UNIFIED, SCALABLE AND REPLICAIBLE CONNECTED AND AUTOMATED DRIVING FOR A SMART CITY

SAE INTERNATIONAL FROM ADAS TO AUTOMATED DRIVING SYMPOSIUM
COLUMBUS, OH

OCTOBER 10-12, 2017

PROF. DR. LEVENT GUVENC
Automated Driving Lab
**AUTOMATED DRIVING LAB**

**Team overview and key expertise**

- Team: two faculty, one researcher, 12+ graduate students with strong focus on connected and automated driving, ADAS, active safety systems, autonomous shuttles for smart cities
- Ford Fusion Hybrid and Dash EV connected and automated driving vehicles with GPS/IMU localization, radar/camera/lidar perception under dSpace microautobox and perception computer control.
- State-of-the-art hardware-in-the-loop simulator with Carsim Real Time with traffic and sensors with interface to the vehicle electronic control unit and DSRC modems for the ego vehicle and the infrastructure and other vehicles.
- Validated models of connected and automated vehicles. Testing capability in parking lot, SR 33, TRC and Smart Columbus deployment sites.

**Application areas**

- Automated Path Following, **Highway Chauffer / Autopilot**
- Low Speed **Autonomous Shuttles for a Smart City**
- Cooperative Adaptive Cruise Control, Platooning
- Pedestrian Collision Avoidance
- Energy Efficient Connected & Autonomous Vehicles
- Cooperative Collision Avoidance

**Partners and sponsoring agencies:**

- TRC
- DENSO
- HYUNDAI
- NSF
- WIND
CATEGORIES OF AUTOMATED DRIVING:
FULL AUTOMATION IS THE GOAL

Level 0: Non-Automated
The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.

Level 1: Assisted
The driving mode-specific execution by a driver assistance system of either steering or acceleration/ deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.

Level 2: Partial Automation
The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.

Level 3: Conditional Automation
The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.

Level 4: High Automation
The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.

Level 5: Full Automation
The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.

Research Aim:
Level 4/5

Two many problems in Level 3 due to the presence of the human driver.
Autonomous electric shuttles will operate in commercial district.

Autonomous electric shuttles planned to operate in Ohio State University campus.
A Scalable and Replicable Architecture for Low Speed Automated Shuttles in Smart Cities
SMART SHUTTLE LEADING TO PROJECT UNIFY


GCTC EXPO 2016 in Austin Texas
June 13-14, 2016

Different Vehicles

Unified Architecture

Different Vehicles

Easton Town Center

Ohio State University

Planned Deployment Sites
Develop and use a unified software, **hardware**, control and decision making architecture.
2015 FORD FUSION HYBRID SE AUTOMATED DRIVING VEHICLE

Power Distribution, MABx and GPS

LIDAR

Mobileye Camera

RADAR
IN-HOUSE AUTOMATION DASH EV AUTOMATED DRIVING VEHICLE
Develop and use a scalable and replicable method of designing longitudinal and lateral vehicle dynamics controllers via parametric approach. Automated path following is used as the first scalable and replicable application.
SCALABLE AND REPLICABLE AUTOMATED PATH FOLLOWING: VEHICLE DYNAMICS MODELING

- Weight
- Wheel load
- Location of CoG
- Yaw moment of inertia
- etc

Vehicle Inertia Parameters Test
- Suspension Vertical Stiffness
- Static Tire Vertical Stiffness
- Bounce Toe, etc

Suspension Kinematics & Compliance Test

Vehicle Dynamics Simulation

Single-Track model
Carsim model
Experimental
AUTOMATED PATH FOLLOWING IMPLEMENTATION
AND MIL AND HIL EVALUATION

Robust PID Path Following Controller

PI based Cruise Controller

Throttle and Braking Actuation

GPS Measurements

Speed Measurement

Digital map and GPS measurement based calculation of $h, \Delta \psi$

Vehicle

$V_{des}^{-}$

$V$

$\gamma$

$\delta$

$\gamma = h + l_s \sin(\Delta \psi)\frac{1}{y}$

GPS Measurements

Desired digital map

Start

Finish

North [m]

East [m]

dSPACE MicroAutoBox

dSPACE SCALEXIO
AUTOMATED PATH FOLLOWING IMPLEMENTATION AND PROVING GROUND EVALUATION

Path

Reference Path (Digital Map)
Test 7 Current Path (Santhosh-5 km/h)
Test 8 Current Path (Santhosh-5 km/h)
Test 9 Current Path (Santhosh-15 km/h)
Test 10 Current Path (Santhosh-15 km/h)
Test 11 Current Path (Santhosh-30 km/h)
Test 12 Current Path (Santhosh-30 km/h)
Test 13 Current Path (Nitish-5 km/h)
Test 14 Current Path (Nitish-15 km/h)
Test 15 Current Path (Nitish-30 km/h)
AUTOMATED PATH FOLLOWING OF FORD FUSION HYBRID IN TRC VDA
SCALE AND REPLICATE AUTOMATED PATH FOLLOWING TO SECOND VEHICLE (DASH EV)
EXTEND SCALED AND REPLICATED SOLUTION TO SMART SHUTTLE PROOF-OF-CONCEPT TESTING

Subsequent proof-of-concept deployment planned on OSU AV pilot route between Car-West and Car

Initial proof-of-concept deployment in parking lot

Sub-project Smart Shuttle of CMU Mobility 21 National UTC (US DOT)
SMART SHUTTLE: OSU AV PILOT ROUTE POINT CLOUD DATA FROM CAR WEST TO CAR
CAV HIL SIMULATOR: OSU AV PILOT ROUTE IN CARSIM REAL TIME WITH SENSORS AND TRAFFIC
PEDESTRIAN COLLISION AVOIDANCE USING V2P COMMUNICATION

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COOPERATIVE COLLISION AVOIDANCE

Electronic Emergency Brake Light (EEBL)

Intersection Movement Assist (IMA)

Curb Side Vehicle Alert

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ELECTRONIC EMERGENCY BRAKE LIGHT (EEBL)

Without V2V  With V2V

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INTERSECTION MOVEMENT ASSIST (IMA)

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Automated Driving Lab
COOPERATIVE COLLISION AVOIDANCE

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END OF PRESENTATION
QUESTIONS ???
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Thank you!

U.S. Department of Transportation Mobility 21: National University Transportation Center for Improving Mobility - CMU (sub-project titled: SmartShuttle: Model Based Design and Evaluation of Automated On-Demand Shuttles for Solving the First-Mile and Last-Mile Problem in a Smart City)

National Science Foundation under Grant No.:1640308 for the NIST GCTC Smart City EAGER project UNIFY titled: Unified and Scalable Architecture for Low Speed Automated Shuttle Deployment in a Smart City