Adaptive Intelligence for Cyber-Physical Automotive Active Safety System Design and Evaluation (CPS Award #: 1544814)

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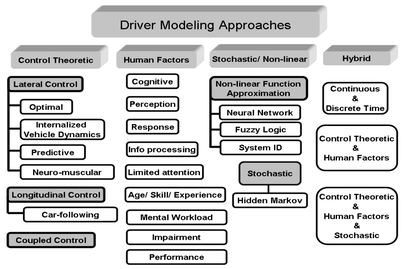
Current State-of-the-Art

- Active safety control systems are currently designed to make them insensitive to individual driver proclivities
- "One size fits all" mentality
- No customization that accounts for individual driving condition, human-automation interaction, or the driver's skills
- Despite a long history of driver modeling, most models are not suitable for control design or deal with the optimal distribution of the workload between the driver and the ASCS

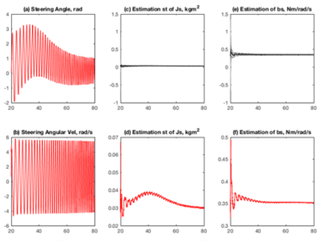


Available Driver Models

- Control-theoretic
- Cognitive
- Stochastic
- Hybrid

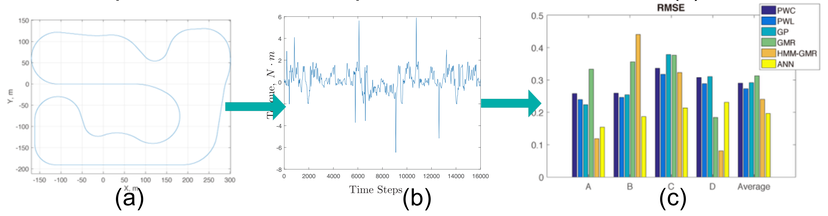
- Previous models separate **tactical** and **strategic** decision layers and low-level execution models separate longitudinal (car-following) with lateral (lane-changing) driver behavior in traffic

Estimating Human Driving Torque



System Identification

- Previous studies employed steering angles, which are effected by steering column dynamics
  - System identification using Joint EKF to extract steering angle and angular velocity are used to estimate inertial and damping parameters (left)
- Human driving data from a road circuit (a) allows a proportional-integral observer to estimate the torque (b) and test parametric and non-parametric control models (c)



(a) (b) (c)

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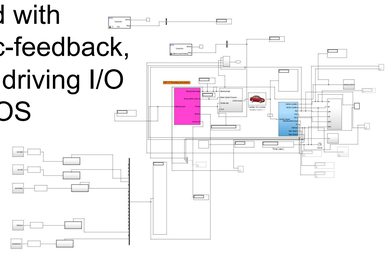
Objective: Improve capabilities of automotive advanced driver assistance systems (ADAS) by taking into account the interactions between the driver, the vehicle, the ADAS and the environment.

Research Approach

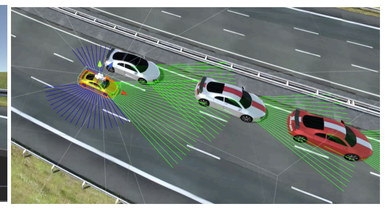
- Putting the focus on **human driving behaviors**
- Better modeling of the human driver within control systems and for behavioral decision making
- Creating a **simulation environment** for validation and human-in-the-loop testing of ADAS systems

Development of the Driving Simulator

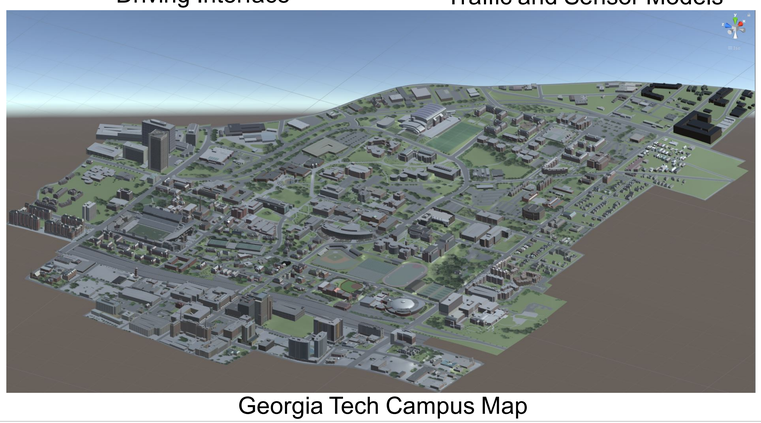
- Integration of state-of-the-art vehicle dynamics wrapped in SIMULINK and integrated with a steering wheel with haptic-feedback, pedals, and other standard driving I/O and tied into Unity3D via ROS
- Supports:
  - Multi-car traffic
  - Realistic scenarios built on satellite maps
  - A variety of sensor, interface, and control modules



Driving Interface

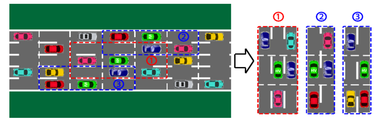


Traffic and Sensor Models



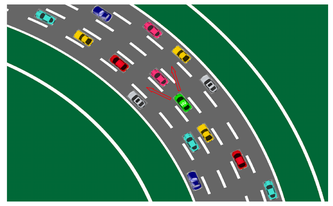
Georgia Tech Campus Map

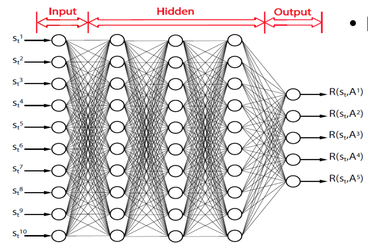
Reinforcement and Deep Inverse Reinforcement Learning



MDP State Decomposition

- **Traffic System Modeling**
  - ✓Define the highway traffic as a Markov decision process (MDP)
  - ✓Use the positions of the host vehicle and the environmental vehicles to represent the state of the MDP
- **Reinforcement learning**
  - ✓Select driver features and design the reward function
  - ✓Solve the MDP and obtain the optimal control policy using reinforcement learning (i.e., Q-learning)





Deep IRL Neural Network

- **Deep Inverse Reinforcement learning**
  - ✓Use a neural network to represent unknown reward function
  - ✓Employ gradient decent method and maximum entropy principle to determine the NN reward and the optimal policy
  - ✓Developed model-free MaxEnt Deep IRL algorithm to solve the MDP problem
  - ✓Able to reproduce typical driving behaviors (i.e., overtaking, tailgating)

Future Work

- Validation and testing of ADAS systems on the driving simulator
- Researching the affects of **transparency and trust** between the human and the assistive driving systems
- Development of a **personalized ADAS** based on the estimated steering torque and non-parametric driver control models
- Solving multi-agent MDPs for traffic navigation, to improve efficiency of traffic flow and reduce congestion

Publications

- Okamoto, K., and Tsiotras, P., (2016). "A New Hybrid Sensorimotor Driver Model with Model Predictive Control" IEEE Conference on Systems, Man and Cybernetics, DOI: 10.1109/SMC.2016.7844510
- You, C., and Tsiotras, P. (2017). "Vehicle Modeling and Parameter Estimation Using Adaptive Limited Memory Joint State UKF" American Control Conference, DOI: 10.23919/ACC.2017.7962973
- You, C., and Tsiotras, P., (2016). "Optimal Two Point Visual Driver Model and Controller Development for Driver Assist Systems for Semi-Autonomous Vehicles" American Control Conference, Boston, MA, July 6–8, 2016, pp. 5976–5981.
- You, C., Lu, J., and Tsiotras, P. (2017). "Nonlinear Driver Parameter Estimation and Driver Steering Behavior Analysis for ADAS using Field Test Data" IEEE Transactions on Human-Machine Systems, Vol. 47, No. 5, pp. 686–699, October 2017.
- You, C., Lu, J., and Tsiotras, P., (2016). "Driver Parameter Estimation Using Joint E/UKF and Dual E/UKF Under Nonlinear State Inequality Constraints" IEEE Conference on Systems, Man and Cybernetics, DOI: 10.1109/SMC.2016.7844407