Autonomous Driving Intelligence for Future Innovation

Masao Nagai
President
Japan Automobile Research Institute
Contents

1. Motivation and objectives

2. S-Innovation project outline

3. ADAS: Adaptive Driver Assistance System

4. Conclusions

Furthermore ...

SIP: Strategic Innovation Promotion program for ADS (Automated Driving Systems)
Traffic accident fatalities in the world

The number of fatalities in the world has been increasing and it is estimated it will reach **1.9 million in 2020**.
Annual transition of traffic accidents in Japan

The number of accidents, fatalities and injuries has been decreasing in recent years.

Source: National Police Agency
Accidents in Japan: age-specific analysis

The number of accidents involving aged people is stable, while that involving younger people has decreased.

This ratio increases rapidly in line with aging.

* = (No. of driver mostly at fault/No. of driver mostly at fault + other driver) x 100

Source: ITARDA Information No. 81

---

Ratio of fatalities, 1998: 1.0

The graph above shows the ratio of fatalities for different age groups over the years. The ratio for those 65 years and older remains stable, while there is a decrease in the ratio for those 24 years and younger. The ratio for those 25-64 years old also shows a decrease.

This indicates that the number of accidents involving older people is stable, while those involving younger people have decreased.

---

Ratio of driver mostly at fault

The graph below shows the ratio of drivers mostly at fault for different age groups. This ratio increases rapidly with age. The formula for this ratio is:

\[ \text{Ratio of driver mostly at fault} = \left( \frac{\text{No. of driver mostly at fault}}{\text{No. of driver mostly at fault} + \text{other driver}} \right) \times 100 \]

This ratio increases rapidly in line with aging.
S-Innovation project supported by JST*

"Autonomous Driving Intelligence to enhance a safe and secured traffic society for elderly drivers" was started in 2010 and will continue until 2019 with the following 3 stages:

✓ Stage 1: Development of autonomous driving intelligence systems
✓ Stage 2: System improvement and assessment by field operational tests
✓ Stage 3: Standardization and commercialization

Project Manager: Mr. Hideo Inoue, Toyota Motor Corporation
Research Leader: Prof. Masao Nagai, JARI
Project Partners: Toyota Motor Corporation
Toyota Central R&D Labs, Inc.
The University of Tokyo
Tokyo University of Agriculture and Technology

*: Japan Science and Technology Agency
S-Innovation project: 3 stages' overview

**Stage 1, 2010-2013**

1. Sensing Technology
   - Laser scanner and camera (Hardware development) and enhancing classification
   - Wide range and rich detail

2. Environmental perception
   - Classification of environmental objects and motion prediction
   - Situational Risk Assessment

3. Driver Model
   - Hazard anticipation, Risk potential estimation
   - Contour of collision risk

4. Collision Avoidance Algorithm
   - Collision avoidance path generation

**Stage 2, 2014-2016**

- Functionalities of Low-speed autonomous collision avoidance (up to 30 km/h)
  - Rear-end collision avoidance
  - Pedestrian/bicycle protection
  - Lane departure prevention
  - Head-on collisions

- Emerging Intelligent mobility technology and commercializing for protect aged drivers

**Stage 3, 2017-2019**

- Global Standard Development
  - Frontier research for enhancing intelligence
- Field Operational Tests (FOT)
  - Acceptance study
  - Effectiveness estimation
- Urban test sites
  - Drive recorder
  - Logging data analysis

- Drive recorder
  - Logging data analysis

- Emerging Intelligent mobility technology and commercializing for protect aged drivers
Adaptive Driver Assistance System

ADAS Concept
with autonomous driving intelligence

Expert driver model

Environment

Detemination of Assistance level

Driver Assist

Actual driver

Experienced driver (Knowledge, intelligence)

Aged driver (actual driver state)

Performance is declined!

Individual characteristics (habit, reaction time, etc.)

Physiological state

Shared control between an expert driver model and actual driver
Adaptive Driver Assistance System

ADAS Concept
with autonomous driving intelligence

ADAS: Adaptive Driver Assistance System is proposed to prevent traffic accidents caused by a decline in elderly drivers' performance.

ADAS's realizes "Driver-in-the-loop Autonomous Driving" which means shared driving between an expert driver model and actual driver.

How to model an expert driver's anticipatory information gathering is one of the most important points to design ADAS.
Expert drivers' anticipatory information gathering

Experienced drivers gather information through both in-vehicle sensors and their driving experience.
Performance limitation of AEB

Current AEB: Autonomous Emergency Braking system is activated after detection of pedestrians with in-vehicle sensors, then braking is not enough to avoid a crash in some situations.

Current AEB

TOYOTA
re-Crash Safety

SUBARU
Eyesight ver.2.0

VOLVO
HUMAN SAFETY

Daimler
6D-Vision

\[ x_{\text{min}} = \frac{V^2}{2a_{\text{max}}} \]

Distance to pedestrian vs. Vehicle speed graph:
- Collision avoidable
- Collision unavoidable
Autonomous Emergency Braking 
without hazard anticipation
Autonomous Emergency Braking

with hazard anticipation
Collision avoidance performance evaluation*

*: with a driving simulator in 'Tokyo University of Agriculture and Technology'

Varying the timing of pedestrian appearance:

- $x_{ped} = 15m$
- $x_{ped} = 13m$
- $x_{ped} = 11m$
- $x_{ped} = 9m$
- $x_{ped} = 7m$

- ●: Predictive Braking Assistance (PBA)
- ▲: Automatic Emergency Braking (AEB)

Theoretical braking distance:

$$x_{min} = \frac{V^2}{2a_{max}}$$

Collision can be avoided at average deceleration under 2.5m/s$^2$
ADAS Control Structure in S-Innovation Project

1. Normal Driving Controller
   - Course Tracing, Model Following, etc.

2. Risk Potential Controller
   - Defensive Driving

3. Emergency Avoidance Controller

4. Seamless override & Hand-over Controller

5. Data Fusion
   - Trajectory and Free Space
   - Object recognition
   - Localization
   - Driving State
   - Vehicle Dynamics

6. Vehicle Dynamics Control
   - F/F+ F/B Controller
   - Model Based
   - Slip Controller
   - Actuators
     - EPS/Steering
     - VSC
     - Brake & power train
     - Chassis, if applicable

7. Dynamic Map

8. Sensors
   - Environment
   - Camera
   - Radar
   - GPS

ICT
   - V2X

Environment

: new sections which need to be developed

3rd AAI Summit, 2-4 Dec. 2014, Bangkok
Experimental vehicle for FOT in Stage 2

- Monocular camera for identifying traffic participants and/or stop lines
- Millimeter-wave radar for intersections with poor visibility
- Radar for detecting objects in twilight and/or at night
- Camera for detecting traffic lane
- ROS system for integration of sensor information
- DGPS for connecting with map information
- Millimeter-wave radar for detecting traffic lane
- IMU for measuring vehicle behavior
- DSP for controlling vehicle
- DGPS for connecting with map information
- ROB system for integration of sensor information
- Monocular camera for identifying traffic participants and/or stop lines
- Millimeter-wave radar for intersections with poor visibility
- Radar for detecting objects in twilight and/or at night
- Camera for detecting traffic lane
- ROS system for integration of sensor information
- DGPS for connecting with map information
- Millimeter-wave radar for detecting traffic lane
- IMU for measuring vehicle behavior
- DSP for controlling vehicle
FOTs of autonomous driving intelligence

DS / Urban Test Sites for system validation

Safety check on public roadways
- Crash-relevant scenario simulation in test sites

Driving simulator study
- Driver acceptance study
- HMI investigation
- System parameter study

Safety impact assessment in certain circumstances

Drive Recorder

Field Operational Tests in Japan

Test car driving data collection

Incident Data Base
- Biometric data
- Fault diagnosis/Negative check
- Accident prevention effectiveness
- Hazard map construction

3rd AAI Summit, 2-4 Dec. 2014, Bangkok
Conclusions:

✓ **ADAS** with Autonomous Driving Intelligence has been studied to enhance safe and secured driving especially for elderly drivers in the aging society.

✓ Proposed control structure is based on an expert driver model, consisting of normal driving, risk-predictive anticipatory driving, and emergency driving.

✓ Prototype test vehicles are evaluated by DS (Driving Simulator) and urban test sites to avoid pedestrian collisions.

Outlook:

✓ FOT will be conducted on public roads to collect naturalistic driving behaviors, and environmental data to improve ADAS and HMI, by incident analysis.
Contents

Furthermore...

SIP: Strategic Innovation Promotion program for ADS (Automated Driving Systems)
SIP: Strategic Innovation Promotion program for ADS (Automated Driving Systems)

Growing interest for automated cars in Japan

- June 2013: Japan’s New IT Strategy published.
  - Requested to plan road maps across ministries
- Oct. 2013: ITS World Conference @ Tokyo
  - Japan’s automakers disclosed their development plans.
- Nov. 2013: First testing on public roads
  - Prime Minister Abe was in the car.

2014 as a starting year of ADS in Japan

Source: Ichikawa, ITS World Congress 2013
ADS: Automated Driving System nominated in SIP

✓ A new cross-ministry Strategic Innovation Promotion (SIP) program in JFY2014 was launched by the Japanese government.

✓ 10 candidate technology fields including "Automated driving system" for accident reduction, mobility and environment improvement, were selected.

✓ Total SIP budget in JFY 2014 is 50 billion Japanese yen (500 million US dollars), and 2.5 billion yen (25 mil. US dollars) for automated driving system.
# Definition of automation level in SIP

<table>
<thead>
<tr>
<th>Full-automated driving system</th>
<th>Level 4</th>
<th>Acceleration, steering and braking are conducted except by a driver. A driver has no involvement.</th>
<th>Late 2020's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly automated driving system</td>
<td>Level 3</td>
<td>Acceleration, steering and braking are conducted by a vehicle. A driver corresponds during an emergency only.</td>
<td>Early 2020's</td>
</tr>
<tr>
<td></td>
<td>Level 2</td>
<td>Acceleration, steering and braking are operated by a vehicle simultaneously.</td>
<td>2017-</td>
</tr>
<tr>
<td>Safe driving support system</td>
<td>Level 1</td>
<td>AEB, LDW</td>
<td></td>
</tr>
<tr>
<td>Independent control</td>
<td></td>
<td>ACC, LKS</td>
<td></td>
</tr>
<tr>
<td>No driving supports</td>
<td>Level 0</td>
<td><strong>Warning</strong></td>
<td></td>
</tr>
</tbody>
</table>

: commercial viability : plan

- Airplane
- Shinkansen

3rd AAI Summit, 2-4 Dec. 2014, Bangkok
SIP for ADS, R&D items

✓ Development & verification of ADS technologies
  “Dynamic Maps (Mapping Data Infrastructure)”, prediction based on IT (cooperative technologies), sensing technologies, drivers’ model (human factors), system securities

✓ Basic technologies
  National DB of traffic accidents, data analysis and simulations technologies, visualization of CO2 emissions

✓ International cooperation
  Open research facilities, social acceptance, package type ITS infrastructures export strategy

✓ Next generation urban transport
  Enhanced local traffic management, next generation transport system (through Tokyo Olympics/Paralympics)
JARI's stance in SIP for ADS

JARI is positioned between the government and industry. Utilizing this unique neutral position, JARI has been contributing to policy making for government and to common problem solutions for industries.

METI: Ministry of Economy, Trade and Industry
MLIT: Ministry of Land, Infrastructure, Transport and Tourism
MOE: Ministry of the Environment
NPA: National Police Agency
Remaining issues

Over the past decade, many automated driving systems have been researched and developed. Manufacturers are increasingly focusing on ADAS and Automated Driving Systems in new model cars.

However, there are still many technical and non-technical issues, such as legal and public acceptance, etc. to overcome so that harmonization between each sectors and regions are needed.
Thank you for your attention.

Masao Nagai
Email: mnagai@jari.or.jp
Tel: +81-3-5733-7921
## System requirements from elderly drivers' interview

<table>
<thead>
<tr>
<th>Elderly drivers’ characteristics</th>
<th>System functionality requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>When using <strong>only a warning system</strong>, the ratio of elderly drivers who cannot completely avoid collisions increases.</td>
<td>The system needs to <strong>assist by vehicle control intervention</strong>, such as autonomous braking.</td>
</tr>
<tr>
<td>People older than 65 years have a <strong>narrower effective field of view</strong>, from the recognition ability survey.</td>
<td>The environment perception and recognition function <strong>with wide range and field of view</strong> is requisite.</td>
</tr>
<tr>
<td>Situations which elderly drivers are not good at, such as <strong>driving in reverse and parking</strong>, increase.</td>
<td><strong>Emergency assist function for pedal misapplication</strong>, with obstacle detection is necessary.</td>
</tr>
<tr>
<td>Elderly drivers still have <strong>high motivation to drive</strong>. Their driving ability is good thanks to their experience.</td>
<td>Driverless vehicle technology is not needed, but <strong>shared driving between the driver and the system</strong> must be developed. It is important to assist drivers adapt to their driving states.</td>
</tr>
</tbody>
</table>