The Road to Autonomous Vehicles

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Macomb Community College
Main Questions

• Why the interest in autonomous vehicles?

• How does the technology work?

• What are the remaining challenges?
GM’s Road to Automated Driving

TECHNOLOGY ENABLERS:
- Perception and Algorithms
- Integrated Sensing with Maps, GPS, V2X
- Driver State Knowledge

Key technologies include:
- Driver Info & Alerts (No Control)
- Emergency Intervention (Limited Control)
- Limited On-Demand Automation (Monitored Control)
- SuperCruise Concept
- Today’s Driver Assist Package
- Complex On-Demand Automation (Transferred Control)
- Autonomous Driving (Chauffeured Driving)
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

Major ADAS systems

<table>
<thead>
<tr>
<th>Active safety system</th>
<th>Passive safety system</th>
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<tr>
<td>Actively engaging/intervening driving to prevent accident</td>
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<td>Autonomous emergency braking</td>
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<td>Adaptive cruise control</td>
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<td>Forward collision warning</td>
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<td>Lane departure warning</td>
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<td>Parking assistance</td>
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<td>Blind spot monitoring</td>
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<td>Rear cross traffic alert</td>
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<td>Night vision &amp; pedestrian detection</td>
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<td>Traffic sign recognition</td>
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<td>Driver Monitoring</td>
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- Activated when collision risk detected using same sensors as Adaptive Cruise Control
- Adjusts speed to maintain safe distance between cars using long & short distance radar sensors (e.g., LiDAR)
- Detects obstacles in front and issues warning on screens using same sensors as ACC
- Detects and warns against lane departure
- Some functions even offer autonomous return to original lane
- Aids parking in varying degrees: simple warning against obstacles → complete autonomous parking
- Warns against lane departure by detecting blind spots during lane change
- Warns for proximity to vehicle when backing up
- Expands scope of detection via infrared camera installed under the bumper or rear view mirrors
- Reads speed limit signs using cameras mainly installed on back of rear view mirrors
- Issues warnings on fatigue level using camera sensors that monitor driver and his/her driving patterns
# NHTSA Automated Driving Levels (0-4)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
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<tbody>
<tr>
<td>Driver only</td>
<td>Active high beam</td>
<td>Traffic jam assist</td>
<td>Collision avoidance</td>
<td>Valet self-parking</td>
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<td>Collision imminent braking</td>
<td>Adaptive cruise &amp; lane keeping</td>
<td>Automated highway</td>
<td>Highway point-to-point</td>
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<td></td>
<td>Cruise control</td>
<td>Self-parking (with driver)</td>
<td>Automated urban</td>
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<td>Urban point-to-point</td>
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<td>Technology</td>
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<td>Lidar &amp; 360° Radar</td>
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<td>Forward Vision</td>
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<td>High accuracy GPS</td>
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<td>Multi-domain controller</td>
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<td>Forward Vision cameras, DSS</td>
<td>Multi-domain controller</td>
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<td>Driver State Sensor (DSS)</td>
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<td>V2X</td>
<td>Forward Vision cameras, DSS</td>
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Potential Benefits of Vehicle Automation

“Autonomous cars may seem like a gimmick, he begins, but when you consider all the time that people won’t be devoting to their rear view mirrors, and all the efficiencies that come from cars that could be zipping between errands rather than idling in parking lots, the world looks like a very different place. Car ownership would be unnecessary, because your car (maybe shared with your neighbors) will act like a taxi that’s summoned when needed. The elderly and the blind could be thoroughly integrated into society. Traffic deaths could be eradicated. Every person could gain lost hours back for working, reading, talking, or searching the Internet.”

Google co-founder Sergey Brin as reported by Brad Stone of Bloomberg Business Week – May 22, 2013
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

For every 1 person killed in a motor vehicle crash:
- 8 people were hospitalized
- 100 people were treated and released from the Emergency Department

The maximum potential saving per year in the US if you believe that ADAS and AVs can succeed in reducing car accidents by 90%

$180-190 Billion
The Past & Present: Automotive Safety...

Automotive fatalities: USA

-座 belt mandates
- Air bag sensors/mandates
- ESC and roll over sensors
- Distracted driving

Source: http://www.iihs.org/iihs/topics/t/general-statistics/fatalityfacts/overview-of-fatality-facts
US Consumers Rate Safety and Advanced Driver Assistance Technologies Most Important
Perspectives On Driverless Vehicles

Later

• Buffett (BH):
  “Aren’t coming soon”
• Mertens (Volvo):
  “Very, very long-term vision”
• Lauckner (GM):
  “Into the future a good distance”
• Insurance Info. Institute:
  “Between 15 and 20 years away”
• Zetsche (Daimler):
  “By 2025”

Sooner

• Musk (Tesla):
  “A solved problem....in a few years”
• Fields (Ford):
  “Within 5 years”
• Brin (Google):
  “By 2018”
• Ghosn (Renault-Nissan):
  “By 2020”
• Zetsche (Daimler):
  “Might not have a steering wheel”

Dr. Lawrence D. Burns, 2015
Integrated Systems Approach to Vehicle Automation

Coming application: 2017 Cadillac “Super Cruise”
ADAS and Automated Vehicle Sensors

- Side Radars
- Side View Cam
- Rear View Cam
- V2V/V2X
- Front View Cam
- Front Radars
- Front Cameras
- Lidar
- Multi Domain Controller
- Driver State Sensing
- Side Radars
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.
Sensor Fusion Improves Performance

Vision Vehicle Information

Adjacent Left

Adjacent Right

Left

Right

Vision Lane Information

Radar Object Information

Angle (deg)
Class:
Height:
Width:
NowEdge:
TimeOut:

Radar Barrier Detection
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
Typical Software Applications: Lines of Code

12 million lines of code
Android Operating System

24 million lines of code
F-35 fighter jet

44 million lines of code
Microsoft Office 2013

61 million lines of code
Facebook

50+ computers
To deliver a world-class user experience, active safety and high performance drivability

Premium vehicles today operate with **over 100 million+ lines of code**

*Software lines of code information courtesy of informationisbeautiful.net*
Automated Driving: Enabling and Supporting Technology

HIGH DEFINITION MAPS

V2X COMMUNICATIONS

Source: Texas Instruments ADAS Solutions Guide
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!
26B connected devices
250M connected vehicles
by 2020...

Source: Gartner
The Connected Car Evolves...

The R&D era
1966–1995
Examples: GM’s DAI/R system

The infotainment era
2007–2012
Examples: Ford SYNC, Kia UVO, GM MyLink

The embedded era
1995–2002
Examples: GM Onstar

The V2X era
2012–ongoing
Examples: Tesla app, Nissan Nismo, Progressive Snapshot

The new mobility era
2020–ongoing
Examples: Tesla Autopilot, self-driving initiatives by Google, Audi, Daimler

Source: Deloitte University Press
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.
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
- Incremental Updates
- Continuously Releasable Map Database
- Transactional Mapmaking Engine
- Intelligent Mapmaking
- Sensor & Report API
- Map In Device
- Quality Assurance

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Once a Vehicle is Connected, Many More Features Become Available

**Connected Car bonuses**

- Communication technologies enables...
  - Connected Car
  - Infotainment
  - Productivity systems
  - Traditional telematics
    - eCall/hCall/Diagnostics
  - Hands free calling
- Same technologies for many tasks = ease of use, integration and cost effectiveness

Autonomous Car users will demand even more productivity and entertainment as they are free from the task of driving
The Vehicle Becomes Integrated with the Web of Everything
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

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

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

**Societal benefits**
Increased safety, traffic management

Penetration in new light vehicle sales by 2021

- **Cellular**: 60%
- **Bluetooth**: 81%
- **Wi-Fi**: 37%
Underneath is the convergence of mobile & auto

Mobile ecosystem brings key technologies at scale; accelerated rate of innovation

**Automotive**
- Investment
- Sensors
- Systems/Expertise
- Applications
- Integration
- Experiences
- Collaboration

**Mobile**
- Cloud
- Secure Connectivity
- Mobility
- Graphics/Image Processing
- SoC
- Technology Blocks
- Scale

The Connected Car of the Future
With Connectivity, Data Becomes “Bigger”

OEMs & Dealerships
- Vehicle diagnostics, location,
- In-car consumption of services
- Aggregated cross-OEM reference

Insurance Companies
- Aggregated / Anonymized driving data, car break-down data, incident data

Smart Cities
- Real Time traffic flow
- Incident alert
- Parking

Data Source
- Connected car data
- Network, data
- App Data
- Enterprise Data
- Contextual Data
- Demographic overlays

Federal / State DoT
- Aggregated / Anonymous driving data, car break-down data, accident data, etc
- Environmental data

Other B2B
- Content usage, frequency, length etc
- Other svc occurrence (Road-side assistance)

Fleet customers
- Fleet performance
- Compare against competition (anonymous)
- Traffic, incident data

Ad. Companies
- Customer / passenger demographics
With More Data and Connectivity Comes More Vulnerability of Cybersecurity

Security involves multiple layers

- **Governance, Risk and Compliance**
  - Prepare to Manage Risk
    - Access Governance
    - Threat Vector Analysis
    - Penetration Testing
    - Partner Security Program
    - PCI Compliance Program

- **Threat Management**
  - Protect the Perimeter
    - Security Configuration Management
    - Vulnerability Scanning
    - Application Scanning
    - Content Scanning
    - Cloud-assessment

- **Authentication and Privacy**
  - Trust the Ecosystem
    - Data Discovery
    - M2M Security
    - Managed Certificate
    - Application Security
    - Smart Credentials
    - SSL Certificates

- **Professional Security Services**
  - Respond to the Threats
    - 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
   ① Advanced sensors (Lidar, Radar and Camera)
   ② 3D maps for real time driving control
   ③ State-of-the-art Recognition Technologies
   ④ Decision making for safety
   ⑤ Complementary information (ITS, Infrastructure)

2. Human Factors
   Cooperation of driver and system for Highly automated system and Complex traffic situations
   ① Avoid overconfidence and misleading
   ② Mind sharing between driver and system
   ③ Handover process from/to human driver and system
Toyota’s Assessment (Continued)

**Important Challenges Toward the Goal**

3. **Vehicle system**
   - Vehicle Dynamics control, System Reliability and ECUs
   - Advanced vehicle control system
   - Highly reliable system design and components
   - Advanced electronics platform (CPU, Communication etc.)
   - Safe Operation System and Cyber Security

4. **Social involvements**
   - Need wide discussions with stakeholders
   - Public understanding of the technology
   - Rules and regulations
   - Harmonization
Mcity at U of M: the First Extensive Testing Facility Built for Automated Vehicles

- Connected Vehicle Wireless, Roadside Equipment
- Stationary & Mechanized Pedestrians
- Range of Roadside Signage, Lighting and Traffic Control Devices
- Wide Variety of Repositionable Obstacles
- Repositionable Building Facades
- Wide Range of Simulated and Complex Roadway Geometries
- Automated and Wirelessly Connected vehicles
- Stationary and Mechanized Bicycles
Summary of Major Advantages

• Fewer traffic collisions
• Increased roadway capacity and reduced congestion
• Relief for occupants from driving and navigation
• Removal of constraints on occupants’ state or handicaps
• Lighter more fuel efficient vehicles
• Reduced insurance costs
• Higher speed limits
• Increased productivity
Summary of Major Concerns

• Assignment of liability for errors
• Resistance to loss of vehicle control
• Hardware function in bad weather
• Software decision protocols
• Software reliability
• Cybersecurity
• Loss of privacy
• Managing the transition from automated control to driver control
Typical Technician Skills Required in the Field of Automated Vehicles

• Basic automotive and prototype shop 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
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Thank You!

Questions?