Preparing Students for Careers that Use New Transportation Technologies

T3e Webinar –February 27, 2019

Bob Feldmaier

Director - CAAT
About the Center for Advanced Automotive Technology (CAAT)

• Located at Macomb Community College South Campus
• Partnered with Wayne State University
• Became an Advanced Technological Education Center in 2010 funded by the National Science Foundation
• Mission
  – Advance the preparation of skilled technicians for the automotive industry’s more environmentally friendly and safer vehicles.
  – Be a regional resource for developing and disseminating advanced automotive technology education.
Strategic Priorities

• Future student focus to fill employment pipeline
• STEM programs/events
• Educational collaboration
• Partnerships with industry
• Curriculum resources
Why CAAT at Macomb Community College?

• Long history of preparing many students to work in the automotive industry

• Leaders of advanced automotive curriculum development for technicians

• Located in the heart of the rejuvenated US auto industry
  – Over 215 Automotive R&D Companies in Michigan
  – Most (85%) are clustered in southeast Michigan
  – 60% of the top 150 automotive suppliers to North America are headquartered in Michigan
CAV Main Questions

• Why the interest in autonomous vehicles?
• How does the technology work?
• What are the remaining challenges?
• How does this affect education?
Some of Today’s
Advanced Driver Assistance Technologies

ADAS system comprises of passive and active safety system depending on the level of human intervention in driving

<table>
<thead>
<tr>
<th>Major ADAS systems</th>
<th>Description</th>
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<tbody>
<tr>
<td>Actively engaging/intervening driving to prevent</td>
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</tr>
<tr>
<td>accident</td>
<td></td>
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<tr>
<td>Autonomous emergency braking</td>
<td>Activated when collision risk detected using same sensors as Adaptive Cruise Control</td>
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<tr>
<td>Adaptive cruise control</td>
<td>Adjusts speed to maintain safe distance between cars using long &amp; short distance radar sensors (e.g., LiDAR)</td>
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<tr>
<td>Forward collision warning</td>
<td>Detects obstacles in front and issues warning on screens using same sensors as ACC</td>
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<tr>
<td>Lane departure warning</td>
<td>Detects and warns against lane departure</td>
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<tr>
<td>Parking assistance</td>
<td>Some functions even offer autonomous return to original lane</td>
</tr>
<tr>
<td>Blind spot monitoring</td>
<td>Aids parking in varying degrees: simple warning against obstacles → complete autonomous parking</td>
</tr>
<tr>
<td>Rear cross traffic alert</td>
<td>Warns against lane departure by detecting blind spots during lane change</td>
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<tr>
<td>Night vision &amp; pedestrian detection</td>
<td>Warns for proximity to vehicle when backing up</td>
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<tr>
<td>Traffic sign recognition</td>
<td>Expands scope of detection via infrared camera installed under the bumper or rear view mirrors</td>
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<td>Driver Monitoring</td>
<td>Reads speed limit signs using cameras mainly installed on back of rear view mirrors</td>
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<td></td>
<td>Issues warnings on fatigue level using camera sensors that monitor driver and his/her driving patterns</td>
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### There are Six Levels of Automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Who is Driving?</th>
<th>Who is Monitoring?</th>
<th>Who Intervenes?</th>
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<tr>
<td>0</td>
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<td>😠🤖</td>
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<td>Full Automation</td>
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<td>😠🤖</td>
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Source: Adapted from NHTSA and SAE J3016

Carnegie Mellon University
How our Driving & Time spent in vehicle will Shift

- **Level 2 system** (today): cognitive focus on driving
- **Level 3 system** (2020): cognitive focus on driving, non-driving activities
- **Level 4 system** (2030): non-driving activities
- **Level 5 system** (2040+): non-driving activities
The Impact of Car Crashes on the Economy beyond 34,000 Deaths per Year in the US Alone

- ~1 Million: Days spent in the hospital each year from crash injuries.
- ~2.5 Million: People in the US that went to the ER for crash injuries in 2012 of which nearly 200,000 were hospitalized.
- $212 Billion: Cost of roadway crashes for the US economy each year.
- $180-190 Billion: The maximum potential saving per year in the US if you believe that ADAS and AVs can succeed in reducing car accidents by 90%.

For every 1 person killed in a motor vehicle crash:
- 8 people were hospitalized.
- 100 people were treated and released from the Emergency Department.
Sources claim significant societal cost benefits of autonomous vehicles

- Lower Congestion: $150 billion per year
- Increased Efficiency: $300 billion per year
- Lower Accidents: $1,200 billion per year
- Increased Productivity: $1,800 billion per year
- Widespread Car Sharing: $1,800 billion per year

Sources:
1) “Crashes vs Congestion”, Cambridge Schematics Inc.
2) “Urban Mobility Report”, Texas A&M Transportation Institute and “Evaluation of the public health impacts of traffic congestion”, Harvard School of Public Health
3) “Can we put a price on Autonomous Driving?”, Frazzoli E, MIT Technology Review
US Consumers Rate Safety and Advanced Driver Assistance Technologies Most Important
Highly Automated Vehicles

- We are in the midst of the most significant transformation in transportation since the engine merged with the horse and buggy
- The merger is technology with the vehicle
- Technology will change the way goods, services, and people move
- This will influence how communities are designed for decades to come by creating places that are sustainable, equitable, and economically vibrant

Dr. Gary Smyth, Executive Director, General Motors Research and Development Laboratories, presentation at 23rd Annual ITS Wisconsin Forum, November 8, 2017
Connected Vehicles

• While automated driving systems continue to advance, it is the combination of connected and automated driving that promises the greatest opportunity to dramatically reduce traffic fatalities and injuries and improve mobility.

• Allows vehicles to effectively see dangerous situations before they encounter them.

• Allows vehicles to coordinate their movements with infrastructure.

THE ROAD AHEAD
Intelligent and Transformative Transportation
The Next Generation of Mobility – A Public Policy Roadmap for 2017

Dr. Gary Smyth, Executive Director, General Motors Research and Development Laboratories, presentation at 23rd Annual ITS Wisconsin Forum, November 8, 2017
Integrated Systems Approach to Vehicle Automation
The Complexity of Automated Driving

- Highly robust in all use cases
- Protection against technical failure and deliberate attacks
- Global standards and clear liability

- Surround sensing
- Safety and security
- Legislation

- System architecture
- Map data

- Redundancies for sensing, ECUs, and actuation required (fail-operational)
- Always precise and up-to-date
Vision/Radar/Lidar Operation and Fusion

**Camera**
- **How it works:** A camera takes images of the road that are interpreted by a computer.
- **Strengths:** Distinguish and classifies objects, such as traffic lights, tail lights, road lines and signs. It can also classify some objects, such as the deer being a large animal.
- **Weakness:** Like us, what it can’t see, it can’t see — in the dark, into direct sunlight and when objects are hidden.

**LiDAR**
- **How it works:** Light pulses are sent out, reflected off objects and received for interpretation.
- **Strengths:** Can define specific objects, such as a deer and its distance. Can tell where lines are on the road. Works in the dark.
- **Weakness:** In bad weather, the light reflects off fog, rain or snow, making objects hard to define.

**Radar**
- **How it works:** Radio waves are sent out, bounced off objects and received for interpretation.
- **Strengths:** Knows there are large objects that could be a deer. Does a good job calculating the deer’s speed and its distance. Can work in all weather, day or night. Can even fill in some hidden objects.
- **Weakness:** Can’t see color or differentiate objects, such as a deer from a big rock.

**Working together for a better image**

**Multi-domain controller**
- With cameras, Radar and LiDAR, you’re getting three forms of input. Putting them all together is the multi-domain controller’s job. It takes the best of all three. Add mapping and navigation information and you can confirm decisions in multiple ways.
What is Sensor Fusion?

- **Definition**
  
  « Information Fusion is to combine information from multiple sources in order to improve decision making » Isabelle Bloch

- **For Autonomous Driving**
  
  Combination of the output data of various sensors to provide an autonomous driving system with a complete perception of its environment and current driving state.

- **Approaches**
  
  - Probability Bayesian fusion
  - Possibility theory Fuzzy Logic
  - Evidence theory Dempster-Shafer
Sensor Fusion Improves Performance

- Vision Lane Information
- Vision Vehicle Information
- Radar Object Information
- Radar Barrier Detection

Adjacent Left
Adjacent Right
Left
Right

Sensor Fusion and Safety Concept

Eyes Off Automated Driving Safety Concept

- ASIL consideration
  - System must fail operational
- Redundancies at several levels
  - Sensors
  - Fusion
  - Actuators
  - Software

Sensor Fusion is an important safety consideration
Advantages of Redundant Sensor Fusion

• **Probability of correct detection and classification**\(^1\)
  - Increases with additional sensors and redundancy
  - Utilize sensors with highest signal to noise ratio (S/N) under the ambient conditions
  - Disregard sensors that have low S/N under the ambient conditions
  - Marginal gains decrease for more than 5 sensors

• **Reliability of systems**\(^2\)
  - Adding more sensors increases the reliability of the overall system
  - Mean time to failure of a system with more sensors is increased

References:
\(^1\)Hall, David L., “Mathematical Techniques in Multisensor Data Fusion”, Artech House Information Warfare Library, February 26, 2004
Multi-domain Controller

- Scalable software platform
- Reduced architecture complexity
- Faster communication/interconnection
- Multi-processor configuration

Production launch in 2017

Enables future system optimization/upgradability
Artificial Intelligence

Three main pillars of automated:
- Sensing
- Thinking
- Acting

Artificial intelligence being used to mimic human ability to reason and decide.
IN YOUR BLIND SPOT! YA' BIG TUB O' LARP!

WATCH WHERE YOU'RE GOIN', YA' OVERPRICED MORON!

GOVERNMENT WANTS AUTONOMOUS CARS TO TALK TO EACH OTHER.
System Flow

Sense
- LiDAR
- Radar
- Camera
- GPS
- Camera in Car
- V2X
- Comm. to Infra

Perceive
- Object Detection & Tracking
- Lane Detection
- Traffic Sign Recognition
- Localization

Decide
- Preceding Vehicle Detection
- Road Shoulder Detection
- Rear/side Warning Detection
- Dynamic Map Building
- Path Generation
- Speed Profile Generation

Act
- Lane Keeping
- Lane Change
- Path Tracking
- Speed Maintaining
- Safe Distance Maintaining

Result
- HAD
- UAD
- PVF
- ESS
Changing ECU Architecture ...

From a decentralized architecture following the general paradigm “one ECU for one ADAS-related functionality” ...

... to a centralized architecture with central sensor data fusion, predictive 360° redundant sensing and artificial intelligence (AI).
Automated Driving: Enabling and Supporting Technology

HIGH DEFINITION MAPS

V2X COMMUNICATIONS

Source: Texas Instruments ADAS Solutions Guide
Adding HD Map layers for Automated Driving

- **Highly Detailed**
  - 3D Lane Geometry
    - markings
    - centerlines
    - road boundaries

- **Highly Accurate**
  - Sub-meter absolute
  - Decimeter-level relative

- **Richly Attributed**
  - Lane-level attributes
  - Position
  - Landmarks
  - RoadDNA
The Process of Delivering Real-Time Maps

Delivering real-time maps
Introducing the Concept of “Connected” Vehicles

What’s the difference: Connected versus Autonomous Car?

An Autonomous Car needs information — lots of it!

- Location and positioning
- Map data
- Traffic information
- Weather data
- V2X
  - Car2Car
  - Traffic lights
  - Local road conditions
  - Police and emergency vehicles

This information is fused with the local sensors and processed to drive the car, autonomously.

The Autonomous Car IS Connected!
Cars talking with surrounding infrastructure...

Vehicle-to-Everything (V2E)

I'm stalled and can't move.

My left light turns green in 30 seconds.

Thanks! I'll change my route and turn at this light coming up.
Dedicated Short Range Communications (DSRC) and Vehicle Ad-Hoc Networks for V2V Communications

- DSRC uses 5.9 GHz frequency and 75 MHz bandwidth (seven 10 MHz channels) plus 5 MHz guard band
- 2017 Cadillac CTS is first to have DSRC
V2V/DSRC/5.9 GHz Safety Spectrum

- ITS America strongly urges the Federal government to protect the 5.9 GHz safety spectrum band that was allocated by the FCC for development of Dedicated Short Range Communications (DSRC)-enabled vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology.
- NHTSA, which proposed V2V standards last year, estimates DSRC potentially could reduce 80% of unimpaired crash scenarios, saving thousands of lives per year.
- DSRC-enabled vehicles effectively can “see” around corners and achieve greater 360-degree situational awareness to inform/warn a driver of an impending crash.
- ITS America is neutral on technology but not neutral on safety. DSRC is the only technology that exists today that has been tested and proven to support safety critical vehicle applications.

Dr. Gary Smyth, Executive Director, General Motors Research and Development Laboratories, presentation at 23rd Annual ITS Wisconsin Forum, November 8, 2017
Connected car is not the future, but a mainstream reality

Most new light vehicles estimated to be cloud-connected by 2021

Drivers for connectivity

Consumer demand
Telematics, hotspot, connected infotainment, remote vehicle management, safety

Manufacturer benefits
Remote diagnostics, subscription services, over-the-air updates, data analytics

Regulatory requirements
Emergency call, stolen vehicle tracking, V2X, road usage, smog certification

Societal benefits
Increased safety, traffic management

Penetration in new light vehicle sales by 2021

<table>
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<th>Connectivity Type</th>
<th>% Penetration</th>
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</thead>
<tbody>
<tr>
<td>Cellular</td>
<td>60%</td>
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<tr>
<td>Bluetooth</td>
<td>81%</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>37%</td>
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</tbody>
</table>
With More Data and Connectivity Comes More Vulnerability of Cybersecurity

Security involves multiple layers

<table>
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<tr>
<th>Governance, Risk and Compliance</th>
<th>Threat Management</th>
<th>Authentication and Privacy</th>
<th>Professional Security Services</th>
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</thead>
<tbody>
<tr>
<td>Prepare to Manage Risk</td>
<td>Protect the Perimeter</td>
<td>Trust the Ecosystem</td>
<td>Respond to the Threats</td>
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</tbody>
</table>

- Access Governance
- Threat Vector Analysis
- Penetration Testing
- Partner Security Program
- PCI Compliance Program

- Security Configuration Management
- Vulnerability Scanning
- Application Scanning
- Content Scanning
- Cloud assessment

- Data Discovery
- M2M Security
- Managed Certificate
- Application Security
- Smart Credentials
- SSL Certificates

- Rapid Response Services
- Digital Forensics
Toyota’s Assessment of Automated Vehicle Technology

**Important Challenges Toward the Goal**

1. **In-car Intelligence**
   - Highly Reliable Perception and Understanding
     - Advanced sensors (Lidar, Radar and Camera)
     - 3D maps for real time driving control
     - State-of-the-art Recognition Technologies
     - Decision making for safety
     - Complementary information (ITS, Infrastructure)

2. **Human Factors**
   - Cooperation of driver and system for Highly automated system and Complex traffic situations
     - Avoid overconfidence and misleading
     - Mind sharing between driver and system
     - Handover process from/to human driver and system
### Important Challenges Toward the Goal

#### 3. Vehicle system

Vehicle Dynamics control, System Reliability and ECUs

1. Advanced vehicle control system
2. Highly reliable system design and components
3. Advanced electronics platform (CPU, Communication etc.)
4. Safe Operation System and Cyber Security

#### 4. Social involvements

Need wide discussions with stakeholders

1. Public understanding of the technology
2. Rules and regulations
3. Harmonization
Challenges: Sense

Weather can blind sensors
Challenges: Sense
Challenges: Plan
Mcity at U of M: the First Extensive Testing Facility Built for Automated Vehicles

- https://www.youtube.com/watch?v=gfSNlIQ5KN8
- https://www.youtube.com/watch?v=aKduQCywuNu4
American Center for Mobility

Phase 1 Highway Environment:
- 2.4 mile loop
- Re-use of west bound US12
- 65-70mph
- On and off-ramps
- Triple overpasses
- 2/3/4/5 lanes
- 700’ tunnel on bend

Campus-Operations:
- Testing Support
- Convening for Standards
- Cybersecurity Lab
- Education
- Technology Park

Network:
- DSRC
- 4G LTE
- 5G
- Cloud
- Traffic control
MEGACITIES

WHY MEGACITIES NEED TO DEFINE THE VEHICLE OF THE FUTURE
Ride Sharing Influence

Carma
BlaBlaCar
Lyft
Car2Go
Relay Rides
Sidecar
Uber
Ridejoy
Getaround
JustShareIt

Autonomous electric cars that you share?
By the mid-21st century, today’s siloed technologies will converge into an on-demand mobility ecosystem.

2025: Emerging Technologies

2050: Integrated Systems

(Source: Navigant Research)
CAV’s will

- enable more efficient use of parking
- create the need for more curbside space
- reduce traffic congestion
- reduce energy use/pollution
- enable people of limited mobility more options
- saves lives

GM Triple Zero
- accidents/fatalities
- carbon footprint
- Stress

ACES – Merger of Automated/Connected/Electrified/Shared
Macomb CAV Curriculum

Three courses available in the CAAT website Resource Library:

1) Sensors used in connected and automated vehicles
2) Navigation techniques used in connected and automated vehicles
3) Automated, Connected, and Intelligent Vehicles
Sensors used in connected and automated vehicles

• This 3-credit course introduces students to principles of sensors (GPS, MEMS, LIDAR, Radar, Ultrasonic, Infrared) used in connected and automated vehicles, locomotion, kinematic models and constraints, maneuverability, workspace of autonomous mobile robots and vehicles.
Navigation techniques used in connected and automated vehicles

- This 3-credit course introduces students to principles of navigation techniques used in connected and automated vehicles. Topics include autonomous navigation and connected vehicles, basic navigational mathematics, mobile robot positioning, inertial sensors and navigation systems, global positioning system, Kalman-fitering techniques, integrated navigation system, multisensory integrated navigation, fault detection and integrity monitoring, and communication among connected vehicles.
Automated, Connected, and Intelligent Vehicles

- It is a 3-credit course designed to introduce the automotive technology student to the next generation of advanced automotive electronics applications. Through the convergence of several rapidly evolving technologies (i.e. embedded microcontrollers, wired and wireless networking, advanced sensor and actuator networks, and sophisticated software) vehicle manufacturers have been rapidly integrating advanced driver assistance systems (ADAS) into their products. This course will provide the student with the knowledge needed to understand collision avoidance systems and autonomous cars and insights into the evaluation and diagnosis of their operation and system maintenance and repair.
Typical Technician Skills Required in the Field of Automated Vehicles

• Basic automotive and mechanical knowledge (teardown vehicles, build harnesses, basic fabrication skills, troubleshoot auto systems without manuals)
• Electronics skills (ECMs, sensors and sensor fusion, antennas, CAN and cable protocols, displays, soldering, shielding, troubleshooting)
• Software Skills (embedded systems, basic programming, networks, security systems, user interfaces)
• Understanding of Communication protocols (Satellite, LTE/cellular, WiFi, DSRC, Bluetooth)
• Lab testing, data acquisition and analysis
# Vehicle Development Technician Associates Degree

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<tr>
<th>Course and Sequence</th>
<th>Course Title</th>
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Impact on Students

• Post high school education required
• Look for schools with strong automotive programs
• Seek hands on opportunities both at school and employment (internships/co-ops)
• CAV curriculum available on in Resource Center on CAAT website for free
Stay Connected with the CAAT

• Visit our website at www.autocaat.org
• Sign up for our monthly newsletter
• Follow us on social media
• Contact us with your seed funding project ideas!
  – Connected/Automated Vehicles
  – Lightweighting
  – Testing
  – http://autocaat.org/Educators/Seed_Funding/
Thank You!

Questions?