Maximizing Vehicle Fuel Economy through the Real-Time, Collaborative, and Predictive Co-Optimization of Routing, Speed, and Powertrain Control

Penn State University, University Park: Hosam K. Fathy, Sean Brennan, Stephanie Stockar
Massachusetts Institute of Technology: Domitilla Del Vecchio
University of North Carolina, Charlotte: Christopher Vermillion
Volvo Group North America: Samuel McLaughlin
Introduction of the team

**Domitilla Del Vecchio**
Expert in connected and automated vehicles, coordinated vehicle control, and intersection automation.

**Samuel McLaughlin**
External Research Manager within Advanced Technology and Research for Volvo Groups Trucks Technology.

**Chistopher Vermillion**
Expert in hierarchical control, model predictive control, and optimal energy management.

**Hosam Fathy**
Expert in powertrain modeling, vehicle power management, and hardware-engine-in-the-loop simulation.

**Sean Brennan**
Expert in connected vehicles, vehicle automation, and vehicle control.

**Stephanie Stockar**
Expert in modeling and control of internal combustion engine and vehicle powertrain.
Project Objective and Description

Improve fuel economy through combined **collaborative** and **predictive** optimization, using **hierarchical model predictive control** to merge vehicle control and powertrain control.

**Vehicle control level:**
route optimization, speed trajectory optimization, platooning, intersection management

**Powertrain/engine control level:**
transmission optimization, engine/accessory optimization

---

**Vehicle control level:**
- Optimal Routing
- Platooning
- Harmonization
- Terrain-Predictive Co-Optimal Powertrain & Chassis Control
- Intersection Automation

20% reduction in fuel consumption

---

**Powertrain/engine control level:**
- Transmission optimization
- Engine/accessory optimization

---

**Project Objective and Description**

**Goal #1: Anticipate**
- Traffic/congestion
- Traffic lights
- Surrounding vehicle speeds

**Goal #2: Coordinate**
- Platooning
- Speed trajectories
- Dept.s/arrivals at intersections

**Goal #3: Optimize (Chassis Control)**
- Vehicle route
- Speed trajectory
- Choice of mode (acc/decel/coast)

**Goal #4: Optimize (PT Control)**
- Accessory load
- Engine pedal
- Engine start/stop
- Cylinder de-activ.
- Driveline diseng.
- Gear shifting
Project Innovation and Impact

A sample of the impact of prediction and speed trajectory optimization alone with and without traffic stop prediction

Technology Impact: Reduce vehicle fuel consumption by 20% for a broad variety of urban, suburban, and highway driving scenarios
Technology-to-Market approach

- The technology will be developed in collaboration with Volvo Group North America and will be validated using a Volvo Truck.
- This technology will be valuable for different vehicle sizes and engines.

Dedicated on-vehicle electronic control unit (ECU) for Chassis control, transmission control, and engine/accessory control will be developed.

Optimal vehicle routing will be developed as a cloud-based service.
- It will allow our team to rapidly deploy different products it develops to the market independently.
- It will make it possible to distribute the cost among many potential users of the service.
Key Challenges

- Need for an unified framework that enable the integrated co-optimization of powertrain and chassis functions.

- Co-optimal control is a fundamentally challenging problem because it is a **multivariable** and **multi-objective** problem.

- The combined dynamics of a vehicle’s chassis and powertrain span multiple time spatial and temporal scales.

- Fuel-conscious optimal vehicle control is a fundamentally non-convex optimization problem.

- Coordinated optimization among multiple vehicles creates significant challenges from the perspective of cyber-security.