Current activities on R&D of automated Driving

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Deployment scenario on ITS services

R&D of automated vehicle technologies

From driver assistance to automated driving

Automated driving
- Automated driving (On ordinary road)

Advanced driver assistance
- Lane keep
- Lane changing
- Cooperative adaptive cruise control (CACC)

Driver assistance
- Adaptive cruise control (ACC)
- Lane keep assistance (LKA)
- Pre-Crash Safety (PCS)
- Driver safety support system with infrastructure (DSSS)

2005 2010 2015 2020 2025 2030
**What is societal needs for automated driving?**

- **Objectives of automated driving.**

  1. Improving of fuel economy by reducing of air drag
  2. Improving of traffic flow by reducing of gap distance
  3. Prevent accident due to **human error** such as distraction or drossiness
  4. Prevent accident due to losing of consciousness by brain infarction
  6. Provision of comfortableness during long distance driving.

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**Platooning (String driving)**

**Autonomous self driving**
Automated vehicles have been developed in EU, US and Japan, since research of autonomous vehicle started in 1975.

**History on R&D on Automated Vehicles**

1. **1ST Stage (1975～1990)**
   - Vision based automation

   - Infrastructure based automation

   - Fusion based automation
Summary of Famous automated vehicle

<table>
<thead>
<tr>
<th>EU</th>
<th>US</th>
<th>Jap.</th>
</tr>
</thead>
<tbody>
<tr>
<td>VaMoRs</td>
<td>Chauffeur</td>
<td>PVS</td>
</tr>
<tr>
<td>VITA II</td>
<td>IVHS</td>
<td>AHS</td>
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<tr>
<td>SARTRE</td>
<td>KONVOI</td>
<td>Cooperative Driving</td>
</tr>
<tr>
<td>HAVEit</td>
<td>Google</td>
<td>IMTS</td>
</tr>
<tr>
<td>PATH</td>
<td>E-ITS</td>
<td></td>
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</table>


1ST Stage 2ND Stage 3RD Stage
Automated platoon

Automated platoon is the string operation coupled electrically with closed gap distance in order to reduce fuel consumption.
Automated platoon developed by E-ITS

Objective of Energy ITS initiative is to achieve automated platoon within four trucks at gap distance of 4m.

1. Lane Tracking Control
   - White lane line recognition
   - Laser
   - Camera
   - Steering Motor

2. Gap Distance Control
   - V2V Communication with 5.8Ghz

3. Collision Avoidance Control
   - Obstacle detection
   - Emergency braking
   - 76Ghz radar
   - Laser Radar

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Configuration of Lane Tracking control

- Lane tracking alone the white line painted on left side of lane.

**Image processing Unit**
- White lane line recognition
- Lateral displacement measurement

**ECU**
- Yaw angle
- Lateral deviation (Front)
- Lateral deviation (Rear)

**Road Data Base**
- curvature
- cant

**Control Algorithm**
- Demanded steer angle

**Servo Unit**
- Steer angle

**Steer Motors**
- Vehicle speed

GPS

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System configuration of gap distance control

V2V Communication (Cycle: 20ms)
Range sensor (Radar and Lider)

VIDEO

Set speed (CC)  Engine /Brake/TM

Speed control model (ACC)

Distance
Speed
Acceleration

V2V communication

Set speed (CC)  Engine/Brake/TM

Speed Control Model (CACC)

Speed
Acceleration
Gap distance
**Fuel economy by platoon**

Fuel consumption of the automated platoon within three heavy duty trucks was measured on test track.

Fuel economy is 15% at gap distance of 4.7m.
Demo of automated platoon

- Automated platoon within four trucks at gap distance of 4m has been demonstrated on test track on this February.

- The demo proved automated truck platoon is coming up to implementable level technically.

DEMO VIDEO
Automated truck platoon within four heavy duty trucks
- Vision based lane tracking control
- Gap distance: 10m

Evaluation test was made on actual highway.
- Total mileage on highway: 3300km
SARTRE

SARTRE: abbreviation of **SAfe Road TRains for the Environment**

- Fully automated platoon mixed with passenger cars and trucks.
- Following vehicles can track automatically the leading truck by manual control.
- Gap distance is approximately 6m.

**VIDEO**
Urban Challenge

- Driverless autonomous driving car race in urban area with intersection.
  - 89 teams join urban challenge
  - Final event was held on Nov. 2007.
  - 1st place: CMU  2nd place: Stanford

- Digital map based trajectory.
- Detection of the path by sensor fusion.
- Detect of obstacles on the path by sensor fusion.

Length of course: 60 mile

RACE VIDEO

Laser range finder with multi-beams

Autonomous car by Stanford

Laser range finder: 4
Radar: 3
TV camera: 1

Range finder video

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Google car

Fully autonomous driving on urban area with traffic signal.
- Predictive trajectory generation
- 3D road map based obstacle recognition

Google VIDEO
Currently, automobile manufactures in Japan and Europe are developing automated vehicles for the implementation in near future.
Key technologies and issues to implementation of automated driving.
## Automation Level

Automation level has been defined by NHTSA and SAE

<table>
<thead>
<tr>
<th>NHTSA level</th>
<th>SAE level</th>
<th>SAE name</th>
<th>Execution of steering and acceleration/ deceleration</th>
<th>Monitoring of driving environment</th>
<th>Backup performance of dynamic driving task</th>
<th>System capability (driving modes)</th>
<th>Final responsibility</th>
<th>Diver's Situation</th>
<th>Distribution on operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>0</td>
<td>Non-Automated</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
<td>All of responsibility: System</td>
<td>Human</td>
<td>System</td>
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<tr>
<td>1</td>
<td>1</td>
<td>Assisted</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
<td>System covers human error</td>
<td>Human</td>
<td>System</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Partial Automation</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
<td>Human covers system error</td>
<td>Human</td>
<td>System</td>
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<tr>
<td>3</td>
<td>3</td>
<td>Conditional Automation</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
<td>Human covers system error</td>
<td>Human</td>
<td>System</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>High Automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
<td>Human covers system error</td>
<td>Human</td>
<td>System</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Full Automation</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
<td>All of responsibility: System</td>
<td>Human</td>
<td>System</td>
</tr>
</tbody>
</table>

**Final responsibility:**
- **Diver's Situation:**
  - Eye: Human
  - Brain: System

**Distribution on operation:**
- Human covers system error
- System covers human error

*Human System covers human error*

*Human System covers system error*

*All of responsibility: System*
## Key technologies for automated driving

### Key technologies

<table>
<thead>
<tr>
<th>Highly reliable computer</th>
<th>On highway</th>
<th>On urban road with intersection</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Fail safe</td>
<td>Vehicle, motorcycle, bicycle, pedestrian</td>
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<tr>
<td></td>
<td>Double Redundancy</td>
<td>Dropped obstacle on road</td>
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<tr>
<th>Highly perceptual sensing</th>
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<tbody>
<tr>
<td>Obstacle</td>
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<tr>
<td>Structure</td>
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<td>Lane and Path</td>
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<th>Advanced range sensor</th>
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<tr>
<td>Lane sensing for whether condition</td>
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<table>
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<tr>
<th>Traffic signal, traffic sign, zebra</th>
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<th>High resolution range sensor</th>
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Main issues on implementation

**Technical issues**

- **HMI**
  - System limitation ↔ Driver takeover

**Safety/reliability**

- Superior perceptibility than human’ driver.
- Higher reliability than human’ driver.
  (Less failure rate than human’ error such as drossiness)

Extensive evaluation on public road will be needed to prove the reliability.

**Non-Technical issues**

- **Societal acceptance**
  - Liability of driver and automated system

- **Legal**
  - Definition on Human driver’s obligation.
  - Confliction national road traffic codes and Geneva or Vienna Convention.

If reliability is proven, non-technical issues will be certainly overcome.
Thanks for your attention