Introduction of S-Innovation Project

Autonomous Driving System to Enhance Safe and Secured Traffic Society for Elderly Drivers

Autonomous collision avoidance system with driving intelligence model to recover degraded recognition, decision-making and operation

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Our Vision:
Mobility which realizes lively and active aged society!
Aged people can actively participate the society and have fun!
Mobility can potentially recover young spirits of aged drivers!
This project aims at the significant improvement of road safety by **intervention of autonomous driving control for preventing accidents** caused by elderly drivers. High driver acceptance and social acceptance are also ones of system requirements.

This project started in 2010 and continues until 2019, including three stages; (1\(^{st}\)) fundamental system development, (2\(^{nd}\)) system improvement, (3\(^{rd}\)) commercialization.

### RESEARCH ORGANIZATION

**Project Manager**  
Hideo Inoue (Toyota Motor Corporation)

**Research Leader**  
Prof. Masao Nagai (Tokyo Univ. of Agriculture and Technology)

**Project Partners**  
Toyota Motor Corporation  
Toyota Central R&D Labs, Inc.  
The University of Tokyo  
Tokyo University of Agriculture and Technology
## Project Overview

### Research issues

1. **Driving Intelligence**
   - Experienced driver behavior modeling with potential hazard anticipation for ADAS design

2. **Driver-in-the-loop Autonomous Driving (Adaptive Driver Assistance Systems)**
   - Human error and Degraded performance of aged drivers
   - Automatic Brake/steer intervention if necessary
   - Driver and social acceptance study by Field operational tests

3. **Collaboration between Industry and Academia**
   - Japan has many research institutes conducting advanced safety vehicle researches, but few collaborations.
   - On the other hand, European joint projects are progressing in these days.
   - Framework of joint projects between industry and academia are strongly expected to invent new technologies.

### Project outcomes and Social Impacts

1. Social activation in countryside area: mobility assistance
2. Lively and active lifestyle of aged people: Social participation, have fun and maintain young spirits.
3. Prevention of accidents due to degraded driving performance
4. Global contribution of a new-type innovative active safety technology

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**Driving Intelligence**

- Driver model 1
  - Experienced driver (Knowledge, intelligence)
- Driver model 2
  - Aged driver (actual driver state)

- Determination of Assistance level
- Driver Assist

- Environment
- Individual characteristics (habit, reaction time, etc.)
- Physiological state
Motivation and Objectives – Aged drivers need active life -

• Aged drivers need active life. → To improve QOL of aged drivers, mobility is necessary.
• However, degraded driving performance reduce their self-confidence in driving.
• Autonomous driving system with intelligence to recover degraded performance is important.

Fig. 1 Necessity of automobiles

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Unmet Needs</th>
</tr>
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<tbody>
<tr>
<td>20~39</td>
<td>Trains and buses cannot be used</td>
</tr>
<tr>
<td>40~59</td>
<td>Trains and buses take time to transport</td>
</tr>
<tr>
<td>60~69</td>
<td>Love to drive for fun</td>
</tr>
</tbody>
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Fig. 2 Ratio of accidents caused by aged drivers

ITARDA Information No81, '09.12

From Yomiuri Newspaper

Fig. 3 Crash-relevant near-miss incident by Aged drivers

- About to crash when going reverse
- About to head-on collisions (intersection)
- About to ride on curbs
- About to rear-end collisions

Fig. 4 Reaction of drivers to active safety system
(Experimental study by using Toyota Driving Simulator)
Concept of the research and goals of each stage

**Goals of each stage**

Stage 1 (2010-2013) Development of sensing/control devices and prototype vehicle completion.

Stage 2 (2014-2016) System improvement based on FOT and driver & social acceptance study


Collaboration and proposals towards standardization.

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### Functionalities of Low-speed autonomous collision avoidance (up to 30 km/h)

1. **Rear-end collision avoidance**
2. **Pedestrian/bicycle protection**
3. **Lane departure prevention**
4. **Head-on collisions**

### Stage 2 (2014-2016)

- **Field Operational Tests (FOT)**
  - Drive recorder
  - Logging data analysis
  - Acceptance study
  - Effectiveness estimation

### Stage 3 (2017-2019)

- **Global Standard Development**
- Frontier research for enhancing intelligence

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### Environmental perception

- Classification of environmental objects and motion prediction
- Situational Risk Assessment
- Contour of collision risk

### Driver Model

- Hazard anticipation, Risk potential estimation
- Contour of collision risk

### Sensing Technology

- Laser scanner and camera (Hardware development) and enhancing classification
- Wide range and rich detail

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### Innovations and Commercialization

- Innovative Intelligent mobility technology
- and commercializing for protecting elderly drivers
Frontier technology: Intelligent driver model

- **Reference driver model based on experienced driver behavior data analysis**

  From *collision avoidance model* in certain circumstances to *intelligent hazard anticipation driver model*

- **Vehicle dynamics control for obstacle collision avoidance**

  → *Man-machine system equivalent to experienced driver* for enhancing driving safety
Fundamental Driver Model of Longitudinal and Lateral Direction, i.e. car following and lane keeping, based on Risk Potential Field

Sensing the position of the ego-car using the curb measured by laser radar, combined with GPS / digital map

Speed control due to curvature and lane tracking

Car following control by using repulsive and attractive forces in Risk Potential Field
② Expert driver model including hazard anticipatory to reduce future collision risk, based on Risk Potential Field

- Expert driver can predict future risk due to his driving knowledge of sudden appearance of pedestrian
- Model of the anticipatory control by Risk Potential Field technique
- Avoidance by steering and braking control
- Path planning and speed control to minimize risk potential
- Sensing obstacle, parked car
Near-miss Data-base from Drive Recorder

Near-miss Incident Data collected in the rear world can be used for the assessment as well as the development of intelligent ADAS.
Control Structure of Autonomous Driving Intelligence

① Fundamental Driver Model of Longitudinal and Lateral Dynamics, i.e. car following and lane keeping
② Expert Driver Model including Hazard Anticipatory to Reduce Future Collision Risk
③ Collision Avoidance Model by Braking and Steering Control

Autonomous driving intelligence is demonstrated by TOYOTA PRIUS as shown below.

No Pedestrian appears

Pedestrian appears from the space behind the parked car
Field Operational Tests of autonomous driving

Urban Test Sites for system validation

Safety check in public roadway
- Crash-relevant scenario simulation in test sites

Safety impact assessment in certain circumstances

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

Social experiments & FOT in public roads

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

Drive Recorder

Test car driving data collection

Field Operational Tests in Japan

Urban Test Sites for system validation
Recognition, Decision-making development

Real-World Cloud (Big Data)

Knowledge discovery from various circumstances

Driver model update & its evolution

Environment database

Environment data collection
- Real-time probe data

Experimental study by DS

Knowledge Discovery between Industry and Academia

Naturalistic driver characteristics study

Dynamic Map, Near-miss data analysis, Accident Analysis

Intelligent driver model

Intelligence enhancement by learning skilled driver behavior

Vehicle motion

Marketing Strategy Standardization

Public road data collection and intelligent model advancement for performance enhancement

Machine learning platform development and Global marketing strategy for system penetration

Human Factor Database

Real world data Collection with DR.
Driving intelligence for **autonomous collision avoidance system is designed** to prevent major accidents;
- Forward Collision Avoidance System
- Pedestrian Collision Avoidance System
- Lane Departure Prevention System
- Intersection Head-on Collision Avoidance System

Drivers have authority in maneuvering the vehicle until the last second before crashes. When the system decides to intervene, **automatic braking / steering** is activated to avoid accidents.

Collaboration between industry and university in Test track study, driving simulator and Field Operational Tests (FOT) is needed for **safety assessment and driver acceptance** study.

We started discussion on collaboration with Nissan, Honda, and Toyota for promoting future advanced safety technology (**FAST-meeting**)

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