Co-Simulation for hybrid vehicle control software development

Marcus Boumans, Sebastian Wansleben
Robert Bosch GmbH

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Contents

→ Scope & Motivation

→ Use cases & Requirements

→ Simulation Environments

→ Parameterization & Validation

→ Summary and Conclusion
Scope of (Co)Simulation

Support the development of innovative energy management control strategies for passenger cars

Domains under investigation:

- Combined control strategy
- Thermal system control strategy
- HEV Powertrain control strategy
Motivation for (Co)Simulation

- Good reproducibility and fast repeatability of experiments
  - Required especially for traffic simulation & warm-up experiments

- Investigation of real world systems with limited availability
  - Not all HEV / thermal topologies are available as real systems

- Time & costs savings by “Virtual Controller Prototyping”
  - Run control strategy model on a rapid prototyping system in a vehicle

Using (Co)Simulation makes us faster and saves money!
Contents

- Scope & Motivation

- Use cases & Requirements

- Simulation Environments

- Parameterization & Validation

- Summary and Conclusion
Development: Thermal System Control Strategy

Function:

- Optimized thermal management with prioritization of comfort and fuel consumption

Considered information:

- Engine load and speed
- Cooling/Exhaust system temperatures/flowrates
- Influence on powertrain control

Requirements for the Simulation:

- Engine model with thermal behavior
- Detailed cooling/exhaust system model
- Powertrain model including friction
- Model of control strategy software

EM  E-Machine
TC  Turbo Charger
HTC  High Temperature Cooler
OC  Oil Cooler
Development: Map-based ecoACC (HEV)

Function:
- Vehicle increases, decreases and holds speed autonomously

Considered information:
- Desired vehicle behavior from HMI
- Track information from navigation
- Traffic information from radar

Requirements for the Simulation:
- Radar system model, traffic model
- Navigation system model
- Powertrain model
- Model of control strategy software

- CO₂-reduction ✓
- Cross domain function ✓
Contents

- Scope & Motivation
- Use cases & Requirements
- Simulation Environments
- Parameterization & Validation
- Summary and Conclusion
Optimization Thermal System Control Strategy (HEV)

Tasks:
- Optimization of the thermal system (HW & SW)
- Testing of optimized SW version in a concept car
Combined HEV & Thermal Strategy Optimization

**Task:** Investigate CO2 benefit of combined thermal and HEV strategy optimization
Simulation Environment for Map-based ecoACC

Tasks: Optimize & develop predictive powertrain control strategy
Co-Simulation For HEV Control SW-Development

Contents

- Scope & Motivation
- Use cases & Requirements
- Used Simulation Environments
- Parameterization & Validation
- Summary and Conclusion
Parameterization

Use data from calibration departments

Perform special vehicle measurements

Use catalogue data geometric data

- EngineDyno XLS
- MotorDyno XLS
- Vehicle.dat
- Script
- Shift strategy

Diesel Gasoline Systems

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Validation: Fuel Consumption

Fuel consumption [ml/s]

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<th>Value</th>
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<td>SDEV</td>
<td>10.94 %</td>
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Accumulated fuel consumption [ml]

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Diesel Gasoline Systems

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Validation: Exhaust Temperature

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<td>SDEV</td>
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Temperature downstream Catalyst

Measurement
Simulation

Temperature [°C]

Time [s]
Co-Simulation For HEV Control SW-Development

Contents

➔ Scope & Motivation

➔ Use cases & Requirements

➔ Simulation Environments

➔ Parameterization & Validation

➔ Summary and Conclusion
Co-Simulation For HEV Control SW-Development

Summary

- There are use case specific simulation environments for
  - **Thermal Strategy**
  - **Combined Strategy**
  - **Predictive Strategy**

- GTSuite is applied for plant models
- CarMaker is applied for radar sensor models & maneuver, traffic simulation
- ASCET & Simulink are applied for control software models
Co-Simulation For HEV Control SW-Development

Conclusion

- GT Suite fulfills our requirements for a scalable simulation/modeling environment for plant models

- To cover all use cases several tools have to be integrated to one useful simulation application
  
  **Requirement:** Standardized interfaces for tool interoperability

- Reuse of subsystem models coming from different tools is essential
  
  **Requirement:** Standardized ex-/import features for model exchange

Continue development in tool interoperability & model exchange features
Thank you for your attention!