Connected Technologies and Their Impact on Urban Driving

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My Background

Completed my PhD at Stanford University focusing on Advanced Driver Assistance Systems (ADAS), Automated Driving and Haptic Steering Interfaces

Previously worked at the Uber Advanced Technologies Center
Starting at Faraday Future
This talk will focus on my research experience while at Stanford
Urban Driving Today

Traffic Jams
Urban Driving Today

Parking Hassles
Urban Driving Today

Lots of People
In conclusion...

Driving in cities is:
- Unpleasant
- Time-consuming
- (Potentially) dangerous

It is a general hassle!

What are connected technologies for automobiles and how can they help?
What are connected technologies for automobiles?

Vehicle-to-vehicle (V2V) communication
  • Relates to the communication between vehicles where they share information on things like position, speed, steering wheel angle etc.
What are connected technologies for automobiles?

Vehicle-to-vehicle (V2V) communication

Vehicle-to-infrastructure (V2I) communication
  ◦ Relates to the communication between vehicles and road infrastructure like traffic lights, road signs etc. which share information about the state of traffic signals and the desired driving conditions for that stretch of road
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Vehicle-to-infrastructure (V2I) communication

Internet connectivity

- Relates to how the vehicle can connect seamlessly to the internet and offer services that flow from this connection via the user interface to improve the driving experience
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How can we use this?: V2V and V2I

Both of these technologies give vehicles a better understanding of its environment
  ◦ Improvement over human vision and sensors (like cameras, lidar, radar etc.) especially in inclement conditions

By using V2V a vehicle gets good information about the position of other vehicles around as well as some idea of their intended motion in the short term

By using V2I a vehicle gets good information about the desired driving conditions (speed limits, upcoming obstacles etc.) and traffic signals (their current state, when they’re going to change etc.)

What does this mean?:
  ◦ Vehicles leveraging V2I and V2V can now better understand the current environment and predict future changes in that environment
V2V and V2I

Consider this unprotected left intersection scenario...
V2V and V2I

V2V ➔ Where the oncoming vehicle is
V2V and V2I

V2V → Where the oncoming vehicle is and what it’s planning on doing
V2V and V2I

V2I → What the traffic light state is currently
V2V and V2I

V2I → What the traffic light state is currently and when the next transition will occur

In 10 [s]

In 10 [s]
V2V and V2I

This information is valuable especially in reduced visibility conditions
What can we do with this information?

Using this information about what the current state of our environment is and its predicted future behavior, we can leverage Model Predictive Control (MPC) to improve vehicle safety.

What is MPC?

- MPC uses a model of the vehicle to predict its behavior in the future.
- Using this predictive ability, MPC finds the set of optimal commands to get the desired vehicle behavior in some fixed time horizon.
Model Predictive Control

MPC will be able to steer the vehicle to the desired lane either before or after the white vehicle has passed by predicting our future motion

- Which one of those options it chooses can depend on things like ride quality, safety etc.
MPC in Vehicle Control

MPC can be used in 2 distinct (yet similar) scenarios for vehicle control
- Advanced Driver Assistance Systems (ADAS)
- Automated Driving (AD)
MPC can be used in 2 distinct (yet similar) scenarios for vehicle control

- Advanced Driver Assistance Systems (ADAS)
- Automated Driving (AD)
ADAS: Obstacle avoidance controller

Based on Environmental Envelope Controller (EEC) developed by Erlien et al. ’13 at Stanford University

Shared controller that uses a Model Predictive Control (MPC) approach

Controller has 2 main objectives
◦ Maintain a collision-free trajectory
◦ Controller tries to follow the driver’s steering command
  ◦ Shared control concept

Controller leverages on active steering
◦ Relies on Steer-by-wire
MPC: Shared control

Finds a feasible collision-free trajectory

Biases its solution to follow the driver’s steering command
X1 Experimental Testbed

- Steer-by-wire
- Force feedback steering system
Haptic steering feedback

To give early indication to the driver as part of the ADAS, we can generate predictive haptic feedback from this controller

\[ \tau_{\text{haptic}} = K_{\text{haptic}}(\delta^{(k)} - \delta^{(k)}_{\text{driver}}) \]

Mirrors the tension between the controller’s two objectives

Looking further in the future (i.e. as \( k \uparrow \)) results in earlier FB
Experimental setup

Want to test:
- Efficacy of feedback

Typically done on simulators [Jensen et al. ‘11]
- Obstacles pop up during driving task and driver reacts with and without feedback
- Obstacles pop up a little after the haptic cue

Do this on a real vehicle!
Experiment setup

(a) Before obstacle deployment
Video of experiment
Video of experiment
Min time to collision (TTC)

Reaction time: 0.7 [s]  
Reaction time: 0.5 [s]

Minimum time the center of mass of the vehicle has till it collides with any point of the obstacle
Driver/vehicle data

\[ p < 0.01 \]

Less aggressive driver inputs

Less aggressive vehicle motion
MPC in Vehicle Control

MPC can be used in 2 distinct (yet similar) scenarios for vehicle control
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AD: MPC used for autonomous control

Recall: ADAS controller has 2 main objectives
- Maintain a collision-free trajectory
- Controller tries to follow the driver’s steering command
  - Shared control concept

For AD:
- The 2nd condition of trying to follow the driver’s steering command is dropped in favor of following a desired path
AD: MPC controller (high speed)
V2V/V2I and MPC

V2V and V2I provide good information about the current state of the environment and how it will change in the near future.

MPC can leverage this information to enable Advanced Driver Assistance Systems (ADAS) and Automated Driving (AD).

ADAS / AD can make urban driving scenarios:

- Safer since they can use information about the environment to plan safe routes and ensure that vehicles stick to them (by either working with the driver through ADAS or being fully automated).

Beyond that, AD can make urban driving scenarios:

- More efficient since with better information about the environment, vehicles can go faster and smoother while maintaining better safety.
Autonomous driving and beyond!

AD can change the way we travel since the interior space of a vehicle is no longer just a functional space for getting from point A to point B.

It can now couple with the last leg of automotive connected technology (internet connectivity) to drastically change the nature of mobility.

Vehicles can now be more than just driving machines, with AD acting as an enabler so that the occupants of a vehicle can leverage internet connectivity to:

- Work
- Enjoy entertainment (i.e. movies, games etc.)
- And More...

This is one of the goals of Faraday Future!
Faraday Future
Questions?