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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

- 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/
2. https://en.wikipedia.org/wiki/Automotive_head-up_display
3. http://business.inquirer.net/100609/a-peek-into-the-future-augmented-reality-windshields-biometric-sensors
4. http://continental-head-up-display.com/
5. https://www.abiresearch.com/press/augmented-reality-redefine-automotive-user-interfa/

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[1]

Level / Explanation	Example
Level 0: No Automation	Vehicles before 1971
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.)

1. 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

1. http://newatlas.com/komatsu-autonomous-truck-mining/45627/
2. http://farmofthefuture.net/#/slideshow/autonomous-tractors-take-field
3. http://www.terex.com/port-solutions/en/products/automated-guided-vehicles/index.htm
4. http://www.gizmodo.com.au/2014/11/the-amstaf-patrols-dangerous-borders-so-soldiers-dont-have-to

Demonstrations of Highly Automated Driving in Trucks

- Truck platooning on expressways has been demonstrated by Volvo and Scania[1]
  - The lead vehicle is driven be 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]

1. http://www.independent.co.uk/life-style/gadgets-and-tech/features/autonomous-vehicles-how-safe-are-trucks-without-human-drivers-9047546.html
2. http://www.goauto.com.au/mellor/mellor.nsf/story2/FD343BD2BA533A74CA257D0F002B26FC
3. http://www.informationweek.com/mobile/mobile-business/first-automated-truck-licensed-to-operate-on-public-roads/d/d-id/1320311
4. http://www.nltimes.nl/2015/02/10/self-driving-trucks-tested-dutch-highway
5. http://www.constructionequipment.com/peterbilt-demonstrates-autonomous-assist-driving

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[1]

1. http://www.novatel.com/about-us/news-releases/news-releases-2016/new-terrastar-l-correction-service-from-novatel-ensures-continuous-positioning-for-broad-accuracy-applications/

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

1. http://safecarnews.com/un-amends-vienna-convention-on-road-traffic-to-allow-driverless-cars
2. http://www.daimler.com/dccom/0-5-1742887-1-1743264-1-0-0-1743248-0-0-135-0-0-0-0-0-0-0-0.html

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