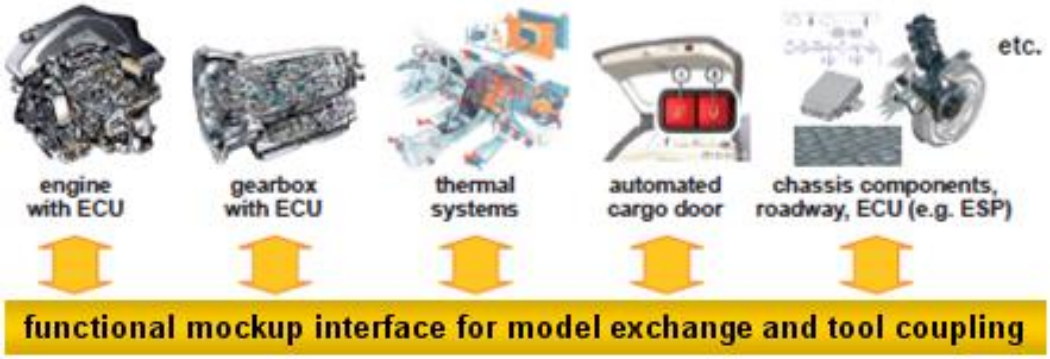
MapleSIM

- System simulating the engine

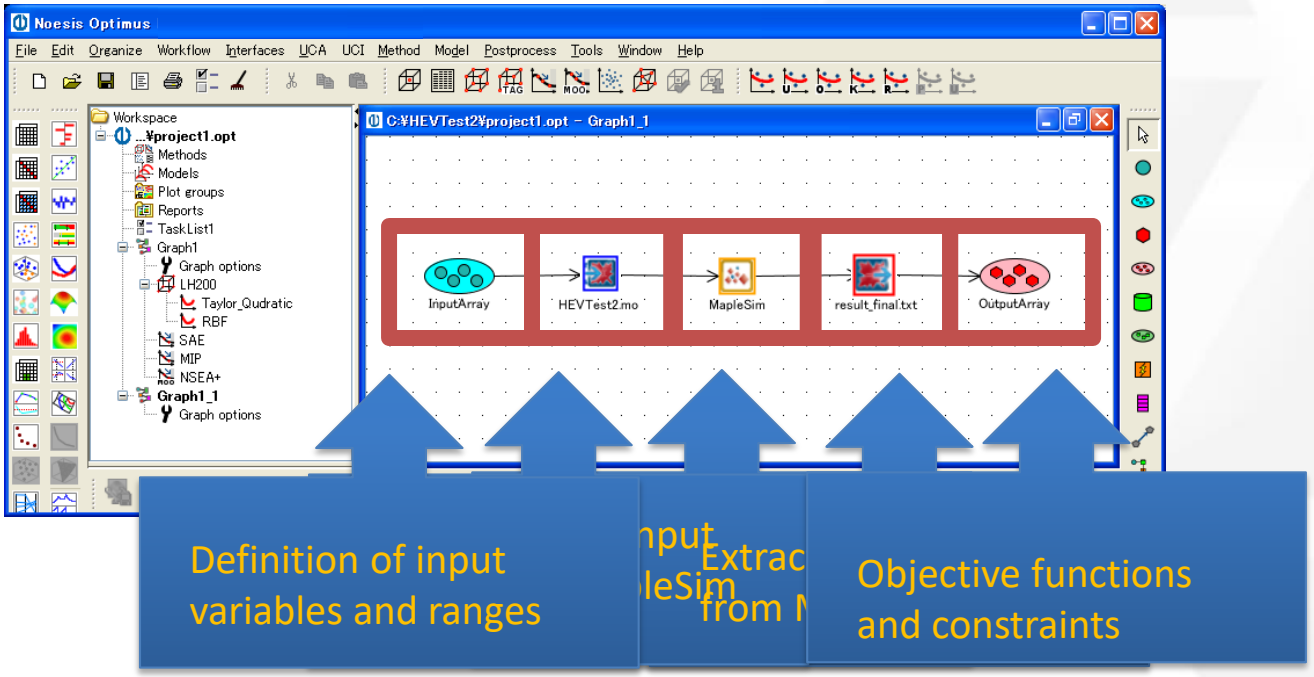


How to use the MapleSIM model in Carmaker ?

FMU – Functional Mockup Unit



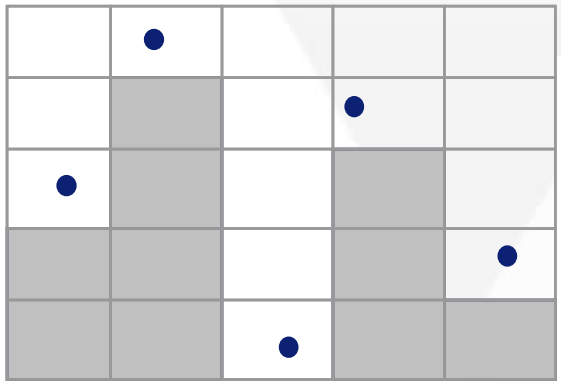
Integration of Simulation Process in Optimus

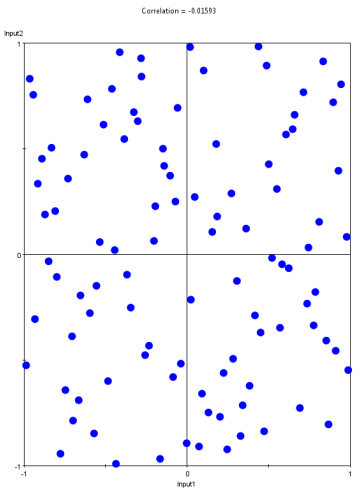


Design of Experiments (DOE)

- Run virtual experiments
- Use DOE methods to fill you design space

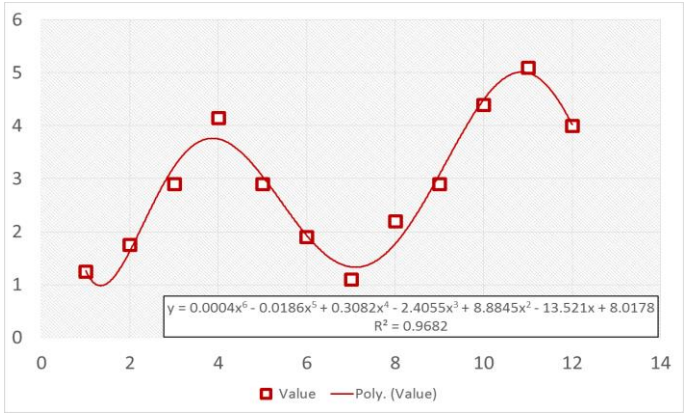
- will use as basis for Response Surface Modeling

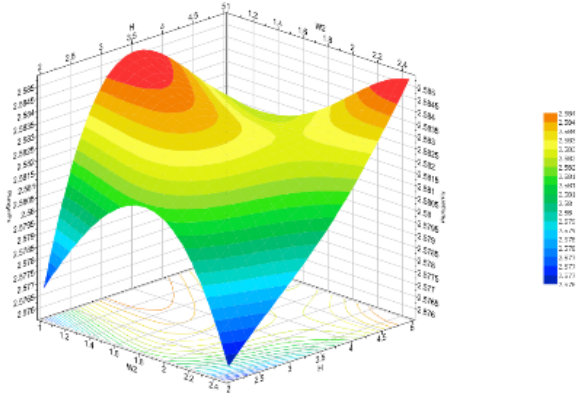




What is a Response Surface Model?

- Trendline approximates a set of experimental data
- RSM does this in **multi-dimensional** space
- Experiment response can be estimated with the formula





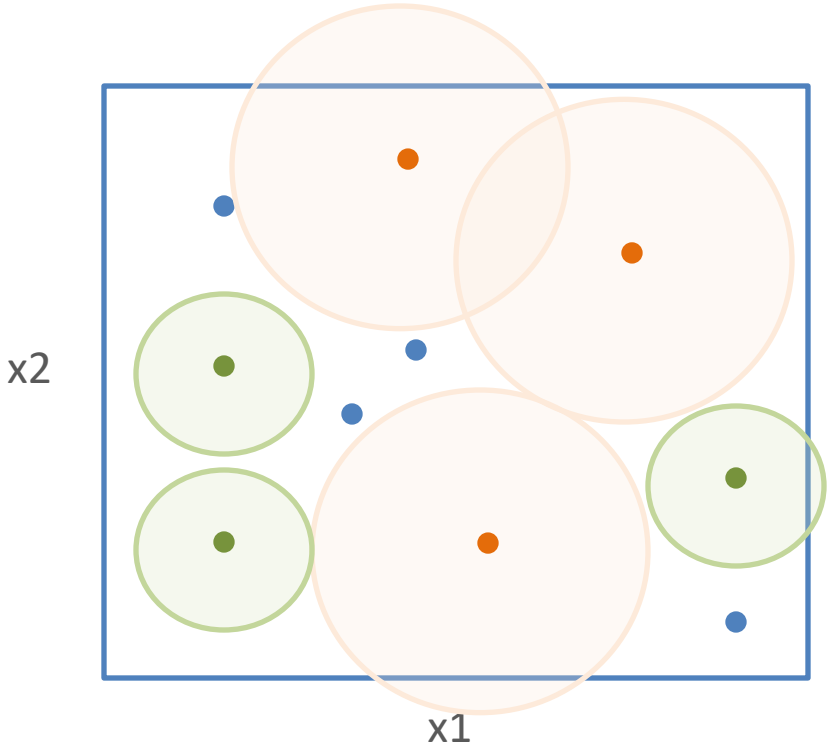
Objectives of the Adaptive DOE

Reuse existing data

Add experiments to areas of uncertainty

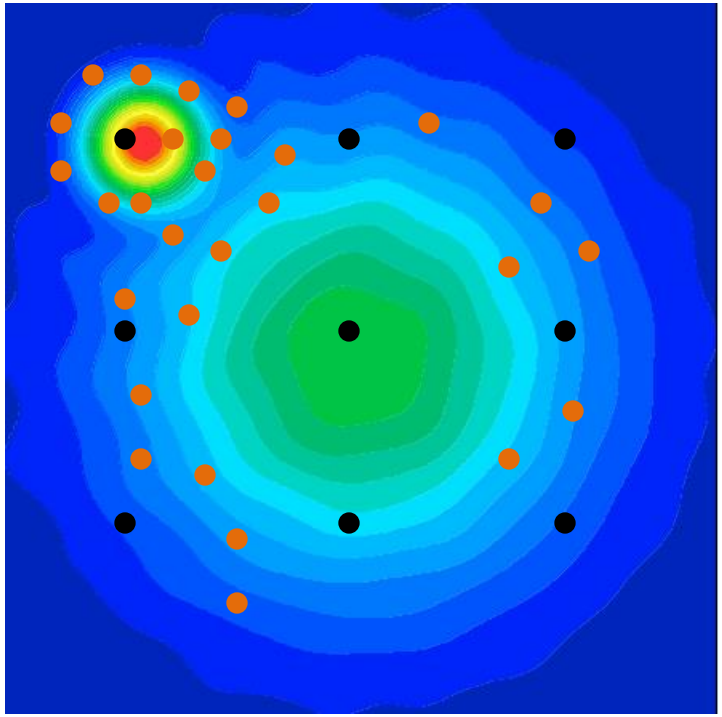
Reduce the number of experiments for a good RSM

ADOE- Exploration



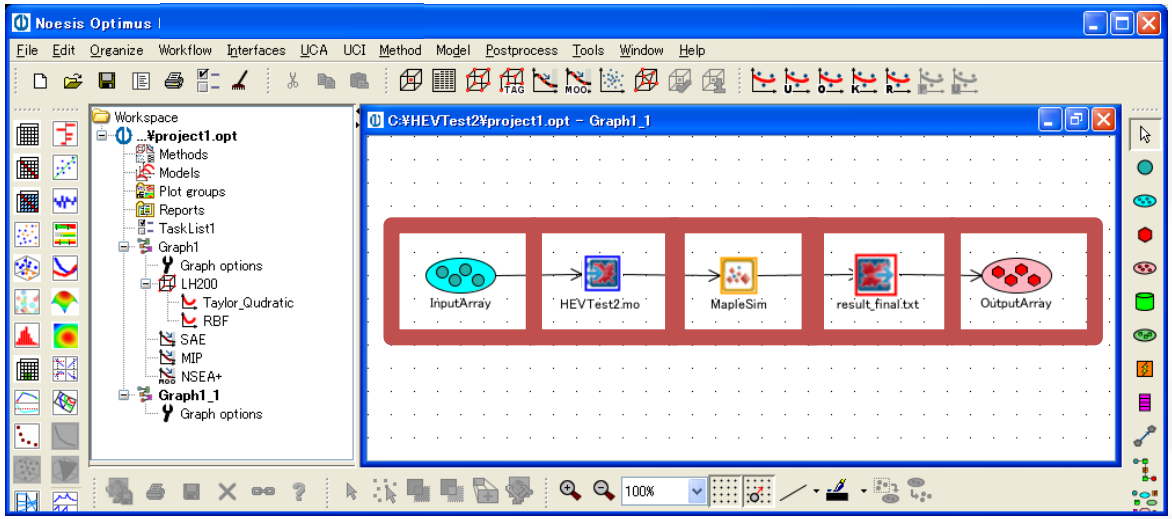
- We start from an initial set
- We add points in the domain, where we don't have points
- Iterative process

ADOE - Exploitation of the function

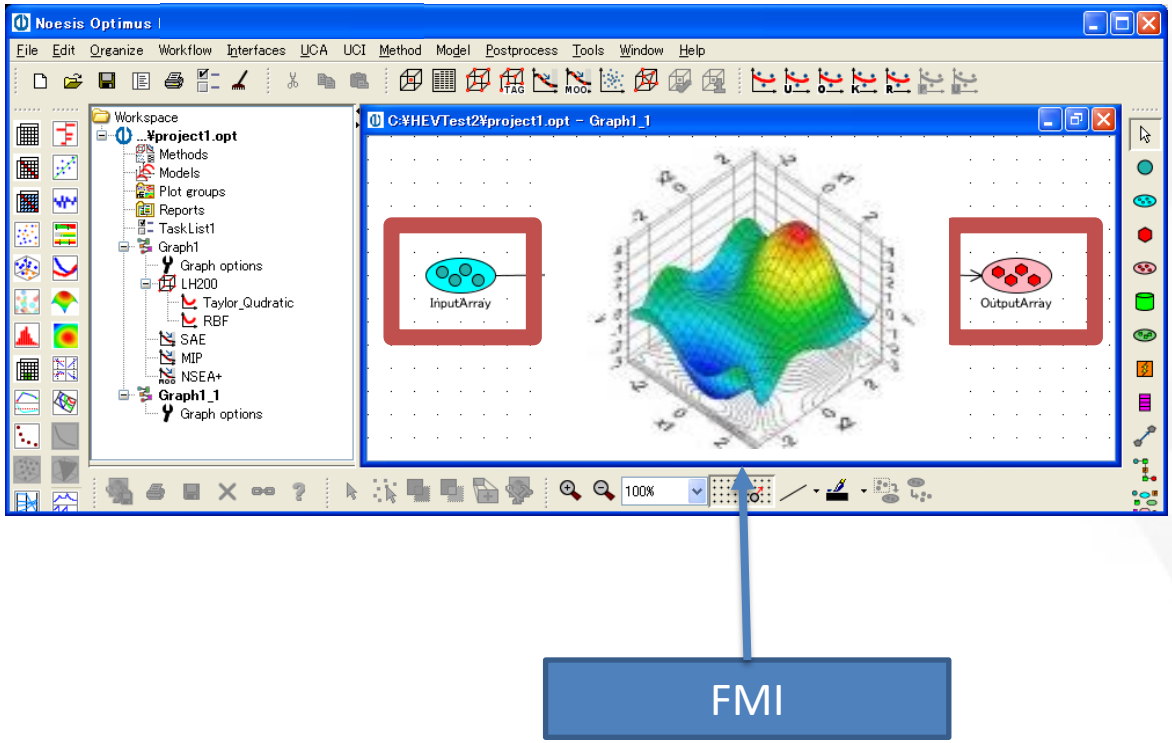


- We start from an initial set
- We add points in the domain, where the points are needed to have a better understanding of the problem
- Iterative process
- The model is re-built at any iterations

Integration of Simulation Process in Optimus

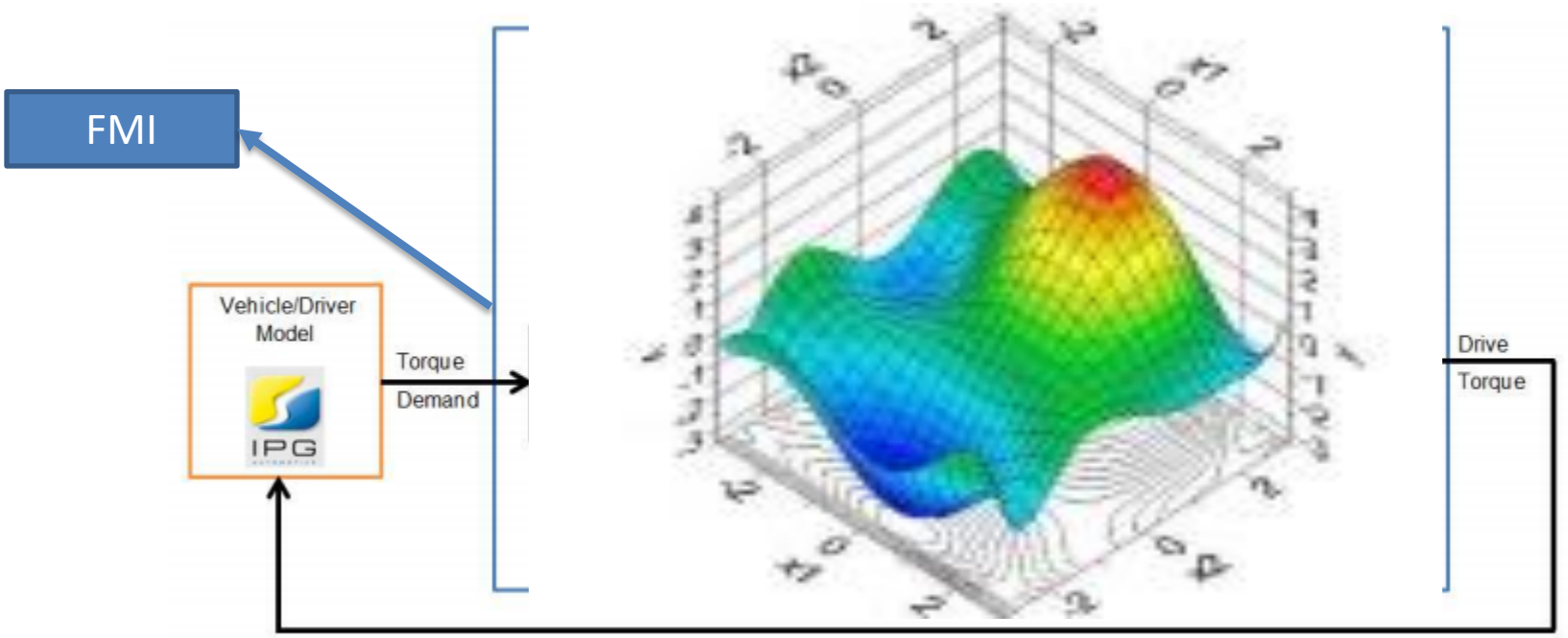


Integration of Simulation Process in Optimus



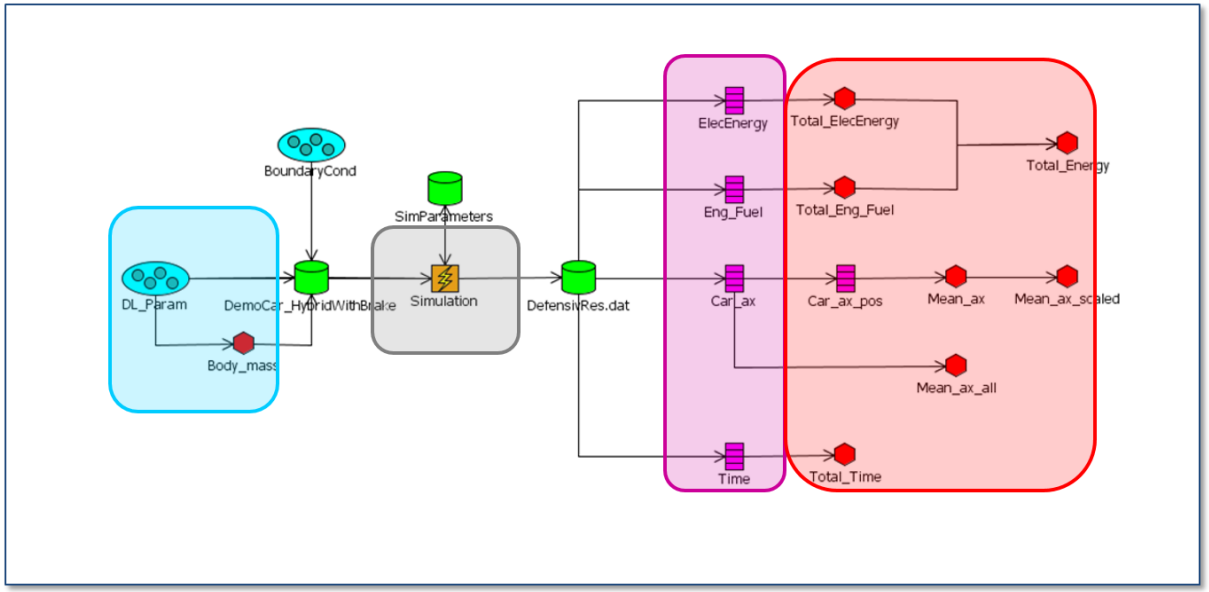
Running Carmaker

- Simulates the car behavior in real situations

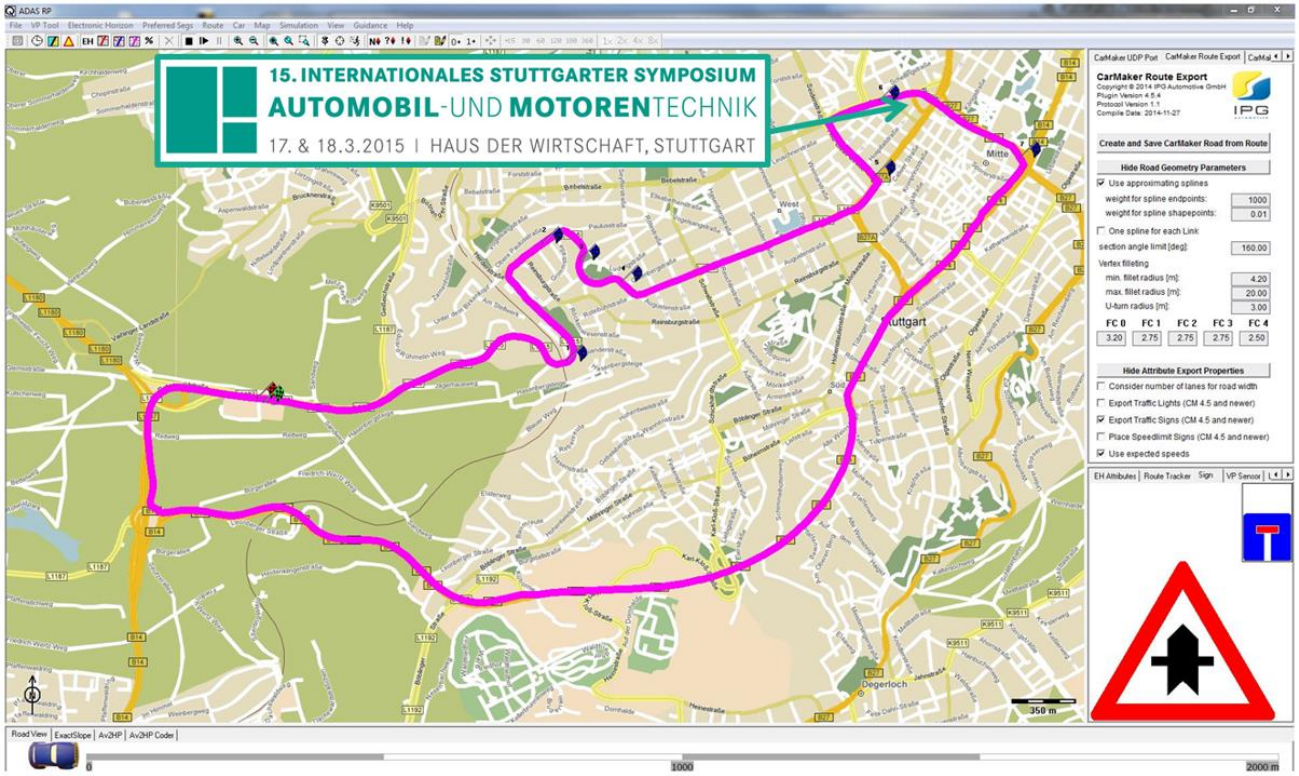


Optimus

- Now we use Optimus to run Carmaker automatically



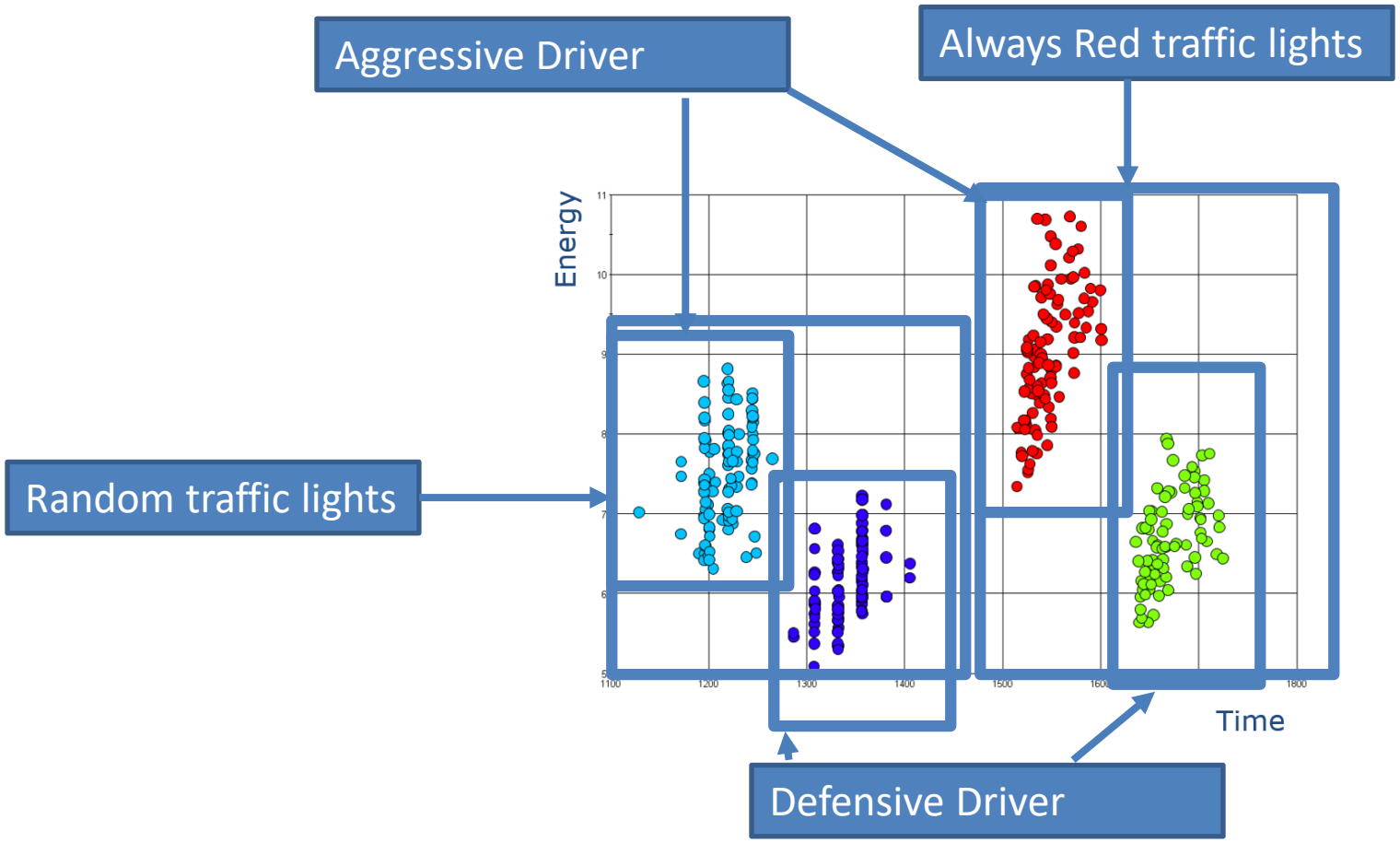
On the Nürburgring & in and around Stuttgart



Optimus Benefits

- Steering the virtual vehicle over virtual roads allows to investigate overall behavior under real-world driving conditions

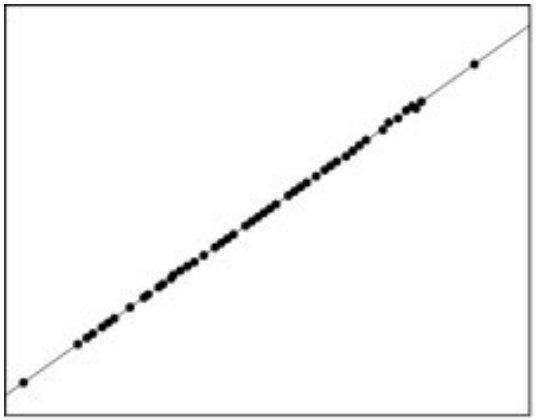
Influence of driver behavior

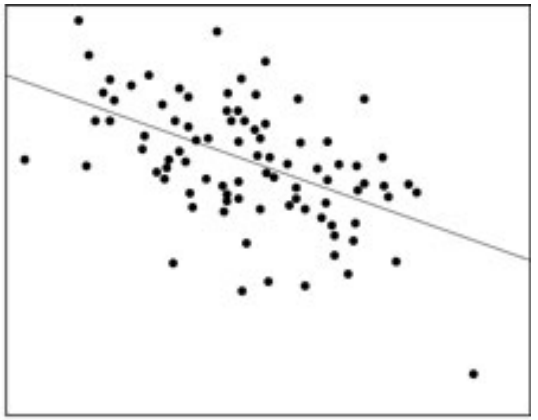


Backed up by statistics

Linear Correlation

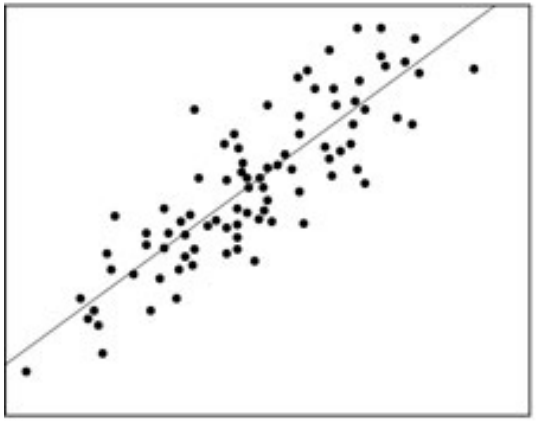
1

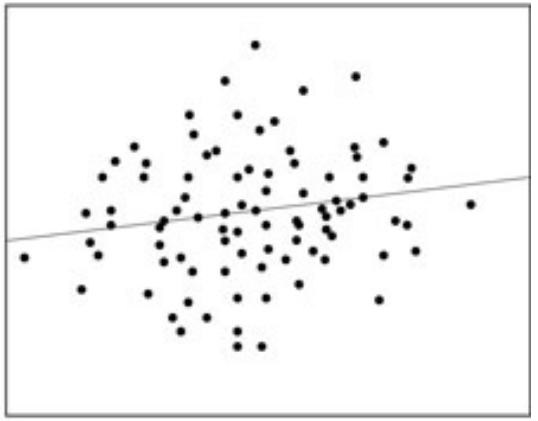




-0.5

0.85





0.15

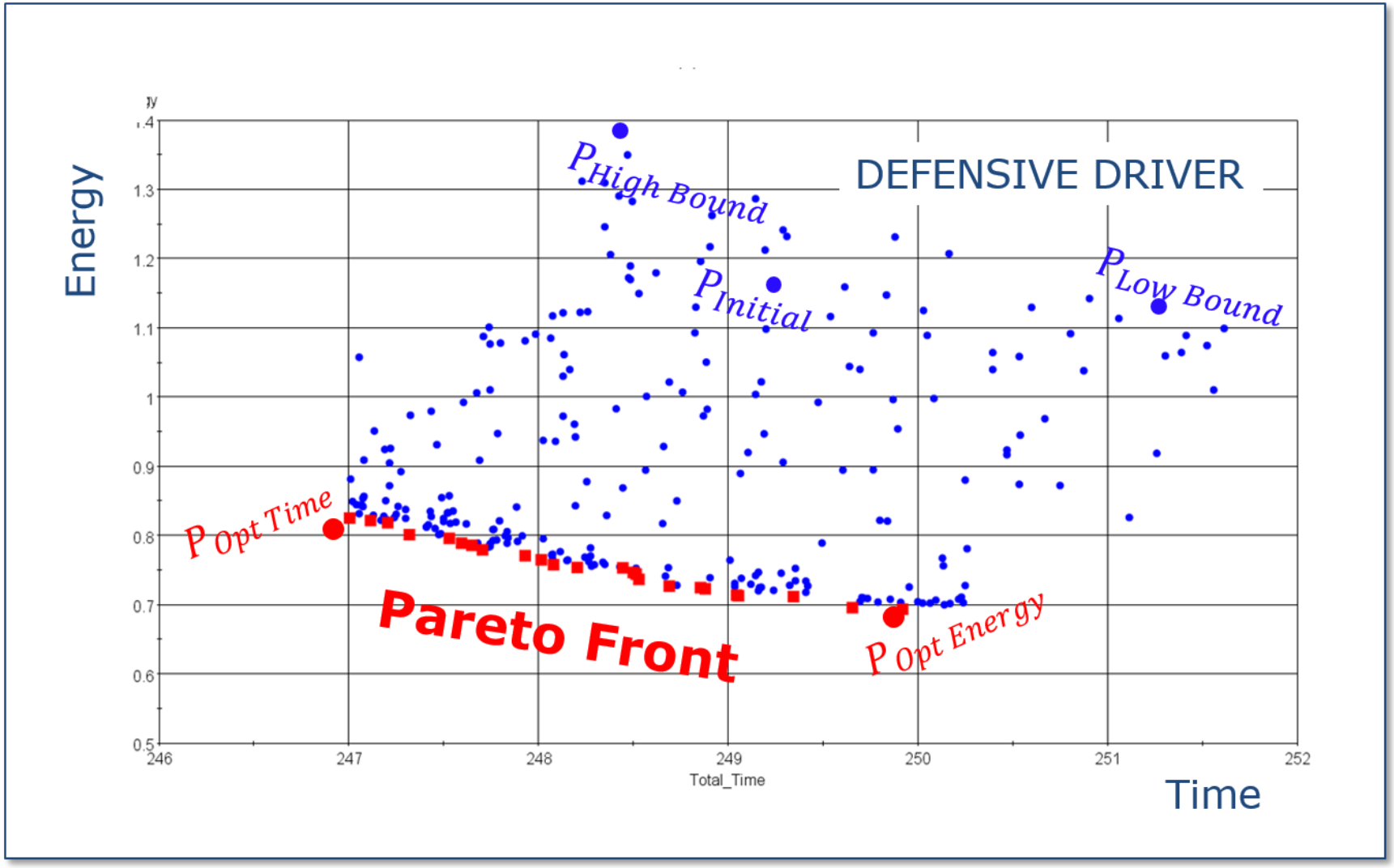
Backed up by statistics

DEFENSIVE DRIVER Pearson (Spearman)	BatCap	TE	TRg	TMA	RegenTr	FinDrRati	Body Mass
Total_Time	0.098 (0.193)	0.082 (0.118)	-0.083 (-0.041)	0.318 (0.723)	0.107 (0.076)	-0.068 (-0.227)	0.098 (0.193)
Total_Energy	0.576 (0.574)	-0.345 (-0.331)	0.245 (0.223)	0.521 (0.524)	0.320 (0.322)	0.121 (0.107)	0.576 (0.574)

AGGRESSIVE DRIVER Pearson (Spearman)	BatCap	TE	TRg	TMA	RegenTr	FinDrRat	Body Mass
Total_Time	0.015 (0.205)	0.173 (0.191)	-0.137 (-0.127)	0.331 (0.682)	0.097 (0.048)	-0.053 (-0.259)	0.015 (0.205)
Total_Energy	0.433 (0.434)	-0.333 (-0.308)	0.196 (0.188)	0.682 (0.683)	0.327 (0.323)	0.083 (0.072)	0.433 (0.434)

Now we can move on to optimization


Solved by Optimus
Particle Swarm
Algorithm


DEFENSIVE DRIVER
Energy
Time
Total_Time
P High Bound
P Initial
P Low Bound
P Opt Time
P Opt Energy
Pareto Front
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
246
247
248
249
250
251
252

Conclusion

Optimus identified a solution that drops 40% of energy consumption compare to the original design