A Multi-agent Traffic Simulation to Predict the Impact of Automated Driving Systems on Safety

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Automated driving systems are expected to contribute to achieve the Japanese government target to become the safest automobile transportation society in the world.

**Impact Assessment Method for "Continuous Functions" (Long Operational Period)**

- Field Operational Test
- Traffic Simulation
- Real traffic flow
- Virtual traffic flow

Implementation challenges:
- Cost
- Acceptance
- Data (Accident)
Characteristics of simulation

◆ **Keyword: Multi Agent Simulation**

1. All traffic participants (driver, pedestrian, rider...) are modeled as agents.
2. Each agent has Perception • Recognition • Decision making • Action process.
3. Agents' actions are interactively affected.

The aim of this project is to develop a multi-agent traffic simulation methodology applicable to predict the potential safety improvements of different automated driving systems.
Developing simulation tool to evaluate traffic safety impact when ADAS/Automated Driving systems are deployed.
Safety impact assessment

【Image of final outcome】

【Japanese government's target】
・Fatalities: less than 2,500 in 2020

Accident reduction effects
・Fatalities
・Injuries
・Number of accidents etc.

Penetration of ADAS/HAD

ADAS: Advanced Driver Assistant System
HAD: Highly Automated Driving
Driver Behavior Model

Perception
- Recognition
  - Driver's visual field
    - Peripheral visual field
    - Central visual field

Decision making
- Based on relative velocity and relative distance
  - R. Wiedemann (1974)
  - Alienation
    - Acceleration
    - Constancy
    - Following
    - Idle running
    - Deceleration
    - Abrupt Deceleration
  - Approach
  - Relative velocity
  - Relative distance
    - Far
    - Near

Action
- Based on decision making status
  - Accelerator pedal
  - Brake pedal
  - Steering wheel

Driver attributes
- (1) Compliance with traffic law
- (2) Driving skill
- (3) Information process ability
- (4) Arousal level

Driver error
- Inattentive/aimless driving
- Misjudgement
- Inadequate operation etc.
Pedestrian behavior model

- Development of pedestrian behavior model of crossing a road
- Reflection of influence of age/sex based on fixed-point observation and examination

Pedestrian agent

Walking velocity \([m/s]\)

Walking velocity while crossing \([m/s]\)

Probability of safety reconfirmation while crossing \([\%]\) 30%

Probability of safety confirmation before crossing road \([\%]\) 77%

Walking route

- Crossing angle \([\text{deg}]\)
- Time to abandon crossing road \([s]\)
Simulation results

Area: 6km $\times$ 3km, 500 Agents including Vehicles and Pedestrians
Occurrence of typical traffic accidents

◆ Traffic accidents caused by driver error (Single, Vehicle to Vehicle, Vehicle to Pedestrian)
HAD penetration rate in the simulation

- Manual driving, ADAS and HAD are considered
  AEB, LDW (SAE Lv.1~2), Automated Driving (SAE Lv.3~5)

<table>
<thead>
<tr>
<th>Simulation Condition</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual driving</td>
<td>100%</td>
<td>50%</td>
<td>25%</td>
<td>25%</td>
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<tr>
<td>ADAS, HAD</td>
<td></td>
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<tr>
<td>AEB</td>
<td></td>
<td>50%</td>
<td>25%</td>
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<tr>
<td>AEB+LDW</td>
<td></td>
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<td>50%</td>
<td>50%</td>
<td>25%</td>
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<tr>
<td>Automated Driving</td>
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<td>25%</td>
<td>75%</td>
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</tbody>
</table>
Simulated results in macro area

Simulated result (Manual driving 100%)

Traffic accident statistics (2012-2017), Ibaraki prefectural police

- Rear-end collision
- Intersection collision
- Lane departure
- Head-on collision
- Crossing pedestrian

- Injury accident
- Fatal accident

500m
Simulated results in macro area

Different automated driving technology penetration scenarios can be set to estimate the potential impact of different technologies on safety.

- **Rear-end collision**
- **Intersection collision**
- **Lane departure**
- **Head-on collision**
- **Crossing pedestrian**

**Manual driving 100%**

**AEB&LDW 25%, Automated Driving 75%**

AEB: Autonomous Emergency Braking
LDW: Lane Departure Warning
Simulated results

Simulation condition
1: Manual driving (MD) 100%
2: MD 50%, AEB 50%
3: MD 25%, AEB 25%, AEB+LDW 50%
4: MD 25%, AEB+LDW 50%, Automated driving (AD) 25%
5: AEB+LDW 25%, AD 75%

• Results should be treated considering the assumptions adopted in the calculations
Model areas for nationwide estimation

Classification of municipalities based on characteristics of population
- Population: 100,000, 300,000, 500,000, etc.
- Population density: 100, 1,000, 3,000, etc.

Model area A (Large city)
Model area B (Local city)
Model area C (Depopulated area)

Population density [people/km²]
Population [people]

Overpopulated metropolis
Metropolis
Dormitory town
Regional nucleated city
Local city
Suburbanized city
Depopulated area

(n=1,728)
Simulated execution of each area

- Area (6km × 4km), 200 agents
- Area (8km × 3km), 400 agents
- Area (7km × 4km), 800 agents

Model area A (Large city)
Model area B (Local city)
Model area C (Depopulated area)

National safety impact will be estimated by expanding results of each model city
Occurrence spot of traffic accidents

Model area C
(Depopulated area)

Model area B
(Local city)

Model area A
(Large city)

National safety impact will be estimated by expanding results of each model city
Summary

• Novel multi-agent traffic simulation software developed and applied to a 6 x 3 km area in Tsukuba city. Over a simulated period of time including more than 500 agents (vehicles, drivers and pedestrian), the software can simulate and identify at least five types of accidents.

• Different automated driving technology penetration scenarios can be set to estimate the potential impact of different technologies on safety.

• Ongoing work:
  – Verification of the reliability of the simulations by comparing the accident patterns predicted by the software and those occurring in the real world
  – Expansion of the software's applicability to other regions in Japan for national impact safety estimations
Thank you