Virtual Testing of Autonomous Vehicles

Mike Dempsey
Claytex Services Limited

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
Functional and Predictive models

- A Functional model is one that captures the key function of the model
- A Predictive model allows us to predict the behaviour and explore its characteristics

- The clutch is there to make sure the two inertias rotate at the same speed when engaged
- Functional model
  - Would reduce the relative speed across the clutch in a predefined manner
  - The controlling parameter would be the engagement time
- Predictive model
  - Would include a model for friction and the torque transfer would be a function of the clutch clamp load, relative speed, temperature, …
  - The parameters would include the geometry and friction characteristics
  - The engagement time could be predicted under different operating scenarios
• 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 using predictive models
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
• 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 to build complex test scenarios
• Ships as standard on the latest generation motion platforms from Ansible Motion, MTS and AB Dynamics
• Use your normal calibration tools to log data and interact with the controllers
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
• Plugin architecture supports using multiple tools to define different parts of the vehicle system
  – Dymola, Simulink, C/C++ and more
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
  – Use masks to simulate dirt on the lens
  – Each pixel can be interpreted as distance information

• Supports ground-truth validation
  – comparing the white lines, road signs, traffic and pedestrians detected by the algorithms vs the real features in the digital road model
Adding your sensor model

• The rFpro Sensor IG option gives us real-time access to the track data
• Plugin architecture enables us to add one or more plugins to process this data
• For example LiDAR sensor:
  – Using rFpro we define a field of view for the sensor, position, orientation, resolution and update rate and this generates range data
    • i.e. for each pixel in the field of view we get the distance to the object
  – A plugin (or multiple plugins) can use this range data in real-time to model what the LiDAR sensor does
  – The output from the sensor model can be sent over Ethernet, CAN, etc.
• Plugins can be defined in C/C++ or using Simulink
Scenario definition

- Traffic can be included in the environment using a number of traffic modelling solutions
  - For example: SUMO from DLR
- You can also use the rFpro Replay Server to record and build your own scenarios
- Connecting multiple rFpro sessions allows you to test the interaction of autonomous vehicles with each other and human drivers
- Extensive library of tracks, proving grounds and public roads
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 for testing autonomous vehicles and ADAS
  – Explore how the human feels whilst the car drives itself

• Integration of simulation and virtual test environment accelerates vehicle development
Thank you

For more information you can contact

Mike Dempsey
mike.dempsey@claytex.com
+44 1926 885900