Smart Vehicles

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Types of Smart Vehicle Efforts

- Traditional telematics and navigation
- Augmented reality
- Vehicle-to-X (V2X) communications
- Highly automated driving
Telematics and navigation are mature products

They are widely available at a variety of levels of cost and service

As vehicles integrate more advanced technologies, new structures and formats will be required to escape the constraints of legacy technologies
Augmented Reality

- Head-up displays (HUDs) have been used in automobiles since 1988\(^1,\ 2\) and are now in wide use.

- Vehicle manufacturers are exploring "contact analog functionality" - using HUD to highlight road objects such as lane boundaries, traffic signs, and other vehicles\(^3,\ 4\).

- Technical challenges include\(^4\):
  - Recognition of road geometry and road furniture
  - Precise vehicle positioning
  - Placing content in the viewing field of the driver

- Augmented reality should be implemented carefully to avoid driver distraction.

1. http://papers.sae.org/890288/
V2X Communications

- V2X communications have been in development for more than a decade
  - Vehicle to vehicle
  - Vehicle to pedestrian / cyclist
  - Vehicle to infrastructure

- 5.9 GHz (700 MHz in Japan)
  - Proposed for V2V communications in the U.S., Europe, Japan, and many other locations

- U.S. NHTSA V2V Status
  - NHTSA is preparing for regulation requiring IEEE 802.11p

- Most of the rest of the world is moving to LTE-V
V2X Communications Requirements

- Positioning information for surface transportation needs to be **very accurate and reliable**
  - Road vehicles often come very close to each other

- Each vehicle needs to send **frequent updates** of time, position, speed, and heading

- All vehicles should use a **consistent data source** for positioning and time

- Data must be **secure** from spoofing, jamming, and other cyber attacks

- The automotive industry does not yet know how to achieve this
  - For hundreds of millions of vehicles of different ages and levels of technology
  - Among dozens of vehicle manufacturers in different countries
# Levels of Automated Driving

SAE defines six levels of automation

<table>
<thead>
<tr>
<th>Level / Explanation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 0:</strong> No Automation</td>
<td>Vehicles before 1971</td>
</tr>
</tbody>
</table>
| **Level 1:** Driver Assistance  
  ‣ Automated steering or acceleration / deceleration in some driving modes | Vehicle with ABS, electronic stability control, adaptive cruise control, etc., operating separately |
| **Level 2:** Partial Automation  
  ‣ Automated steering and acceleration / deceleration in some driving modes | A vehicle with lane centering combined with adaptive cruise control |
| **Level 3:** Conditional Automation  
  ‣ Automated functions can control the vehicle  
  ‣ Driver is present and able to take over | ‣ Mercedes Future Truck 2025  
  ‣ Freightliner Inspiration Truck  
  ‣ Peterbilt Advanced Driver Assist |
| **Level 4:** High Automation  
  ‣ Automated functions can control the vehicle even if the human driver cannot take over | Vehicles used at low speeds in closed environments (mines, farms, ports, borders, etc.) |
| **Level 5:** Full Automation  
  ‣ Automated driving at all times and under all conditions that a human driver can perform | Vehicles used at low speeds in closed environments (mines, farms, ports, borders, etc.) |

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1. [http://www.sae.org/misc/pdfs/automated_driving.pdf](http://www.sae.org/misc/pdfs/automated_driving.pdf)
Autonomous Heavy Vehicles

Level 4 and 5 automated heavy vehicles are already used in closed environments

- Example uses
  - Mining\(^1\)
  - Farming\(^2\)
  - Ports\(^3\)
  - Border patrol\(^4\)

- Guidance technologies
  - GNSS
  - Inertial navigation sensors
  - Digital maps
  - In-vehicle cameras, radar, lidar, other sensors
  - Markers or magnetic guides

2. [http://farmofthefuture.net/#/slideshow/autonomous-tractors-take-field](http://farmofthefuture.net/#/slideshow/autonomous-tractors-take-field)
Demonstrations of Highly Automated Driving in Trucks

- Truck platooning on expressways has been demonstrated by Volvo and Scania\(^1\)
  - The lead vehicle is driven by a human driver
  - The following vehicles drive in automated mode following the first vehicle using a Wi-Fi connection for coordination

- Truck manufacturers have demonstrated Level 3 automated driving in trucks
  - Daimler in Europe\(^2\) and the U.S.\(^3\)
  - Scania in Europe\(^4\)
  - Peterbilt in the U.S.\(^5\)

Technical Challenges of Highly Automated Driving

- Object recognition and localization in all weather and lighting conditions
- High-definition map or road data (static data)
- Validation and testing of software for 200,000+ use cases
- HMI for handoff between vehicle and driver
- Driver monitoring
- Humanized driving and vehicle-human interaction
- Security and privacy
- Interaction with police authorities
Sensors in Automated Vehicles

Current

- Visible-light cameras
- 24 GHz & 77 GHz radar
- Lidar
- IMUs
- GNSS

Future Possibilities

- 1065 lidar
- 78-81 GHz wide-band radar
- Short-wave infrared (SWIR)
- Improved IMUs
- Novatel GPS enhancement satellites

GNSS in Automated Vehicles

- GNSS is currently used in prototype automated vehicles on public roads for gross positioning.

- Currently, GNSS is inadequate for precise positioning for automated vehicles on public roads because of inaccuracy, signal loss, and jamming:
  - Needs augmented GNSS with accuracy to less than 10 cm and devices with complete reliability.

- In current prototype automated vehicles on public roads, precise positioning is often provided by processing sensor data (cameras, radar, lidar), with or without use of pre-existing data about the environment (map or other database).
Human Behavior Challenges of Highly Automated Driving

- Acceptance / adoption of HAD
- Complacency / recklessness with automated driving features before full HAD is implemented
- Interaction between humans and HAD vehicles
- Operating HAD vehicles in environments not designed for them
Regulatory Challenges of Highly Automated Driving

• Update of regulations
• Avoiding regulations and standards that could hinder development of HAD
• Creating consistent regulations across jurisdictions
• Safety standards for HAD vehicles
• Data privacy and security standards and regulations
• Ability of police authorities to perform their functions
Regulatory Status

- The 1968 Convention on Road Traffic (the “Vienna Agreement”) is being updated to allow Level 4 automated driving on public roads\(^1,\ 2\)
  - The related Geneva Convention will be updated in parallel

- UN-R 79 forbids automatic steering at speeds over 10 km/h except for corrective steering
  - UNECE WP.29 is working on a revision to allow full steering control, possibly by 2018\(^2\)
  - The U.S. follows this structure by choice

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Predictions

• Most vehicle manufacturers will skip Level 3
  ‣ Hand-off and driver awareness monitoring still need to be worked out for Level 2 systems

• Specialty vehicles might begin to be offered in five years for geo-fenced Level 4 ride services near depot points and in controlled areas
  ‣ Such uses might help increase public acceptance of HAD

• Production vehicles that support Level 4 capability on map-certified limited-access highways might begin to be offered in five years
Predictions

- There will be Level 4 automated driving in passenger vehicles on expressways, possibly in 2020.
- There will be Level 4 automated driving in trucks on expressways, possibly by 2023.
- There will also be Level 2 automated vehicle control functions used on expressways and/or local roads to improve fuel economy.
  - Stop light signal phase and timing
- There will be more Level 4 automated vehicles in more closed and remote environments:
  - Road trains
  - Ports
  - Manufacturing facilities
Thank You