Development of an Enhanced Heavy Duty Truck Autonomous Driving Simulation Environment

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Outline

• Motivation: Connectivity and Advanced Driver Assist Systems (ADAS) and Automated Driving Systems (ADS) for Transportation
• Interaction of ADAS and ADS with the Powertrain Systems
• Need for Simulation Framework
• Simulation Framework Overview
  • Collaboration with MathWorks and integration of Mathworks Automated Driving Toolbox Motion Planning and Motion Control Features
• Identify Improvement Opportunities and Simulate Advanced Solutions on Different Scenarios
Motivation: Connectivity and ADAS/ADS for Transportation

• Only limited research/solutions available combining autonomous driving with Fuel/Energy Efficiency

• Extend our core competency and expertise in Powertrain controls development to help in system integration and automation

• Goal is to provide interface for ADAS/ADS solutions considering Powertrain Efficiency and Fuel/Energy Optimization

• Deep integration requirements between our powertrain, ADAS and ADS Suppliers and OEM

SAE AUTOMATION LEVELS

- **0**: No Automation
  - Zero automation; the driver performs all driving tasks.

- **1**: Driver Assistance
  - Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.

- **2**: Partial Automation
  - Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.

- **3**: Conditional Automation
  - Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.

- **4**: High Automation
  - The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.

- **5**: Full Automation
  - The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Cruise Control (CC)
Predictive Cruise Control (PCC)
Adaptive Cruise Control (ACC)
Co-Operative Adaptive Cruise Control (CACC)
Lane Keep Assist
Forward Collision Warning/Avoidance
Path Planning
Behavior Planning
Perception
Trajectory Generation
Motion Control

More Longitudinal and Less Lateral Control
Longitudinal and Lateral Control

Interaction of ADAS and ADS with the Powertrain Systems

• Important to understand the interaction between the components and features: CACC Example

• Typically path planning/motion planning does not consider optimizing energy utilization of the powertrain system
  • Mostly considers start/end locations and trip time for global path planning

• Global path/speed profile can be optimized considering powertrain, road grade profiles, traffic etc.

• Local optimization during short horizon trajectory generation for
  • Lane change decisions
  • Opportunistic platooning
Need for Simulation Framework

- Plug and play interface for components and ADAS options for longitudinal and lateral control
- Assess existing and new controls
- Simulink as integration platform
  - Engine, Transmission, Aftertreatment
  - Different levels of fidelity of components
- Motion Planner and Motion Controller from Mathworks Automated Driving Toolbox
- IPG Truckmaker
  - Longitudinal and lateral vehicle dynamics
  - Tractor/Trailer/Tire models
  - Visualization
Importing Real World Routes/Scenarios

- Import real world road networks into the simulation framework using the OpenDrive file support
  - Elevation and Speed limit required
- OpenDrive is a standard open format specification for describing road networks
Motion Planning from Automated Driving Toolbox (Customized)
Custom Behavior Layer

• Customizable behavior layer for
  • Optimal speed target, preferred lane, target gaps to the front and rear vehicles
  • For example inhibit lane change under certain conditions

• Can interface advanced control methodologies to utilize connectivity, and look ahead information
  • Model Predictive Control (Online)
  • Dynamic Programming for global optimization (Offline + Cloud connectivity)
Motion Tracking Controllers from Automated Driving Toolbox

- Longitudinal and Lateral Stanley controllers from Automated Driving System toolbox
- Tunable controller parameters makes it easy to adapt these controllers for different class of vehicles
  - Gains
  - Acceleration/Deceleration Limits
  - Mass
  - Steering Angle
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Stanley Longitudinal and Lateral Motion Controller

Accelerator to Torque

Torque Request to Engine

Electronic Control Unit

Sensors and Actuators

Emission NOx/PM

Torque

Speed

Drivetrain

Aftertreatment Plant

Force

Vehicle Dynamics from TruckMaker

Simulink

Motion Controller and Vehicle Dynamics

MathWorks Automotive Conference 2021
Scenario 1.1: Highway Passenger Car Merging

- Merging scenario with left lane occupied
  - Option 1: Go with the target speed and at the merge apply deceleration or brake => Energy Loss
  - Option 2: Coast down to the merge (Zero Fueling), and then change to left lane => Energy Efficient
Scenario 1.2: Highway Truck Merging Opportunity for Platooning

- If the truck which is merging is equipped with V2V / DSRC communication and exchange information such as the destinations, planned paths, trip times, their weights etc. and decide to form platoon instead of changing lane and trying to overtake

- Drag reduction benefits
Concluding remarks

• Used MATLAB, Simulink as a plug and play simulation integration platform for evaluating existing and new control strategies for ADAS features

• With MathWorks collaboration and support, blocks and algorithms from Automated Driving Toolbox are used for Motion Planning and Motion Control, with customized behavior planner

• Integrated with IPG Truckmaker for detailed vehicle dynamics, visualization, and Traffic objects interaction

• Developed plug and play interface ready to be used with Motion planning/control features from different ADAS suppliers