Virtual Testing of the Full Vehicle System

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Software, Consultancy, Training

• Based in Leamington Spa, UK
  – Office in Cape Town, South Africa
• Experts in Systems Engineering, Modelling and Simulation
• Business Activities
  – Engineering consultancy
  – Software sales and support
  – Modelica library developers
  – FMI tool developers
  – Training services
    • Dassault Systemes Certified Education Partner
• Global customer base
  – Europe, USA, India, South Korea, Japan
The need for virtual testing and development

• Automotive products are complex systems covering many domains
  – Mechanical, Electrical, Hydraulic, Pneumatic, Thermal, Chemical, Control, Magnetic, …

• No longer sensible to wait for prototypes to verify that all these systems interact in a good way
  – Parts arrive too late in the process to make cost effective changes if they don’t work together as intended

• It’s not practical, or perhaps even possible, to fully verify and validate control systems using prototypes
  – There are too many scenarios to be considered some of which would be dangerous to the driver and prototype
Virtual testing and development

• Need to simulate the complete vehicle
  – Plant and controller
  – Must use predictive models and not just functional ones to make simulation useful from an early stage of the project
• Need a complete virtual test environment
  – Should provide an immersive environment for both the human driver and vehicle sensors
  – Needs to be flexible to define different driving scenarios
• Our solution:
  – Dymola for the vehicle physics
  – rFpro for the virtual environment
  – SiL and/or HiL for the control systems
• Multi-domain modelling and simulation of complex dynamic systems
  – Mechanical, Electrical, Hydraulic, Pneumatic, ThermoFluids, Thermal, Control
• Component orientated modelling
  – Components represent physical parts: valves, gears, motor
  – Connections between parts describe the physical connection (mechanical, electrical, thermal, signal, etc.)
• Built on open standards of Modelica and FMI
  – Modelica is the modelling language
  – FMI is an open standard for model exchange
• Supports a model based development process
Vehicle Modelling and Simulation

DYMOLA focuses on physical modelling using Modelica and the integration of these models into the design process.

• Engine
  – Air flow
  – Mechanics
  – Cooling system
  – Fuel system
  – Control system
  – Electrification
  – Hydraulics

• Thermal Management
  – Engine Cooling
  – HVAC
  – Battery Cooling
  – Power Electronics Cooling

• Gearbox and Driveline
  – Mechanics
  – Thermal
  – Hydraulics
  – Electrification
  – Control
  – Cooling

• Battery
  – Electrical
  – Thermal
  – Cooling
  – Control

• Chassis
  – Mechanics
  – Active systems
  – Control

• Electric Drive
  – Electrical
  – Thermal
  – Control
Modelica Libraries for Automotive

- Extensive suite of libraries covering every aspect of the vehicle
- The Automotive Library provides the foundation
  - Defines the model architecture, coordinate systems, etc.
    - Flexible so any vehicle architecture can be created
  - Provides models for performance, fuel economy and energy analysis
- Application focused libraries provide detailed simulation capabilities
  - Engines Library includes 1D thermofluids, MultiBody mechanics, combustion models
  - Chassis Dynamics Library provides MultiBody suspension and tyre models
  - Electrified Powertrains Library provides a motor/generator and power electronics models at a wide range of detail levels
- Many of the models are suitable for real-time simulation
Vehicle Dynamics Simulation

• Full vehicle model including engine, gearbox, driveline, cooling system, suspension
• Visibility of every variable within the model to investigate the behaviour
• Easily define different test scenarios with open and closed loop driver models
  – 3D roads
  – Drive cycles
  – Varying ambient conditions
• Animation aids the understanding of the data traces
rFpro provides an environment for vehicle testing and development

- Allows you to reintroduce the human test driver into the model based development process
- Accurate digital track models using LiDAR
  - Extensive library of race tracks, proving grounds and public roads
- Capable of feeding camera, LiDAR, radar and ultrasound sensor models to support ADAS and autonomous vehicle development
- Incorporate traffic simulations to build complex test environments
Virtual Test Environment

- Scaleable from workstation to full DiL simulators
- Modular architecture enables the system to be scaled to suit evolving needs
- Supports SiL and HiL for vehicle physics and controllers
  - Run a mixture of models and real controllers to suit the project requirements
  - SiL environment supports standard calibration tools
  - Wide range of HiL platforms have been integrated
- Dymola models can be easily compiled to run in either SiL or HiL environments
Drivers view

- rFpro using LiDAR scans of public roads
- Dymola providing the vehicle physics and control
- Human driver
Sensor feeds

- Sensors need to be fed with the same high fidelity data as the driver
- Apply lens distortion effects to replicate what the real camera sees
- Each pixel can be interpreted as distance information to feed LiDAR, Radar and Ultrasound sensors
Summary

• Dymola provides a comprehensive suite of automotive focused libraries
  – Built on the Modelica modelling language
  – Application libraries cover every aspect of the vehicle: engine, vehicle dynamics, electrification, hvac, …

• rFpro provides an immersive virtual test environment
  – High fidelity graphics, audio and track data
  – Extensive library of tracks, public roads and proving grounds
  – Define complex scenarios including traffic

• Integration of simulation and virtual test environment accelerates vehicle development