Emerging Technologies and Transportation Implications

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Civil and Environmental Engineering
UNIVERSITY OF WISCONSIN—MADISON
Presenter

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Permissive Left-Turn Operations

- Flashing yellow arrow indications (FYA)
- FYA approved by FHWA in 2006
  - Initially Four-Section Vertical or Horizontal
Automated Vehicles

Take Different Forms

AV

GM

FORD

NAVYA

CASE IH

GOOGLE

TESLA

STARSHIP
Connected Vehicles

CV

V2V

V2I

V2X

IoT
CV/AV Simultaneous Operation

Autonomous Vehicle
Operates in isolation from other vehicles using internal sensors

Connected Vehicle
Communicates with nearby vehicles and infrastructure

Connected Automated Vehicle
Leverages autonomous and connected vehicle capabilities
Why the push to CAVs? – Safety!
Improve Mobility for Children, Elderly, Disabled
Eliminate Traffic Signage?
Autonomous Vehicle Platooning

- 4 full Chrono::Vehicle systems
- Lead vehicle: interactively driven
- Follow the leader
  - Each vehicle follows the one before it
- Throttle and braking based on LiDAR data
- All data overlaid is for vehicle 4
  - LiDAR data shown on lower left
  - Approximate GPS/IMU data overlaid on map (right)

Source: Professor Dan Negrut
Wisconsin Full-Scale Driving Simulator
SPaT Challenge

What is the Challenge?

Challenge state and local public sector transportation organizations to cooperate together to achieve deployment of DSRC infrastructure with Signal Phasing and Timing (SPaT) broadcasts in at least one corridor or network (approximately 20 signalized intersections) in each state by January 2020.
Madison CV/AV Corridor – Park Street Connected Corridor

- Goes beyond SPaT Challenge
- 26 DSRC deployment
- TSP/MMITSS application
- Transit/VRU interaction apps
- Red light violation warning
- V2I general testing
- Simulation-to-design
- Preparation for C-V2X / 5G

Starting with five intersections
Installed in April 2018
CV Corridor Initial Installs – Spring 2018
Initial Madison Projects

- SPaT Testing
- Transit-Signal Priority
- Emergency-Vehicle Priority
- Vehicle-to-Pedestrian Applications
- Signal Coordination
- Radar to BSM
Connected Vehicle Applications

- V2I Safety
- V2V Safety
- Agency Data
- Environment
- Road Weather
- Mobility
- Smart Roadside
Ten Federally Designated AV Proving Grounds

- American Center for Mobility (ACM) at Willow Run
- City of Pittsburgh and the Thomas D. Larson Pennsylvania Transportation Institute
- U.S. Army Aberdeen Test Center
- North Carolina Turnpike Authority
- San Diego Association of Governments
- Contra Costa Transportation Authority (CCTA) & Go Mentum Station
- University of Wisconsin-Madison
- Iowa City Area Development Group
- US Department of Transportation
- Texas AV Proving Grounds Partnership
- Central Florida Automated Vehicle Partners
Wisconsin Facilities

400 acres, private and secure, numerous testing capabilities
Wisconsin Facilities

UW-Madison Campus and City of Madison
CAV Operating Models

- True ownership
- Exclusive license
- Non-exclusive license
- Service-based
Shared Mobility
Transformative Redesign of Roadway Infrastructure

• Current roadways are not designed for door-to-door service
Changes in Roadway Cross-Section

BEFORE

Roadway: 80%
Green Space: 0%

AFTER

Roadway: 20%
Green Space: 42%

adapted from Henderson and Spencer 2016
Autonomous Vehicle Parking Lot Model

Ferreira et al. 2014
Mobility for Everyone
Freight Platooning

A Report from the MAASTO Working Group and Mid-America Freight Coalition
Platooning Research

- No study modeled the effects of truck platooning.
- Comprehensive impact of truck platooning on sign occlusion.
Traffic Control Visibility
## Results with One Advanced Sign

(Percent of time sign occluded)

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<th>Truck percentage</th>
<th>Platooning penetration (%)</th>
<th>Traffic demand (veh/hr/ln)</th>
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Study projects autonomous trucks could replace nearly 300,000 long-haul drivers

Jobs with average annual earnings between $60,000 and $70,000 have the highest risk of automation.

SEPTEMBER 10, 2018

Here's what's likely to happen with automation:

Local driver: Low pay, more often, polling trucks & inefficient operations.

Delivery driver: Low wages, likely to be misclassified as independent contractors.

A new report suggests autonomous trucks could replace as many as 294,000 long-haul drivers in the next 25 years.

ILLUSTRATION BY JEFF BARRERA

In the report, "In Driverless?: Autonomous Trucks and the Future of the American Trucker," author Steve Viselli, sociologist at the University of Pennsylvania
WISCONSIN AUTOMATED VEHICLE PROVING GROUNDS
Use I2X and V2X communication and information interchange with arranged communication protocol and data interchange

Achieve intelligent transportation management, intelligent dynamic information services, and automated driving

Ultimate form of development of Intelligent Transportation System
Connected and Automated Vehicle Highway (CAVH) System — Key Technology

Connected and Automated Vehicle
- Internet of Vehicles
- Telematics
- CAV
- Automated Vehicle

Connected and Automated Highway System
- Internet of Highway
- I2X and V2X
- Active Management
- Automated Highway System
Development Direction of CAVH

Vehicle Based Approach

IT & OEM Firms

Infrastructure Based Approach

Transportation Industry

Connected and Automated Vehicle

Connected and Automated Highway Systems

CAVH
Future Integrated Development of CAVH

- **Weak AI**: L1(DA)
- **Medium AI**: L2(PA)
- **Strong AI**: L3(CA)
- **Super AI**: L4(HA)
- **Future Integrated**: L5(FA)

**Road Based**
- Time:
  - 2018
  - 2020
  - 2025
  - 2030
  - 2050

**Vehicle Based**

**Level of AI**
- Weak AI
- Medium AI
- Strong AI
- Super AI

**Automation Level**
- L1(DA)
- L2(PA)
- L3(CA)
- L4(HA)
- L5(FA)
System Based Approach: Simple Vehicle, Smart System

Technical Features:

- The majority of the sensor functions can be achieved using sensor systems on highway infrastructure or vehicle/highway system

- The majority of the vehicle operation and control functions can be achieved via the cooperation of control systems on highway infrastructure and vehicle

- Multiple redundant systems for sensor system, computing system, control system, communication system, information safety
Client-Server Analogy of Automated Driving Approaches

- Vehicle-Based Approach:
  - Very Fat Client - Thin Server
  - Very high total cost, especially for vehicle
  - Local optimal for driving tasks

- Infrastructure (or System) Based Approach:
  - Thin Client - Fat Server
  - Low total cost & substantially lower cost for vehicle
  - Global optimal for trips and travels
CAVH Eco-System

Vehicle
(Level 1/1+/2/2+)

- Microwave Radar (lots of companies in China)
- Vision
- Inertial Navigation Systems
- DGPS

- DSRC, 4G LTE, 5G
  (Qualcomm, Huawei, ZTE(Zhongxin))

Cloud

RSU

T2V
V2I

- Radar and LiDar (US: Velodyne, etc)
- Vision (China, HIKVision; US, MobileEye)
- RFID
- CPU
- GPU (Nvidia, INTC)

Intelligent Road Infrastructure System (IRIS)

OBU

TCU

TCC

TOC
Typical Sensing
Google/Waymo - Cost

Vehicle: $32,000
Equipment: ~$250,000+, including
Sensors: LIDAR ($70,000), Camera, Radar (Millimeter, Microwave, Ultrasonic)
Computing systems: CPU, GPU

Rotating sensor on roof generates 3D map of surroundings
Radar sensors help determine position
Video camera on windscreen detects traffic lights and moving traffic
Cost Comparison – Google/Waymo vs CAVH

Google/Waymo
Average Price: $250,000

CAVH:
On-Board Unit (OBU):
IMU, DGPS, Radar, Camera
Average Price: $5,000 - 10,000
CAVH Road Side Unit (RSU) – Sensing & Fusion
Joint Research Institute on Internet of Mobility
Between
Southeast University and
University of Wisconsin-Madison
National IOM Demonstration Area Establishment

CATARC Test Site for Internet of Mobility at Yancheng City

China Automotive Technology & Research Center
Operator Simulation

Multi DOF Driving Simulator at SEU

National IOM Demonstration Area Establishment
Demonstration Project Introduction

Vehicle Type
- Passenger Car
- Bus & Truck

Communication Tech
- 4G LTE / DSRC
- 5G/4G LTE / DSRC

System Settings
- Cloud
- Control
- Fusion
- Cyber Security

Introduction
Roadside Infrastructure and Telecommunications

Roadside Infrastructure
CAVH Demo – Nanjing, China
(An) AV Timeline

- **2015**
  - driver assistance common
  - some partial automation available to consumers

- **2020**
  - limited / conditional AVs widely available to consumers

- **2025**
  - autonomous shared mobility fleets

- **2030**
  - high automation required in all new vehicles

- **2035**
  - human operation is the exception in many places

- **2040**
  - transition to driverless largely complete
  - fleet turnover continues…

- **2100**

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- Any estimate is debatable
- We are only at the beginning of a long transition period
Governor’s Committee on CV/AV

- May 2017 EO #245
- Sept 2017 Kickoff
- June 2018 Report
- Members:
  - Government: WisDOT, WSP, WEDC, Assembly, Senate, Iowa Co Sheriff, Insurance Commissioner
  - Academic/Nonprofit: UW-Madison, Tech Council, ABATE
  - Industry: MGA, Roadview, Waymo, Uber, Tesla, AAM, Global Automakers, Dealers Assn, Harley, Schneider, HNTB

“the removal of barriers to the testing and deployment of automated and connected vehicle technology in Wisconsin”
Thank You!

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Civil and Environmental Engineering

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