Simulation-Based Optimization Methodology for Hydraulic Hybrid Vehicle

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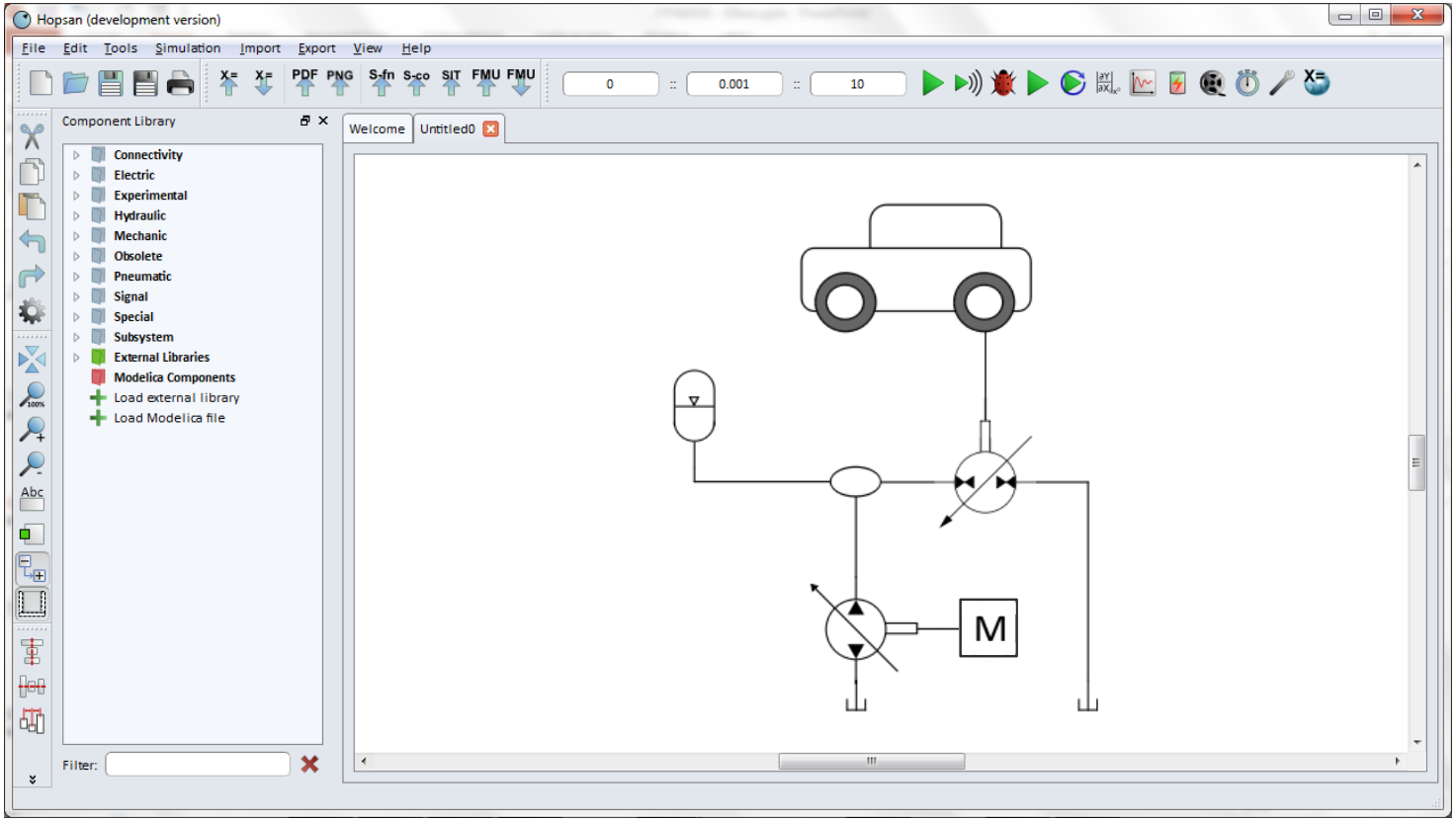
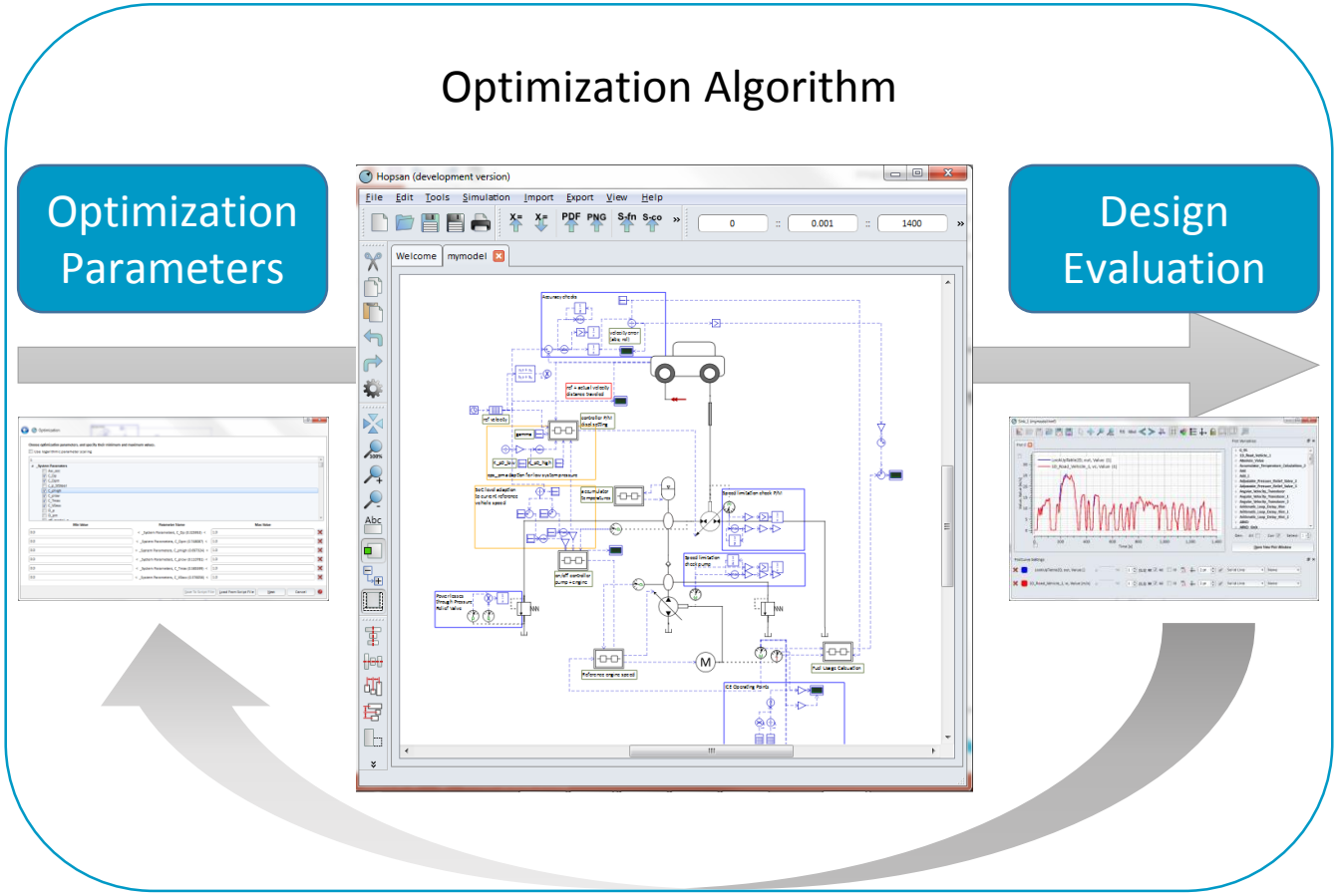
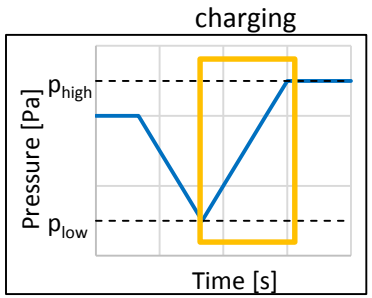
Design of a Series Hydraulic Hybrid Vehicle

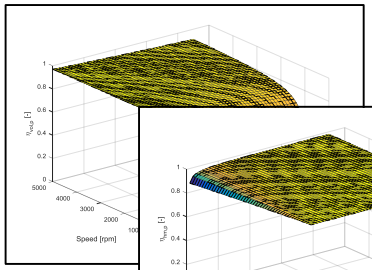


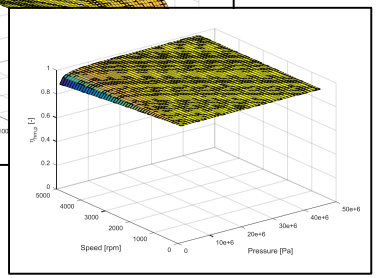
Simulation-Based Design Optimization

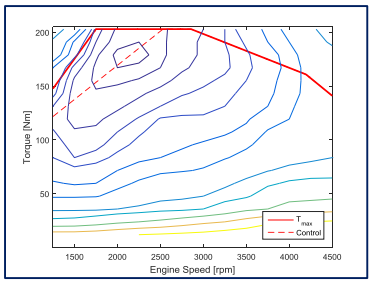


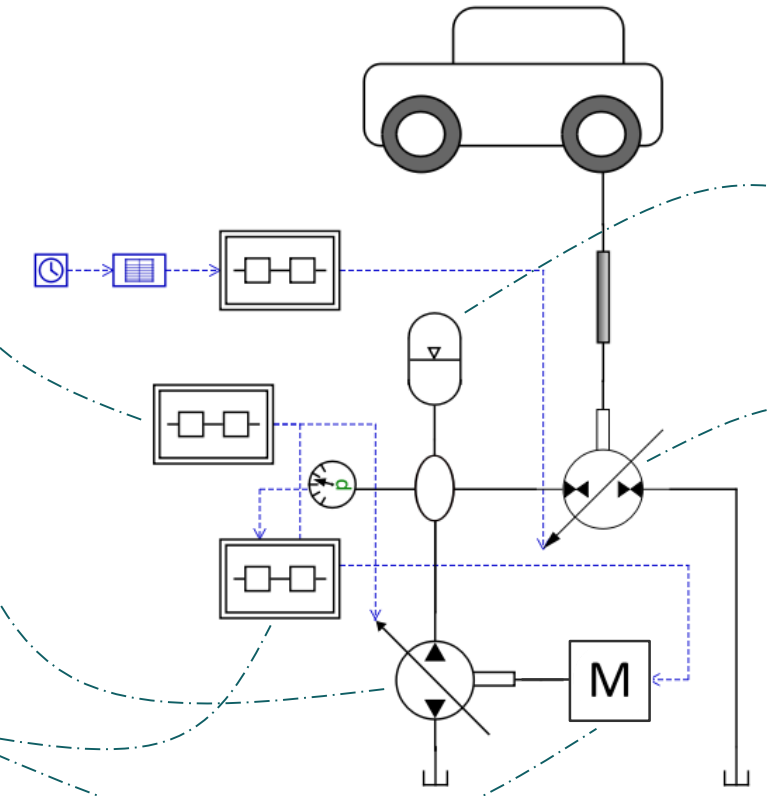
Series Hydraulic Hybrid Vehicle Model

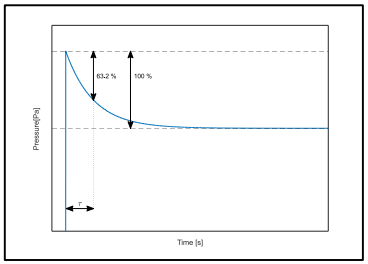


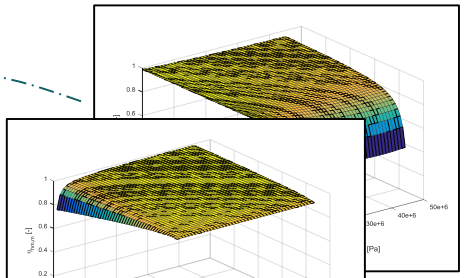






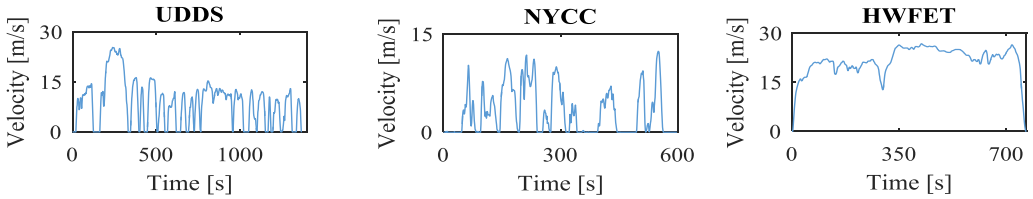






Optimization Problem

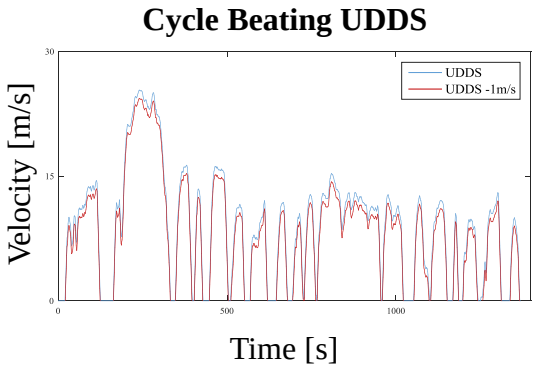
- Application: 2700 kg vehicle, standard drive cycles



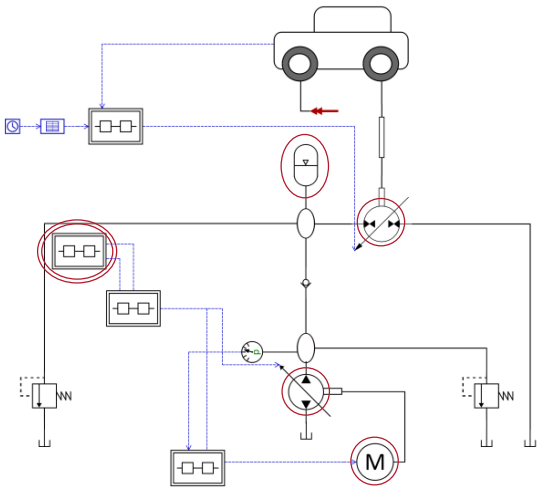
- Objectives for optimization:
  - Minimize Fuel consumption (FC)
  - Ensure tracking of reference velocity

$$ARVD = \frac{\int \text{velocity deviation } dt}{\text{Total distance}} \leq 1\%$$

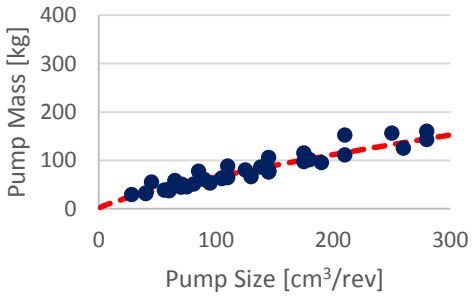
ARVD: Average Relative Velocity Deviation

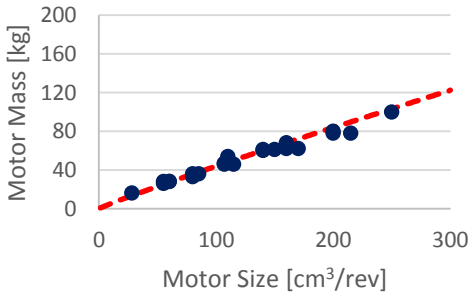


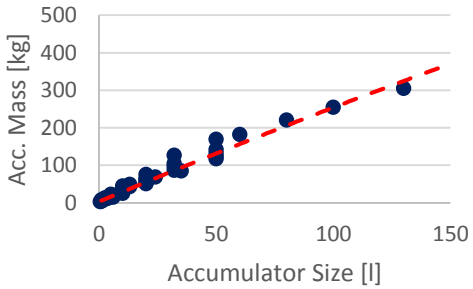
Optimization Parameters



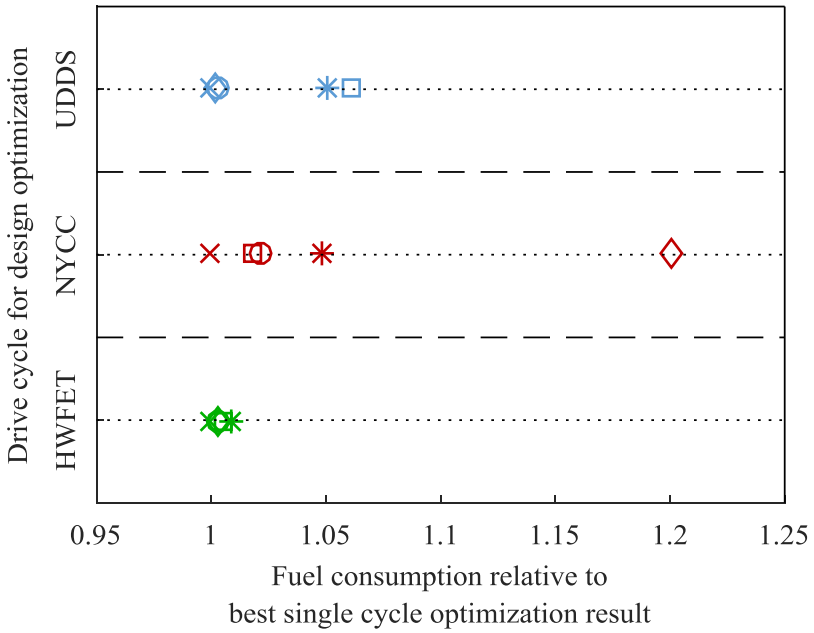
Design parameter	Range	
Pump size	0 … 250	cm^3/rev
Pump/motor size	75 … 250	cm^3/rev
Upper SoC limit	15 … 45	MPa
Lower SoC limit	12.5 … 44	MPa
Diesel engine size	150 … 520	Nm
Accumulator size	10 … 100	l

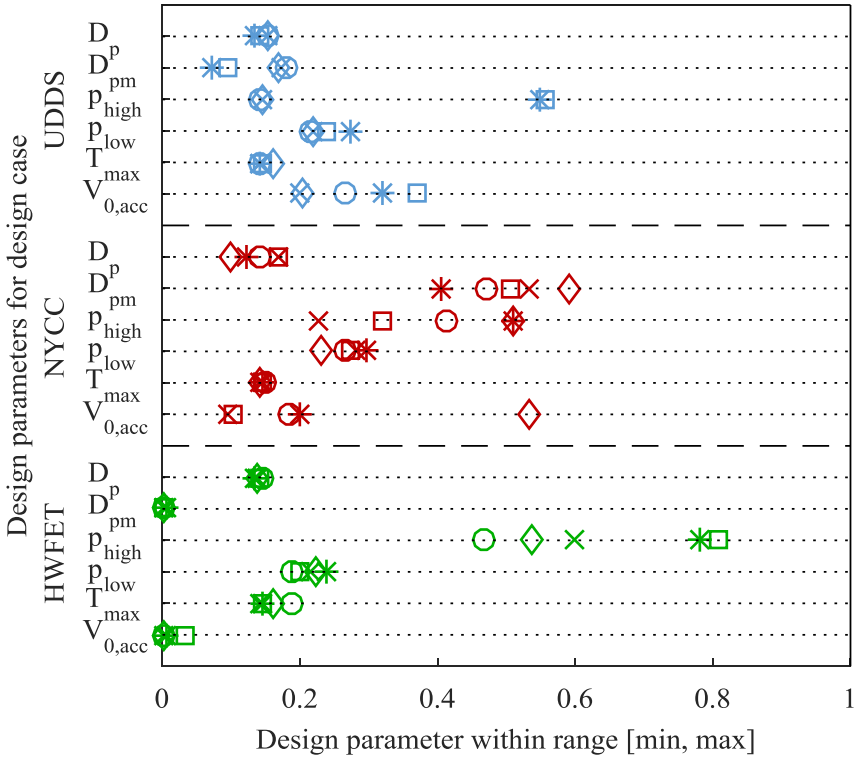






Optimization Results





5 different experiments per drive cycle (x□◇○x)

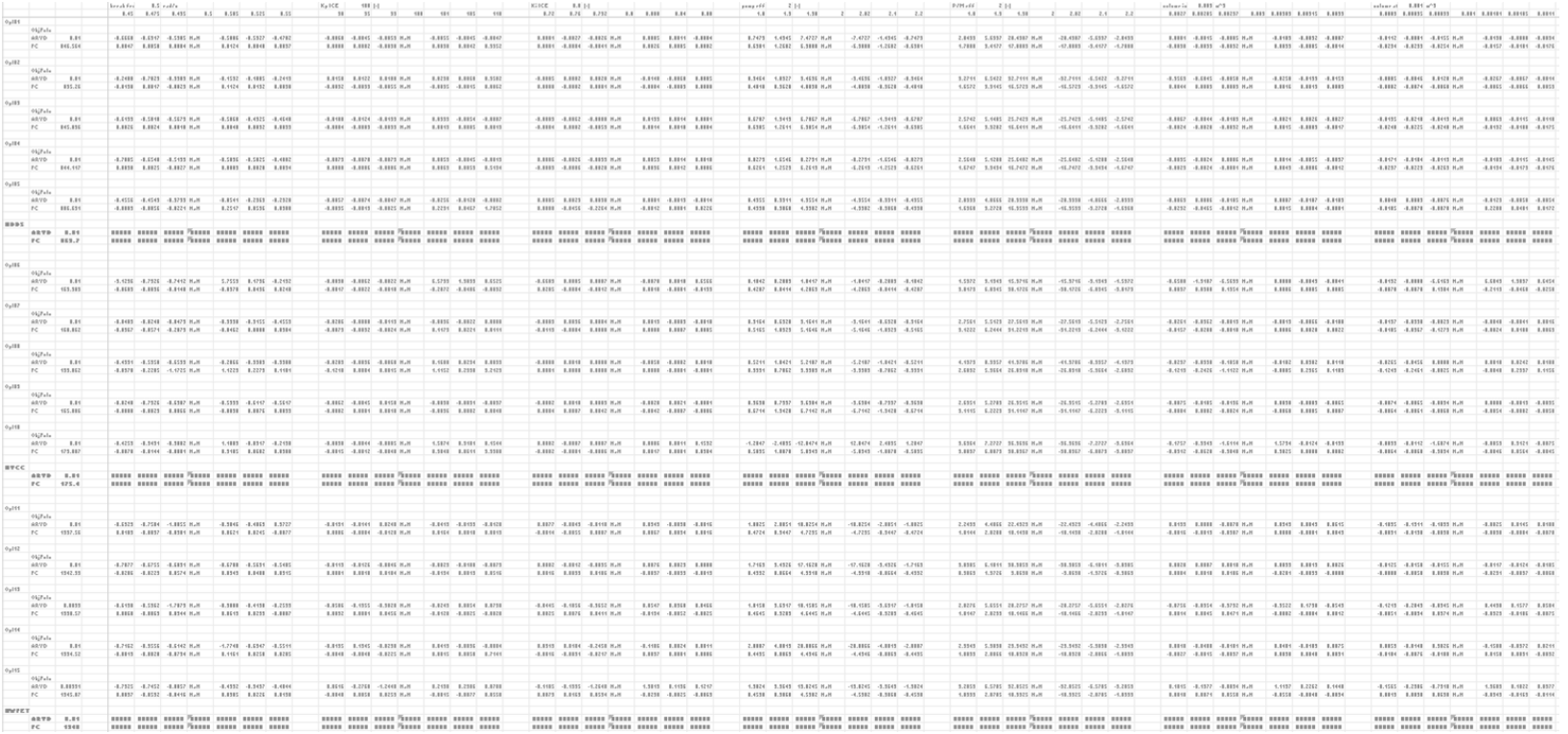
Sensitivity: Design Parameters

$$\text{Sensitivity Index} = \frac{\Delta\text{Objective}/\text{Default Objective}}{|\Delta\text{Parameter}|/\text{Default Parameter}}$$

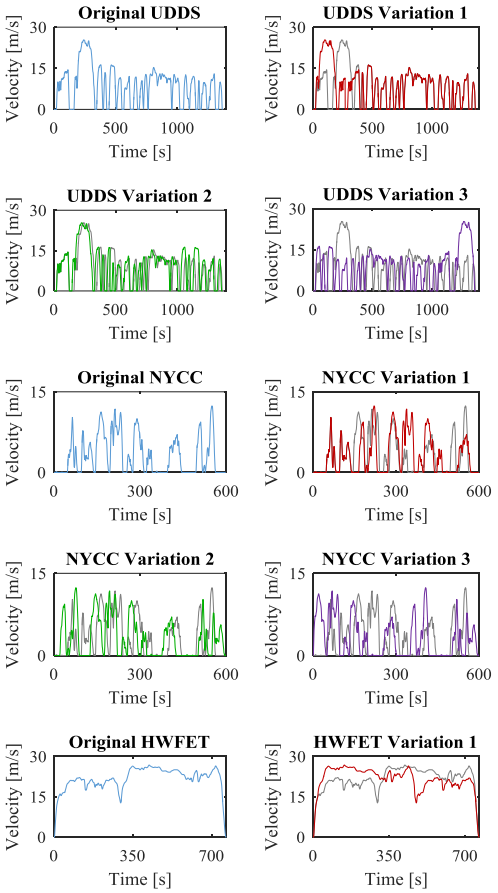
			D_p	D_{pm}	p_{high}	p_{low}	T_{max}	V_{0acc}
UDDS	ΔP<0	ARVD	4.06	4.03	>9	3.45	>9	0.19
		FC	-0.18	-0.21	-1.21	-0.20	<-9	-0.01
NYCC	ΔP<0	ARVD	1.36	2.95	2.45	3.72	>9	1.11
		FC	-0.08	-0.29	0.26	-0.13	<-9	0.06
HWFET	ΔP<0	ARVD	6.85	-0.02	2.51	8.96	>9	0.15
		FC	-0.14	0.00	-0.05	-0.14	<-9	0.01

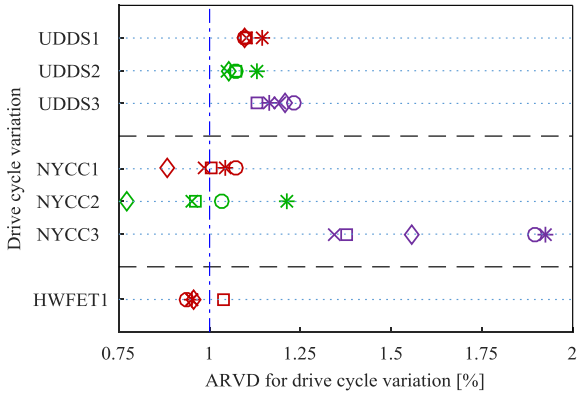
			D_p	D_{pm}	p_{high}	p_{low}	T_{max}	V_{0acc}
UDDS	ΔP>0	ARVD	-0.91	-1.50	-1.42	>9	0.30	0.02
		FC	0.13	0.18	0.28	-0.57	0.05	0.03
NYCC	ΔP>0	ARVD	-0.33	-1.60	-1.40	-0.44	0.31	-0.18
		FC	0.28	0.35	0.53	0.95	0.12	0.15
HWFET	ΔP>0	ARVD	-2.87	-0.51	-0.46	-2.34	0.47	0.22
		FC	0.16	0.11	0.11	0.22	0.07	0.02

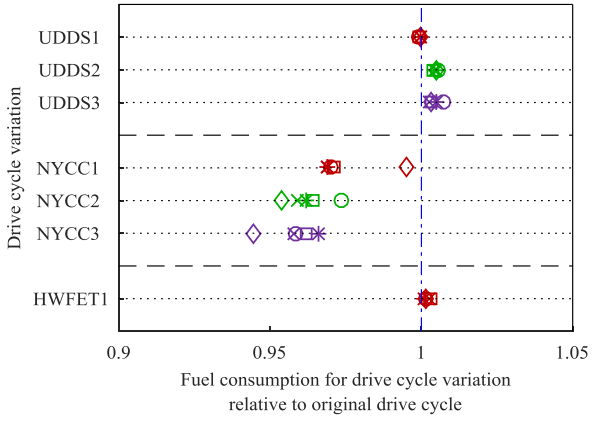
Sensitivity: System Parameters



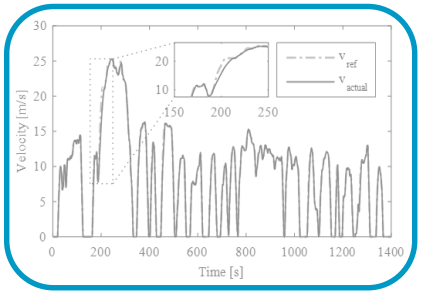
Sensitivity: Variation of Drive Cycle Definitions



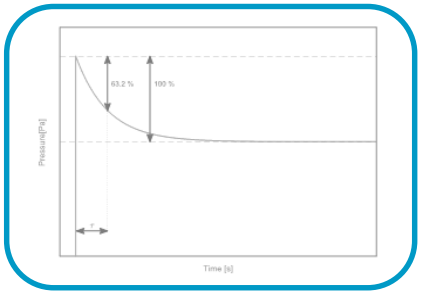




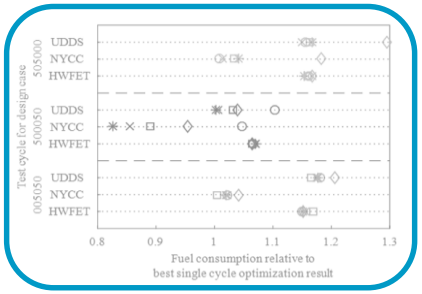
Conclusions and Outlook



Performance: Accuracy Definition



Performance: Fuel Consumption



Performance Requirements

- Control refinement & optimization
- Additional hardware for flexibility
- …

Performance Improvements

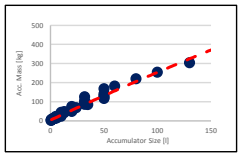
- Correlation of parameters
- Include robustness in optimization
- …

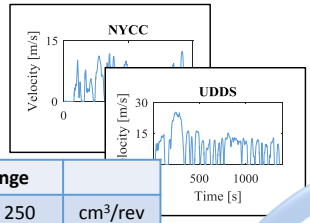
Optimization and Sensitivity Analysis

- Extend to other vehicle types
- Extend to other hybrid architectures
- …

Application of Methodology

Summary





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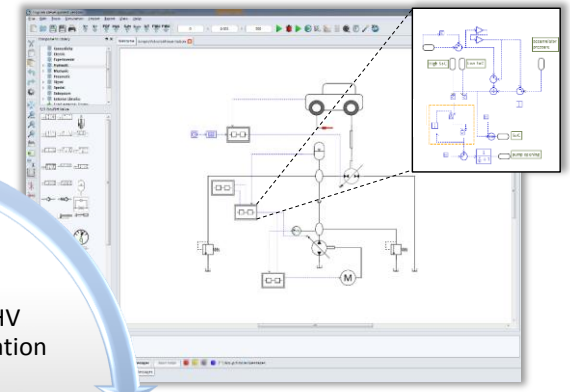
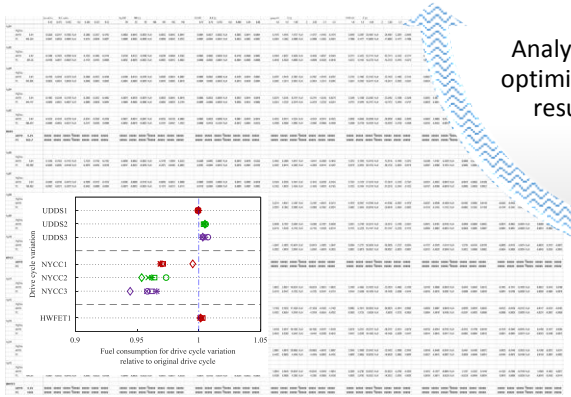
Accumulator size	10 … 100	l

SHHV parameters, application, model

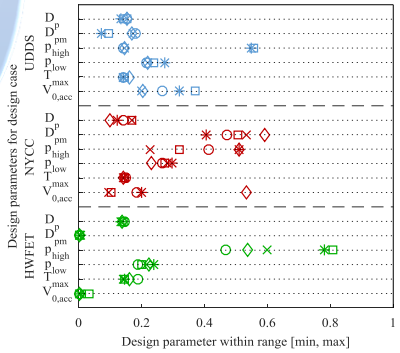


SHHV simulation

Analysis of optimization results



Design optimization



Thank you for your attention!

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