Driving Intelligence for Safer Automobiles

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The History of the Automobile

1769

The world's first automobile:
A steam-powered vehicle

Invented by Nicolas-Joseph Cugnot

Today (from 2006)

Pre-collision system (PCS)

Emergency avoidance of objects and pedestrians

Our perspectives of safe & secure driving

Tomorrow

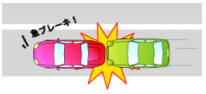
Today

Driving quality enhancement based on safety technologies

?

(2) Emergency avoidance

*Rear-end collision avoidance
*Pedestrian protection
*Head on collisions
*PCS, ESC, ABS, etc.



(1) Mitigation

*Airbag
*Seatbelt
*Body structure

Time

Our perspectives of safe & secure driving

Tomorrow

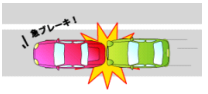
Today

(3) Avoidance of human-error induced accidents

1) Distraction, fatigue, drowsiness, heart attacks, etc.
2) Less stress in monotonous driving situations
   e.g., highway/interstate driving/trips, congested/stop-and-go traffic
3) Elderly/disabled drivers

(2) Emergency avoidance

*Rear-end collision avoidance
*Pedestrian protection
*Head on collisions
*PCS, ESC, ABS, etc.



(1) Mitigation

*Airbag
*Seatbelt
*Body structure

Driving quality enhancement based on safety technologies

Time

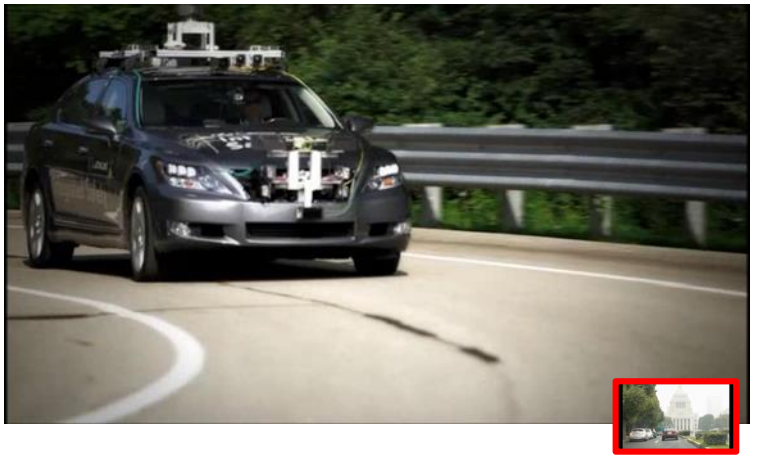
Our research into intelligent driving technology

- ✓ Monitor around the vehicle and predict risks.
- ✓ Find and follow safe routes

From 2005:

Learn from skilled drivers

→ Verify potential of autonomous vehicle dynamic controls



From 2007:

Pursue sensing, perception, and recognition technology

Two topics for tomorrow

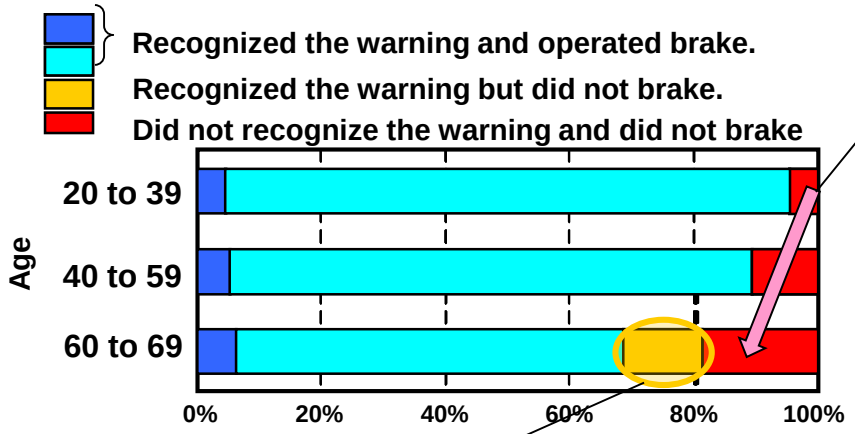
1. ***ADAS with Driving Intelligence for a Safer and More Secure Traffic Society for Elderly Drivers (S-Innovation Project in Japan)***
2. ***Traffic Congestion and Highway Driving Intelligence***

Two topics for tomorrow

1. ***ADAS with Driving Intelligence for a Safer and More Secure Traffic Society for Elderly Drivers (S-Innovation Project in Japan)***
2. ***Traffic Congestion and Highway Driving Intelligence***

Motivation and objectives: Overcoming fear of driving

- Deterioration in driving ability reduces self-confidence in driving.
- However, elderly drivers are highly motivated to improve QOL.
- Intelligent driving systems can help to compensate for this deterioration in physical ability and overcome the fear of driving.



The older the driver, the higher the ratio that could not recognize the warning.

Drivers over age 60 recognized the warning but did not brake.

Fig. 1 Reaction of drivers to active safety system
(Experimental study using Toyota Driving Simulator)

Elderly drivers have high motivation to drive.

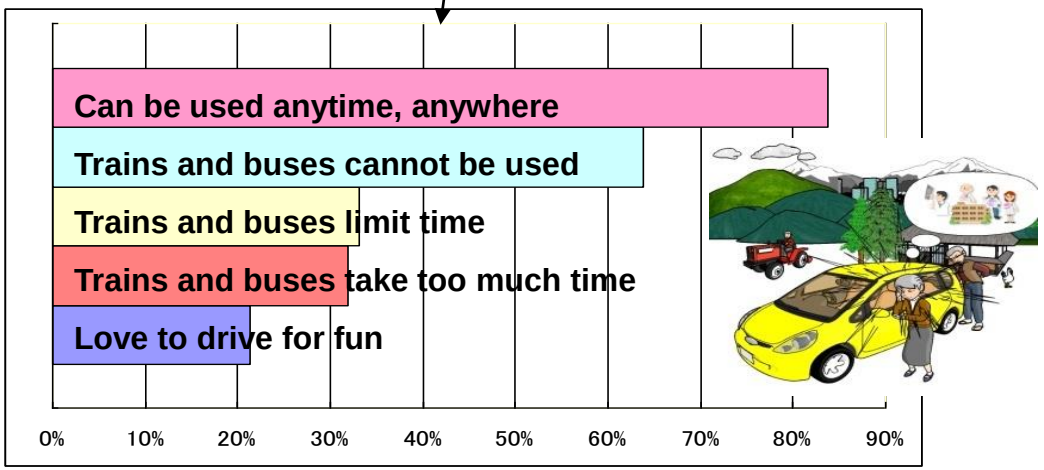


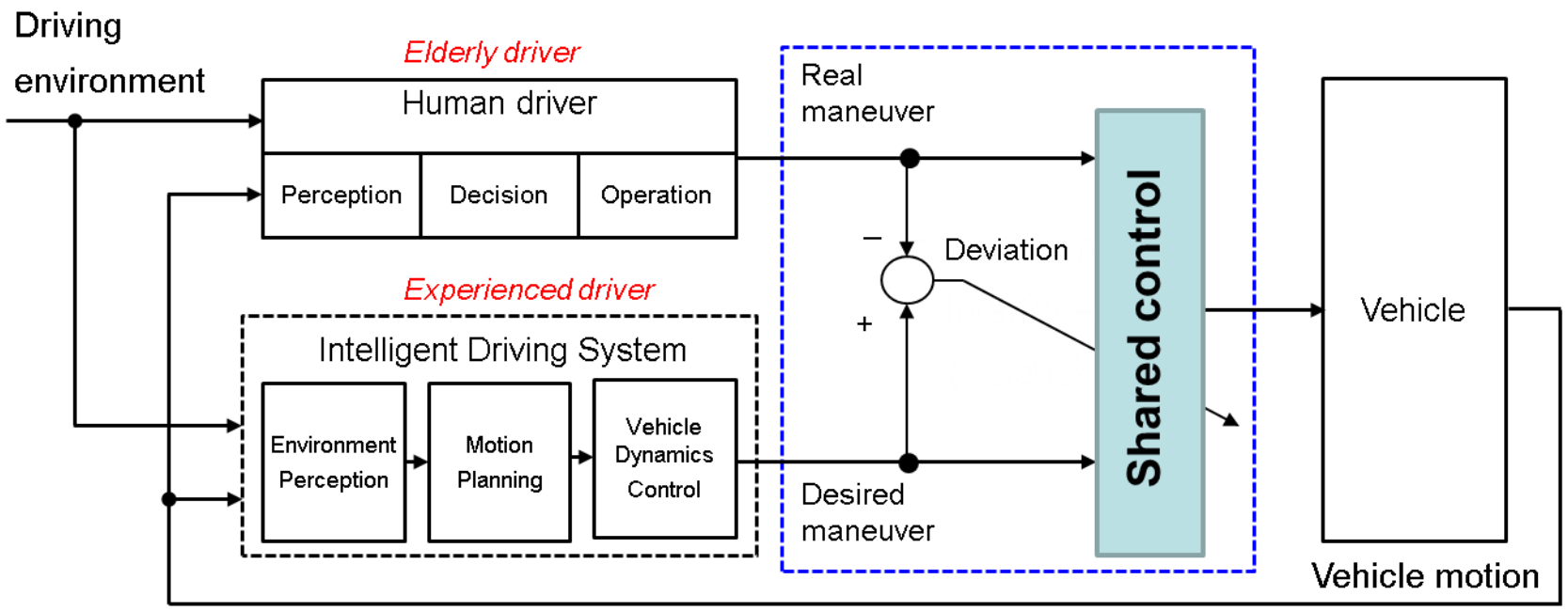
Fig. 2 Vehicle necessity

ADAS concept with driving intelligence

Shared control between an expert driver model and actual driver

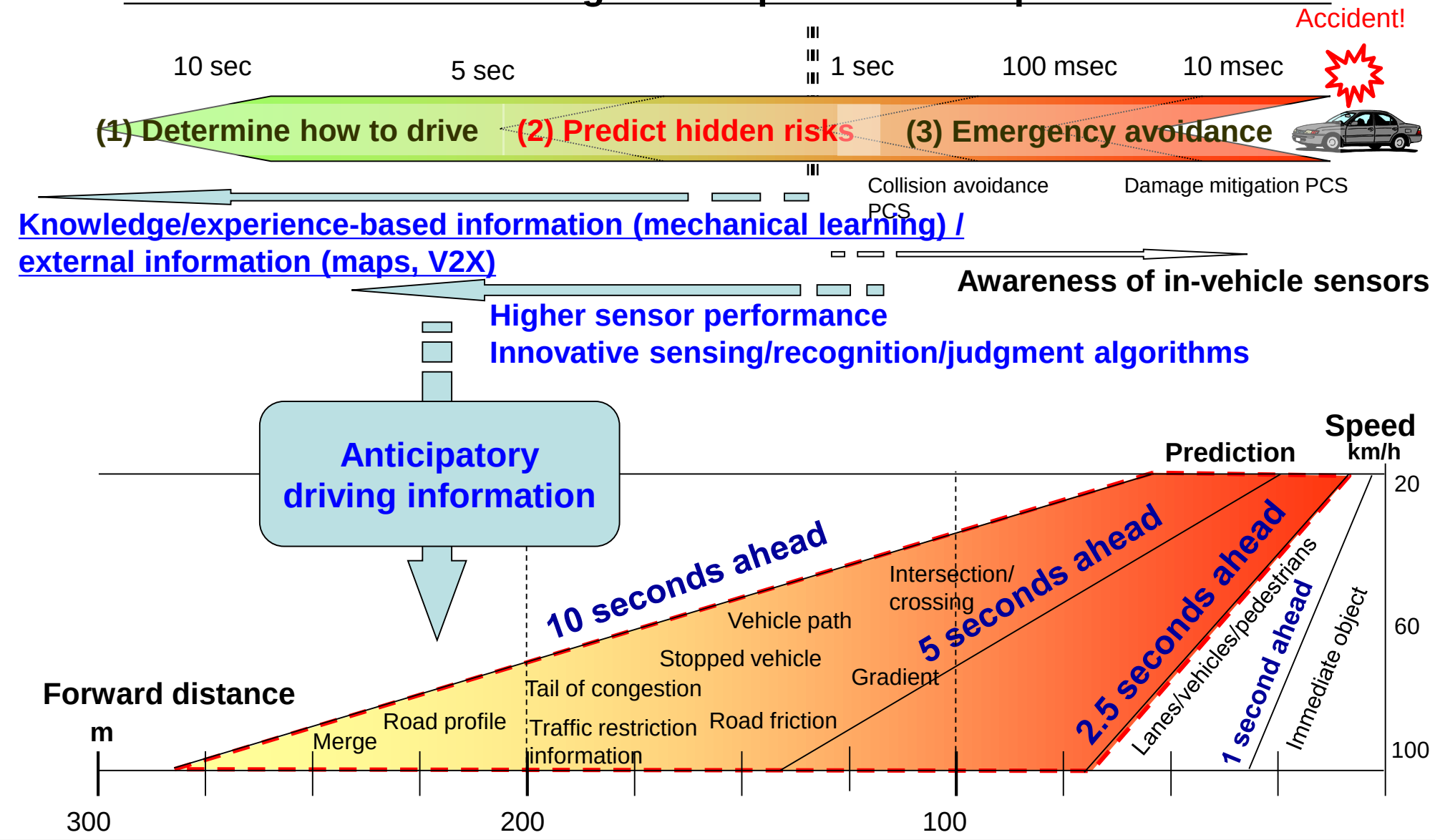
- **Driver-in-the-loop** ADAS concept (not fully automated)
- Driver **can override** the system if necessary
- Driver-vehicle cooperative system **>= Experienced driver**

Haptic-based control is important.

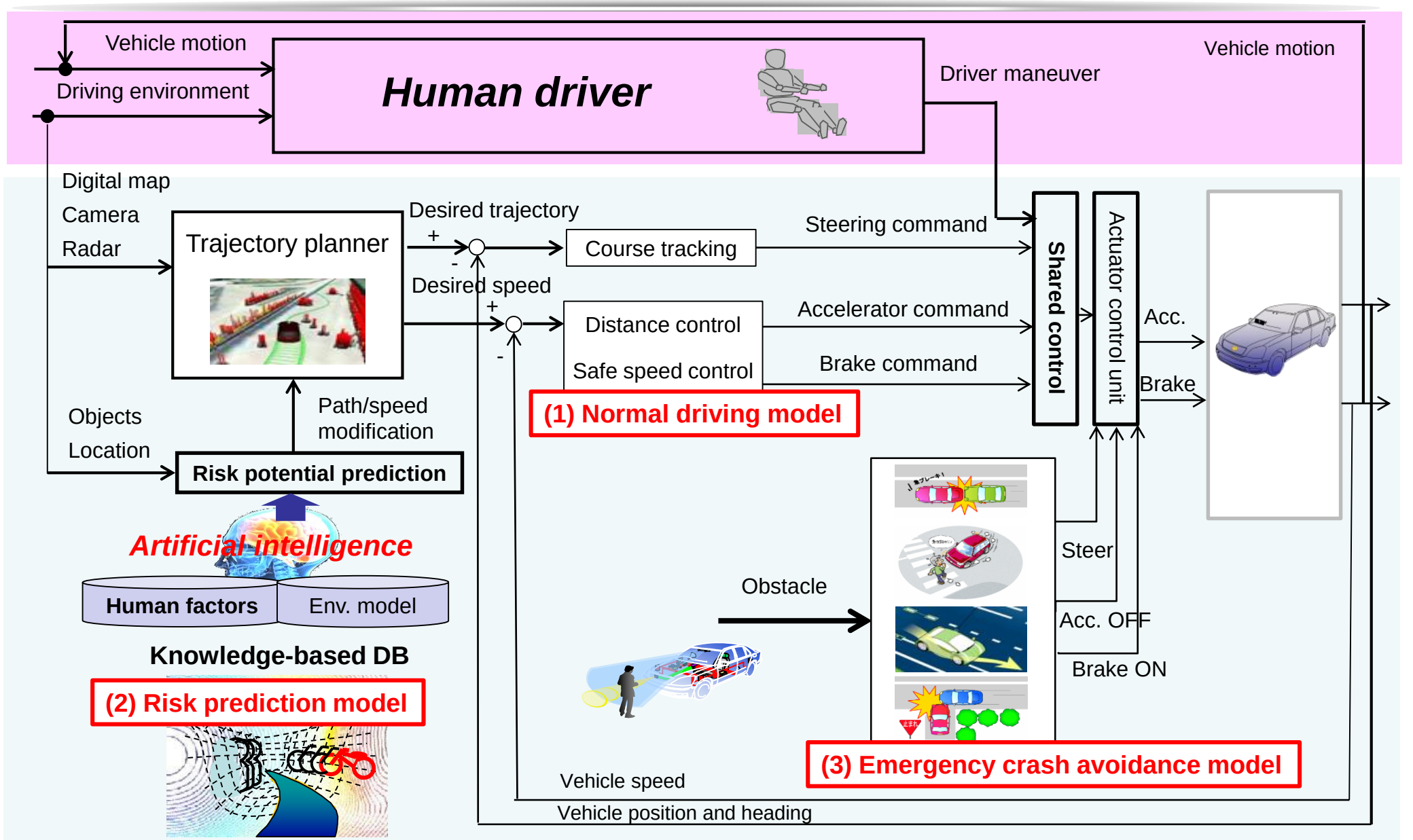


Safe driving concept: Obtaining anticipatory driving information

- Learn from the knowledge and experience of experienced drivers

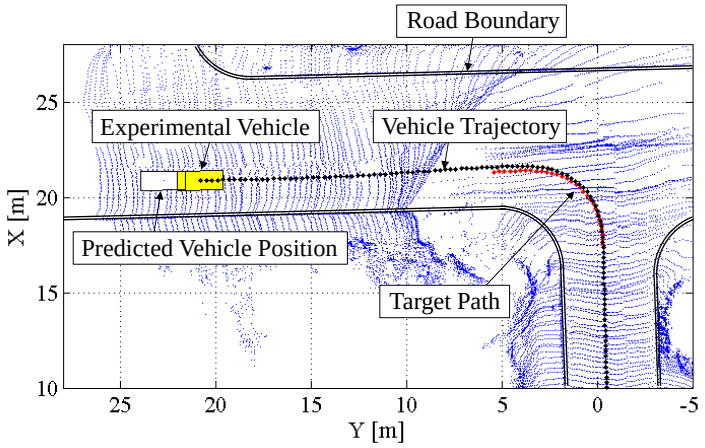


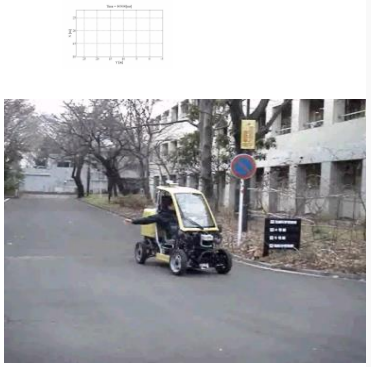
Control scheme of experienced driver model

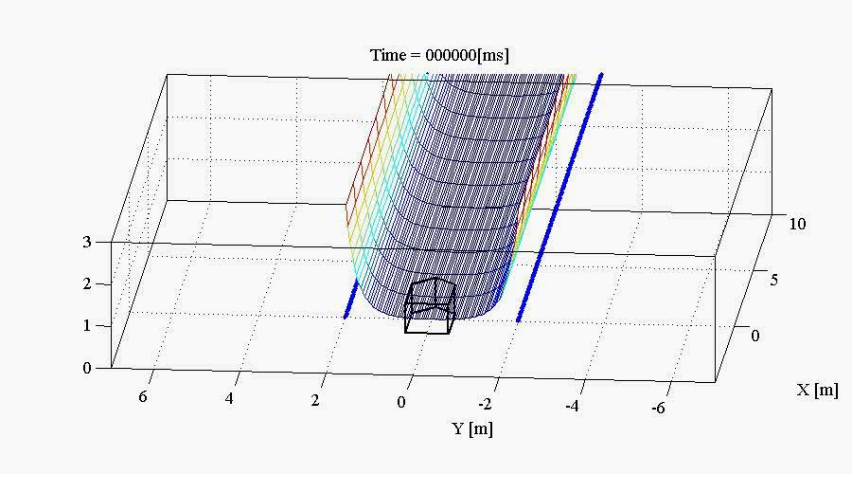


Driving intelligence: (1) Normal driving control

(1) Normal driver model for longitudinal and lateral direction, i.e. , car following and lane keeping, integrating the risk potential field

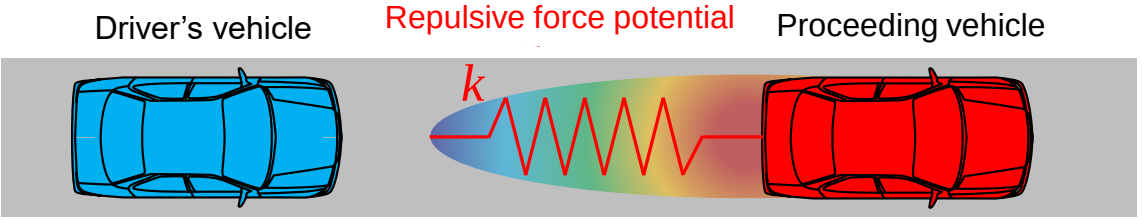


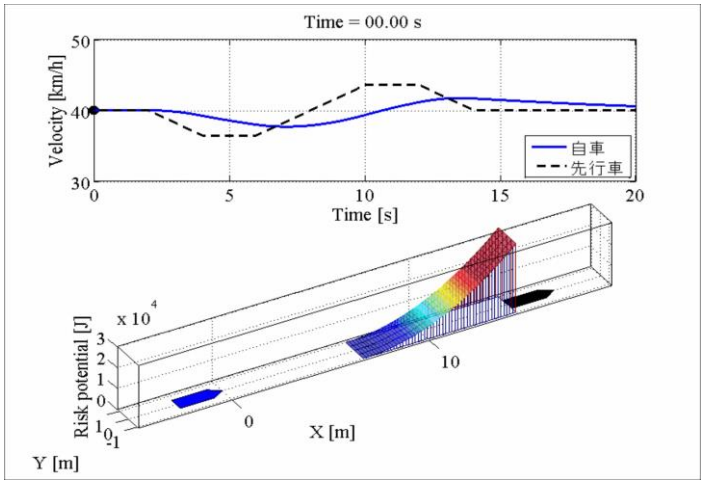




Sensing the position of the driver's vehicle using the curb measured by laser radar, combined with GPS/digital map

Speed control using curvature and lane tracking





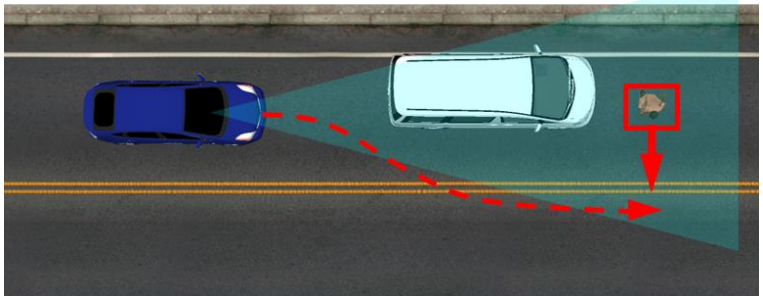
Car following control using repulsive and attractive forces in the risk potential field

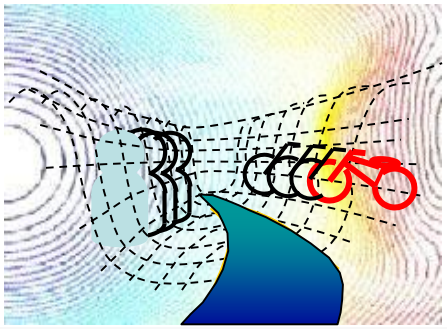
Typical hazardous situation from near-miss database

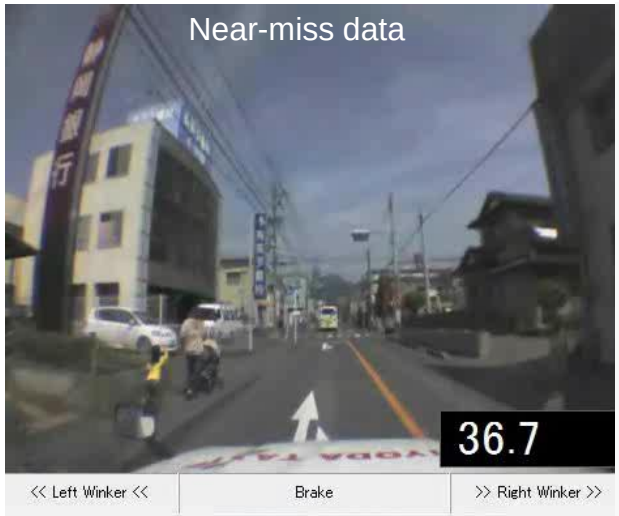
Near-miss incident data collected in the real world can be used for the assessment and advanced development of autonomous driving intelligence systems.

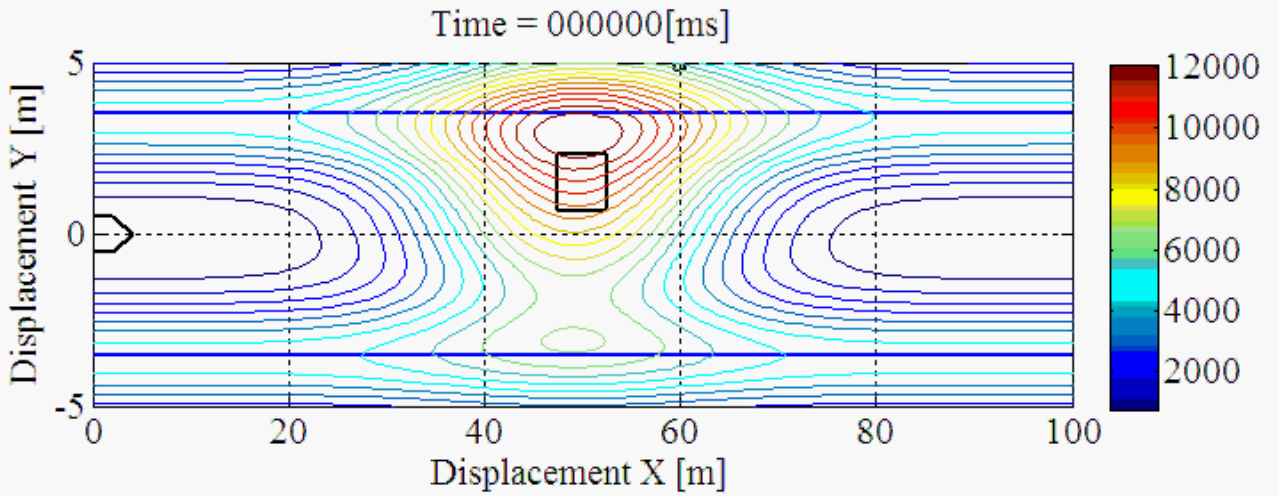
(2) Risk prediction model

Risk prediction model: Defensive driving, object motion prediction, hazard anticipation









Contour of risk potential generated from surroundings and on-road objects

Driving intelligence must predict the possibility of the appearance of pedestrians from **behind an object** and determine the optimum safe speed.

Demonstration of driving with risk prediction

(1) Normal driving control of longitudinal and lateral dynamics,
i.e., car following and path tracking
(2) Risk potential based control including hazard anticipation to minimize collision risk
(3) Emergency avoidance control by braking and steering

Anticipatory driving intelligence is demonstrated using a Toyota Prius as shown below.

No pedestrian appears
(2) Risk potential based control

Pedestrian appears from
behind the parked car
(2)+(3) Emergency avoidance

Effect of defensive driving by driving intelligence

- **Collision avoidance performance can be effectively enhanced by introducing risk prediction into the driver model (Fig. 2).**
- **The driving intelligence model can express expert driver behavior (Fig. 1).**

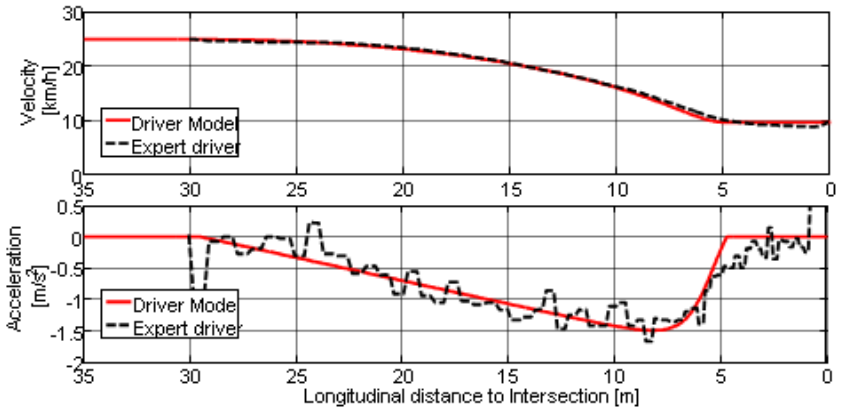


Fig. 1 Comparison with data of expert drivers

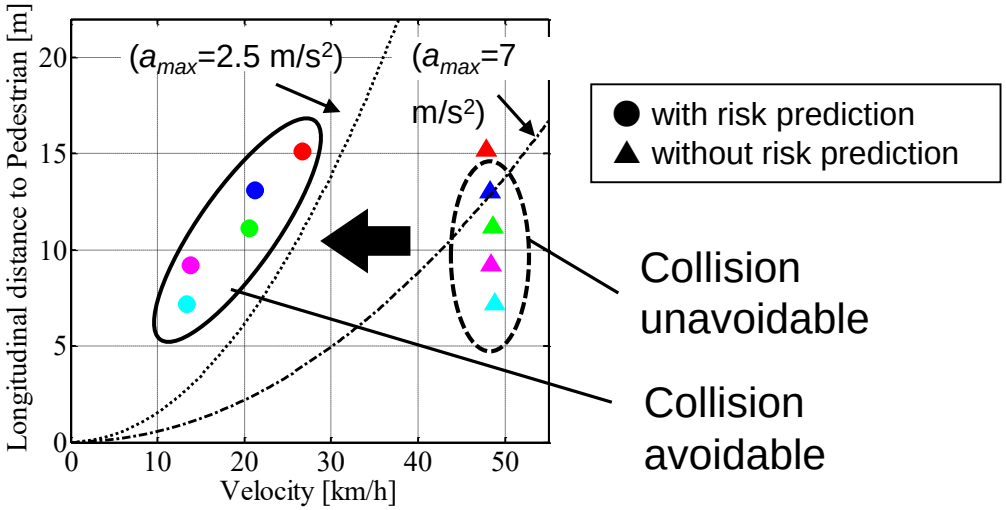
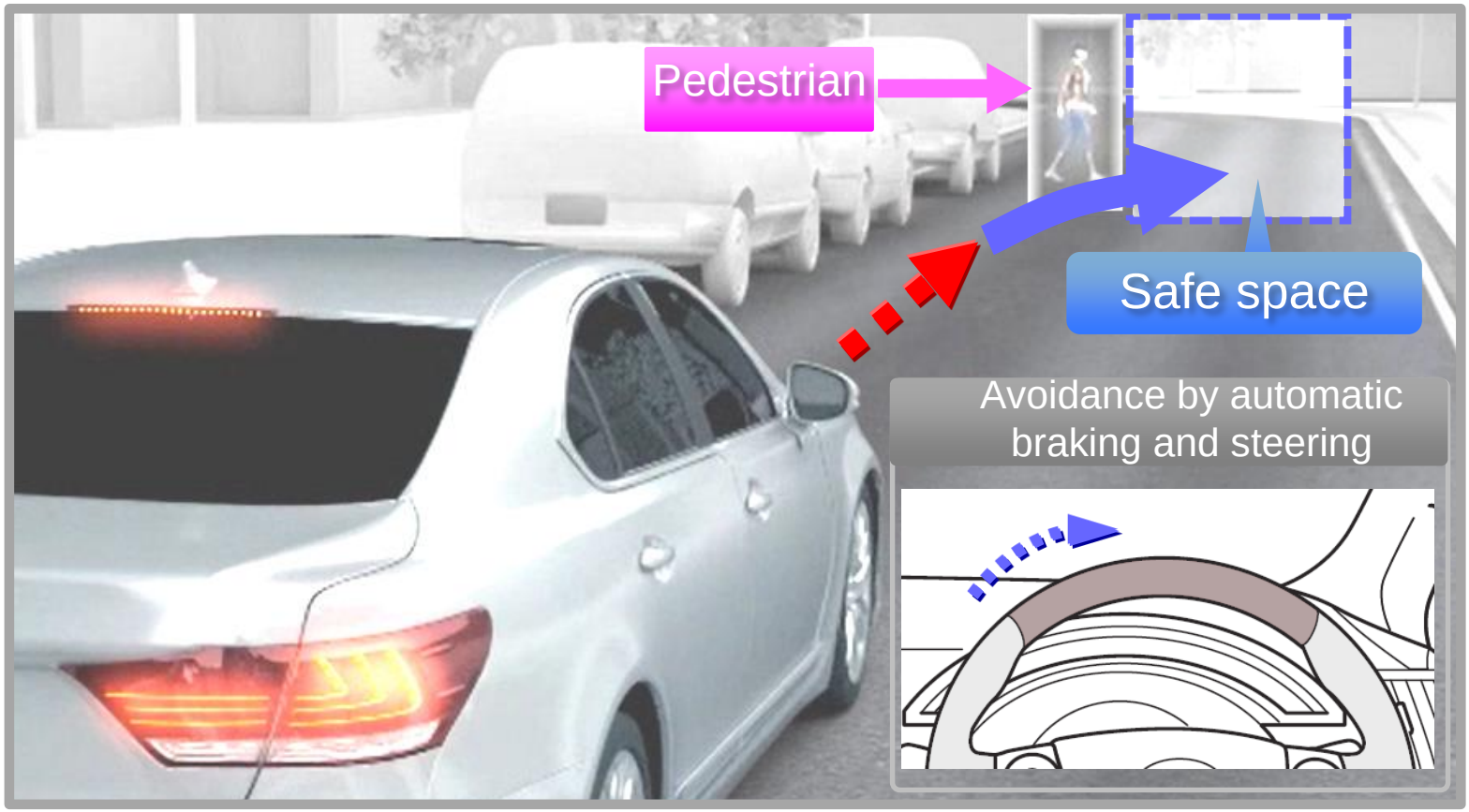


Fig. 2 Collision avoidance performance

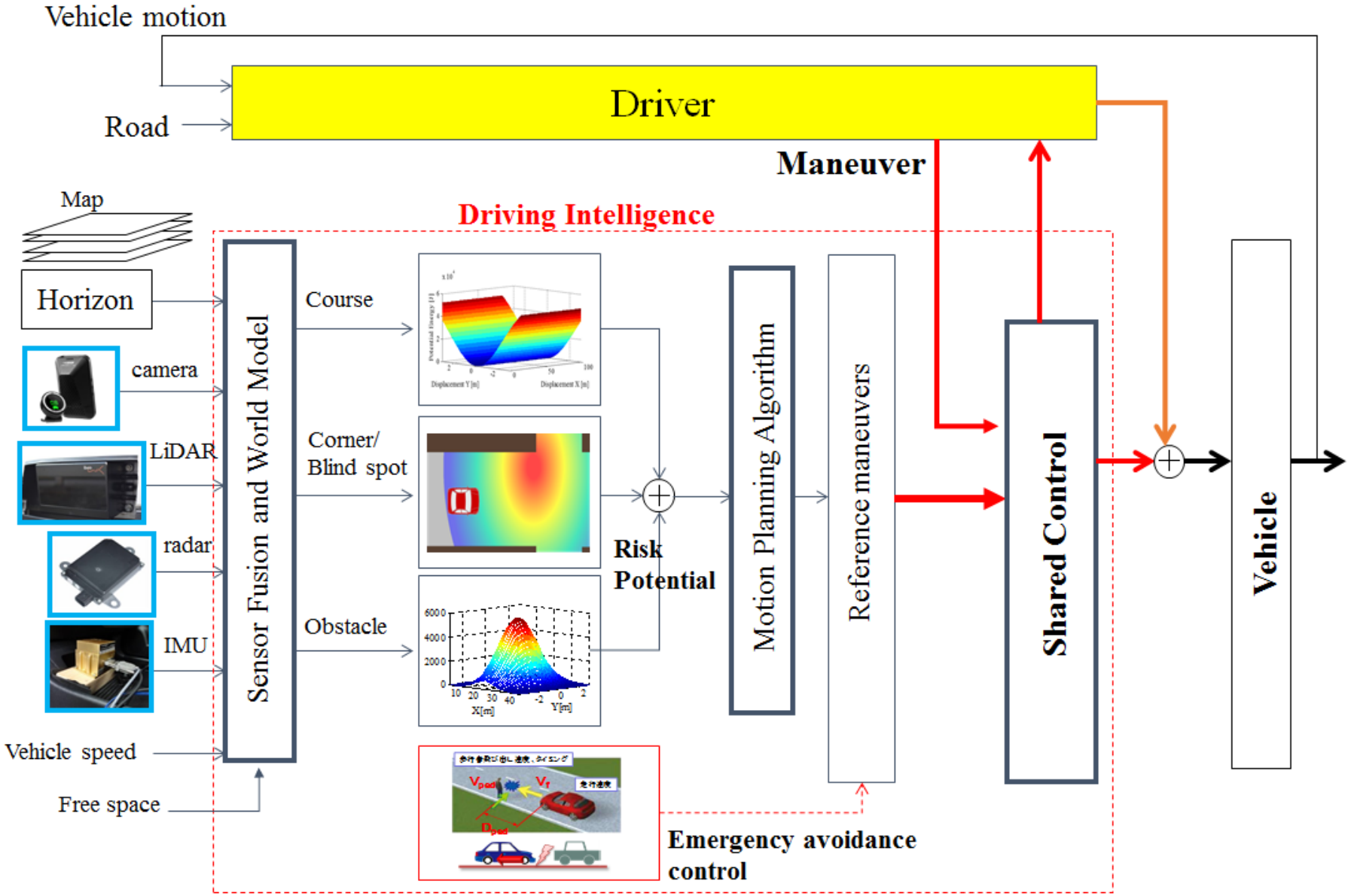
Synthesis of defensive driving model by learning expert driver data for enhancing driving safety.

(3) Emergency avoidance control: New Pre-Collision Safety (PCS) system

- Steering control added to conventional emergency brake.
- System controls the steering if a collision cannot be avoided by braking.

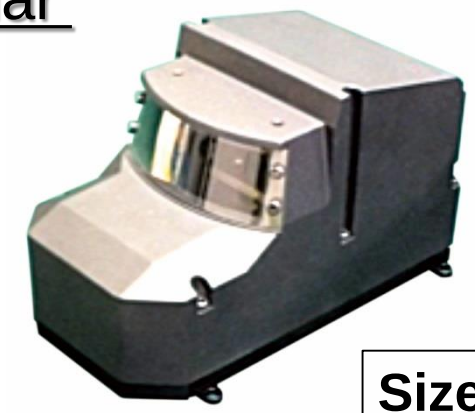


Conceptual diagram of ADAS with driving intelligence



Smaller 3D Lidar

SPAD Lidar*



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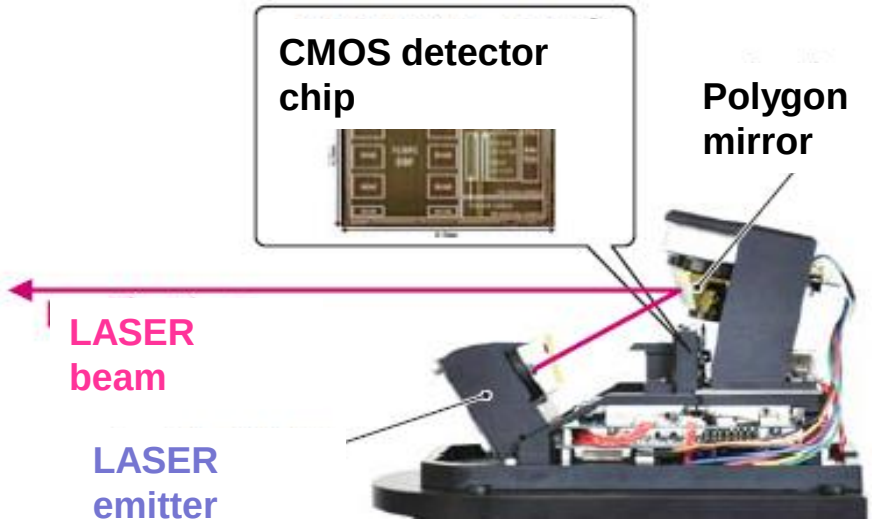
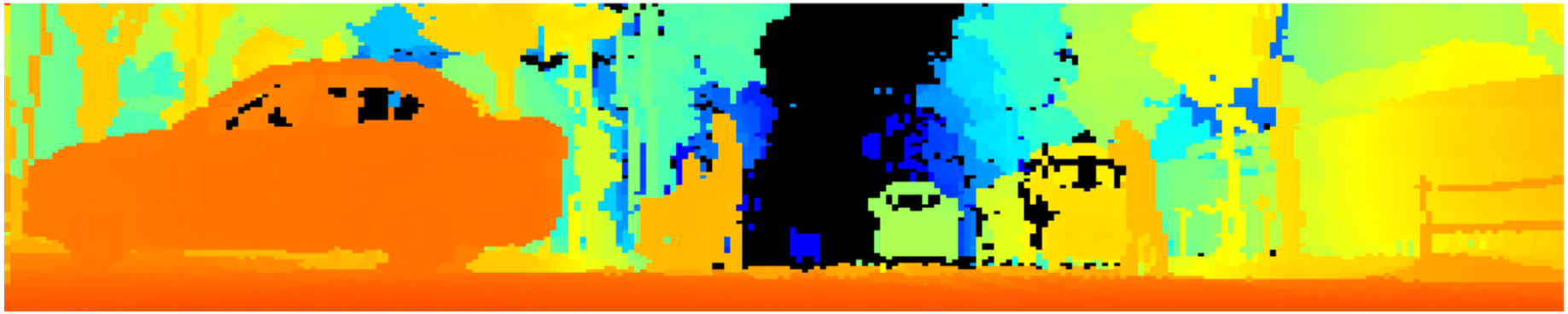


Output by dist. image



Smaller/highly reliable/optimized processing

* SPAD: Single Photon Avalanche Diode, Lidar: LIght Detection And Ranging

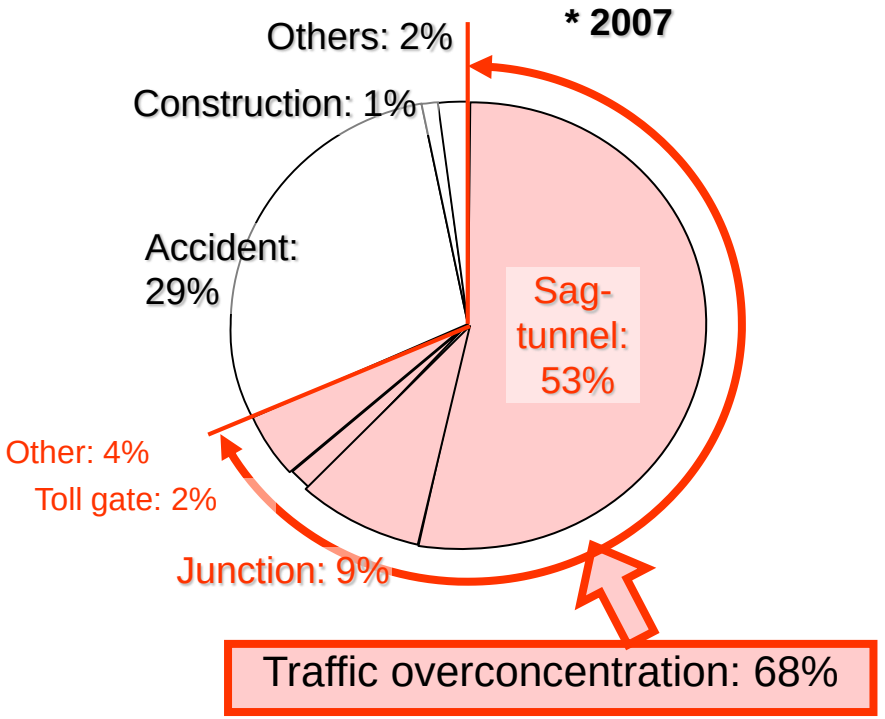
Two topics for tomorrow

1. *ADAS with Driving Intelligence for a Safer and More Secure Traffic Society for Elderly Drivers (S-Innovation Project in Japan)*

2. ***Traffic Congestion and Highway Driving Intelligence***

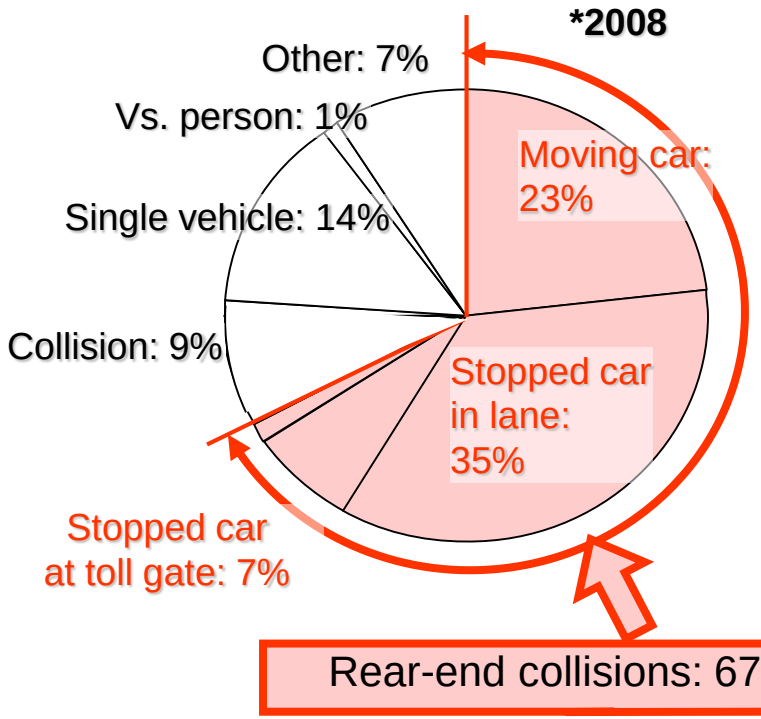
Situation of highways in Japan

Congestion



Traffic overconcentration: 68%

Accidents



Rear-end collisions: 67%

Targets

Reduction of
- Traffic congestion
- Traffic accidents
- CO_2

⇦

Global & local driving intelligence
- ✓ V2X, ACC/cooperative ACC
- ✓ Smart highway traffic system

V2V: Cooperative Adaptive Cruise Control (C-ACC)

- With millimeter-wave radar, vehicle to vehicle communication capabilities (760 MHz) have been added to ACC to maintain an appropriate distance between leading and following vehicles.
- C-ACC provides a greater margin of safety for the driver, helps to prevent waves of deceleration, and contributes to reduced highway traffic congestion.

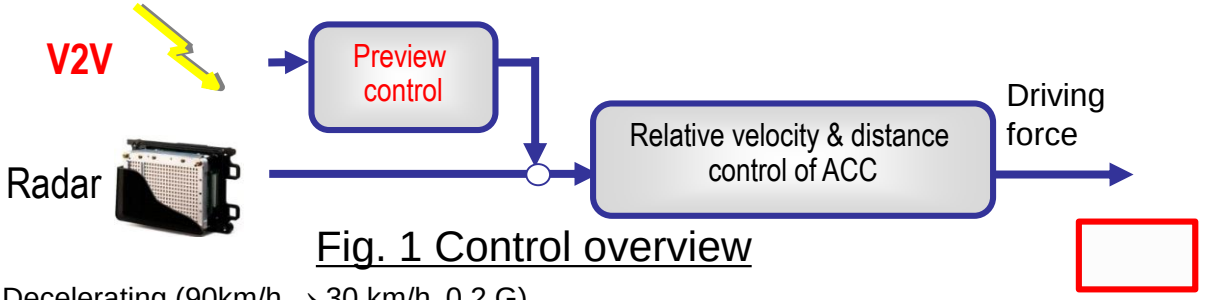
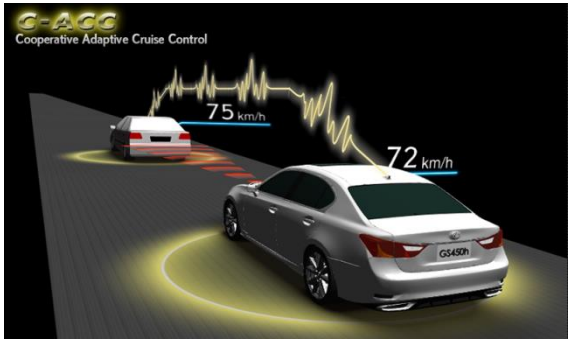


Fig. 1 Control overview



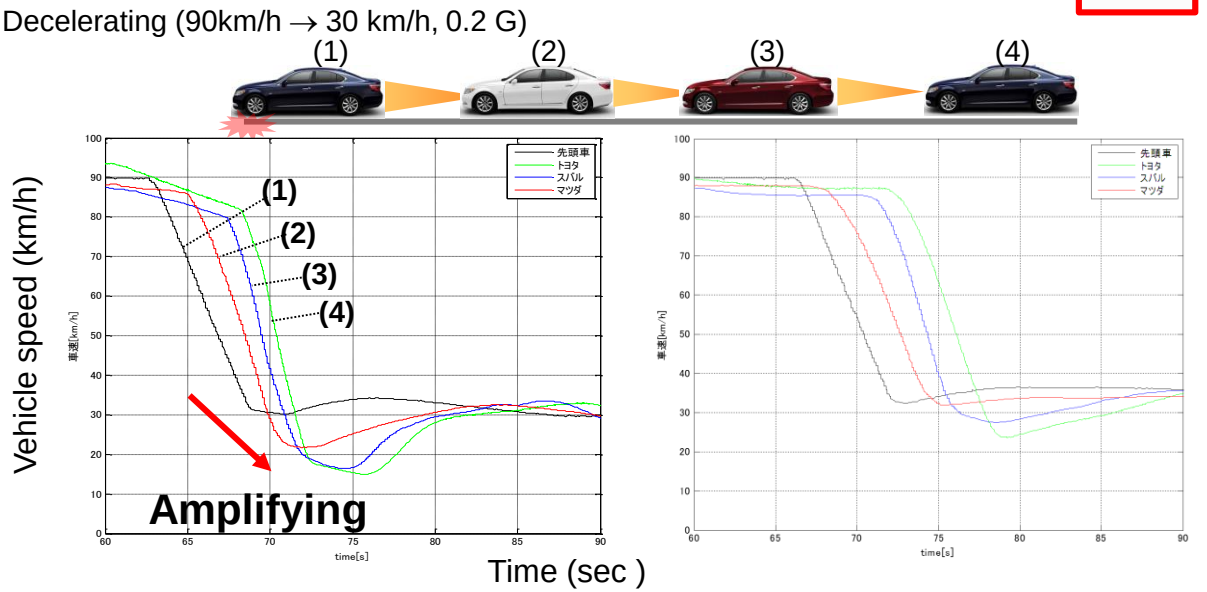
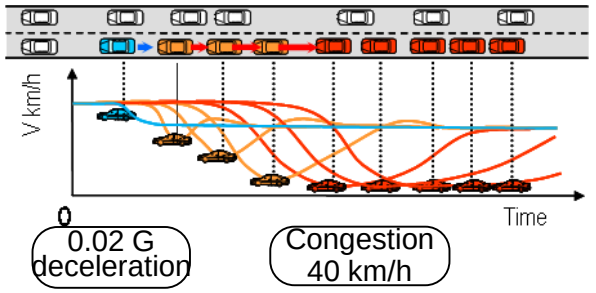


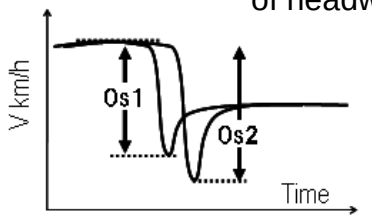
Fig. 2 String stability performance of C-ACC (field operational test)

Traffic congestion reduction effect by simulation

Simulation to evaluate the quantitative relationship between the amplification rate and the penetration rate. (e.g. amplification rate of **0.98** is needed **to halve** the congestion rate at a penetration rate of **20%**)

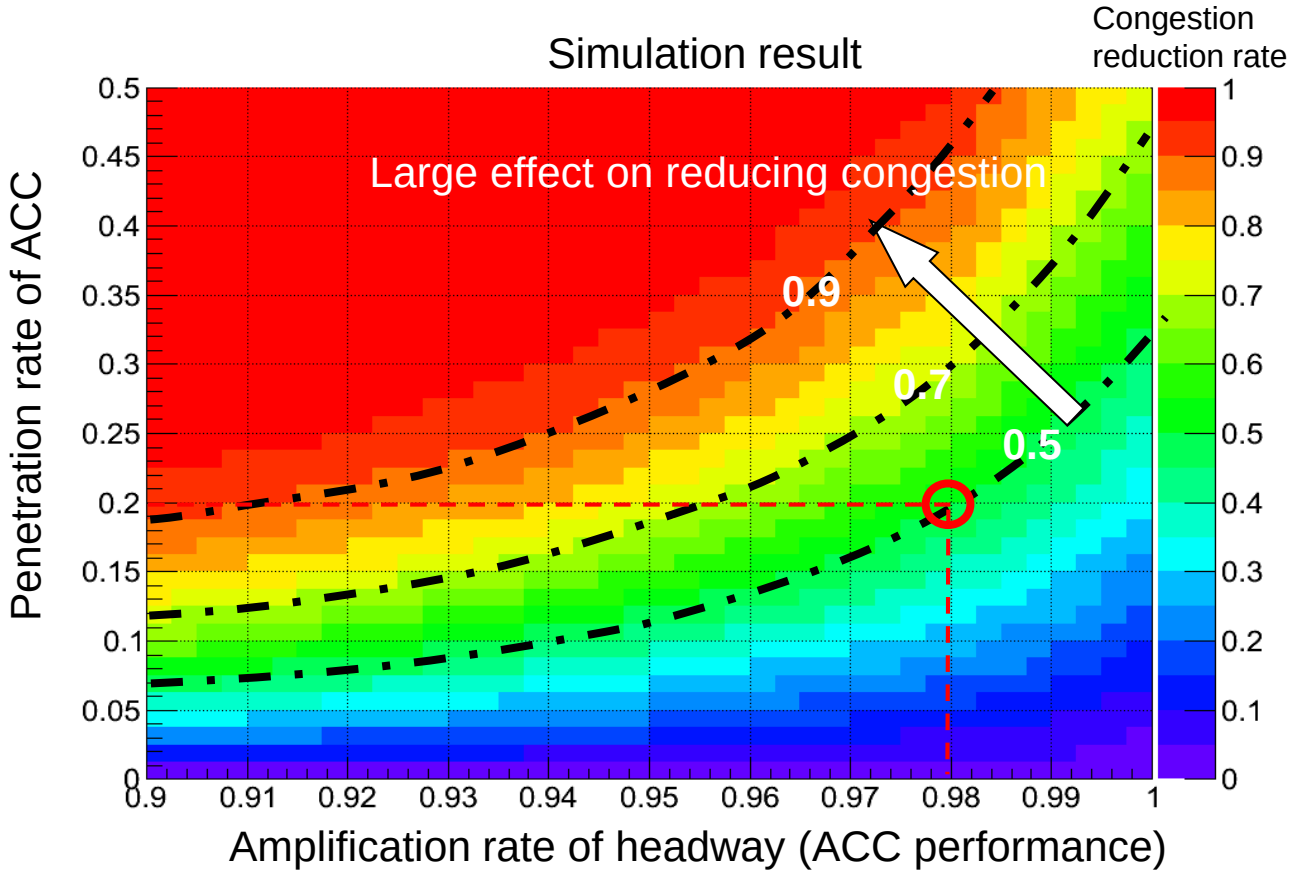


Amplification rate of headway = Os2 / Os1



Time headway to ensure a basic traffic flow rate of **more than 2,000 veh/h** depending on the ACC penetration rate.

Simulation result



Traffic congestion reduction rate = (Congestion before widespread adoption of ACC - Congestion after widespread adoption of ACC) / Congestion before widespread adoption of ACC

TOYOTA CENTRAL R&D LABS., INC.

Automated highway driving

Automated Highway Driving Assist (AHDA)

Automated driving technology: Gate-to-gate

Summary: Cyber-physical system for intelligent driving systems

Big data

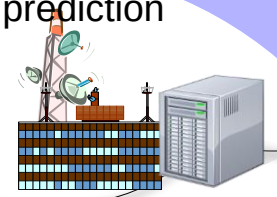
• Global driving intelligence

✓Near-miss data analysis/accident analysis

✓Enhanced map for dynamic usage

✓Traffic congestion prediction

✓etc.



• ICT: Info. & communication technology

✓V2X

Feedback

Travel conditions database

Human factor database

Vehicle

• Local driving intelligence

✓ADAS with autonomous driving intelligence

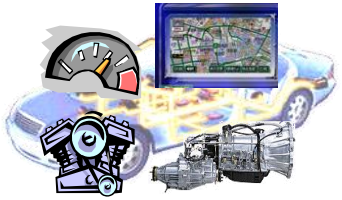
Accident avoidance

Fun to drive

Optimum eco-driving

Expectations for non-volatile memory

Integrated vehicle control



Advanced driver assistance

Connected driving

20XX year

Memory size increasing

Calibration

Performance

Reliability

Driving intelligence

Machine learning

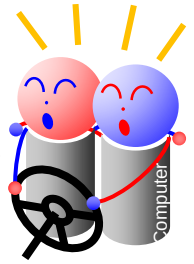
- Localized map model
- Sensor fusion model
- Motion planning
- Driver model etc.

Power train

Automated driving

Non-volatile memory

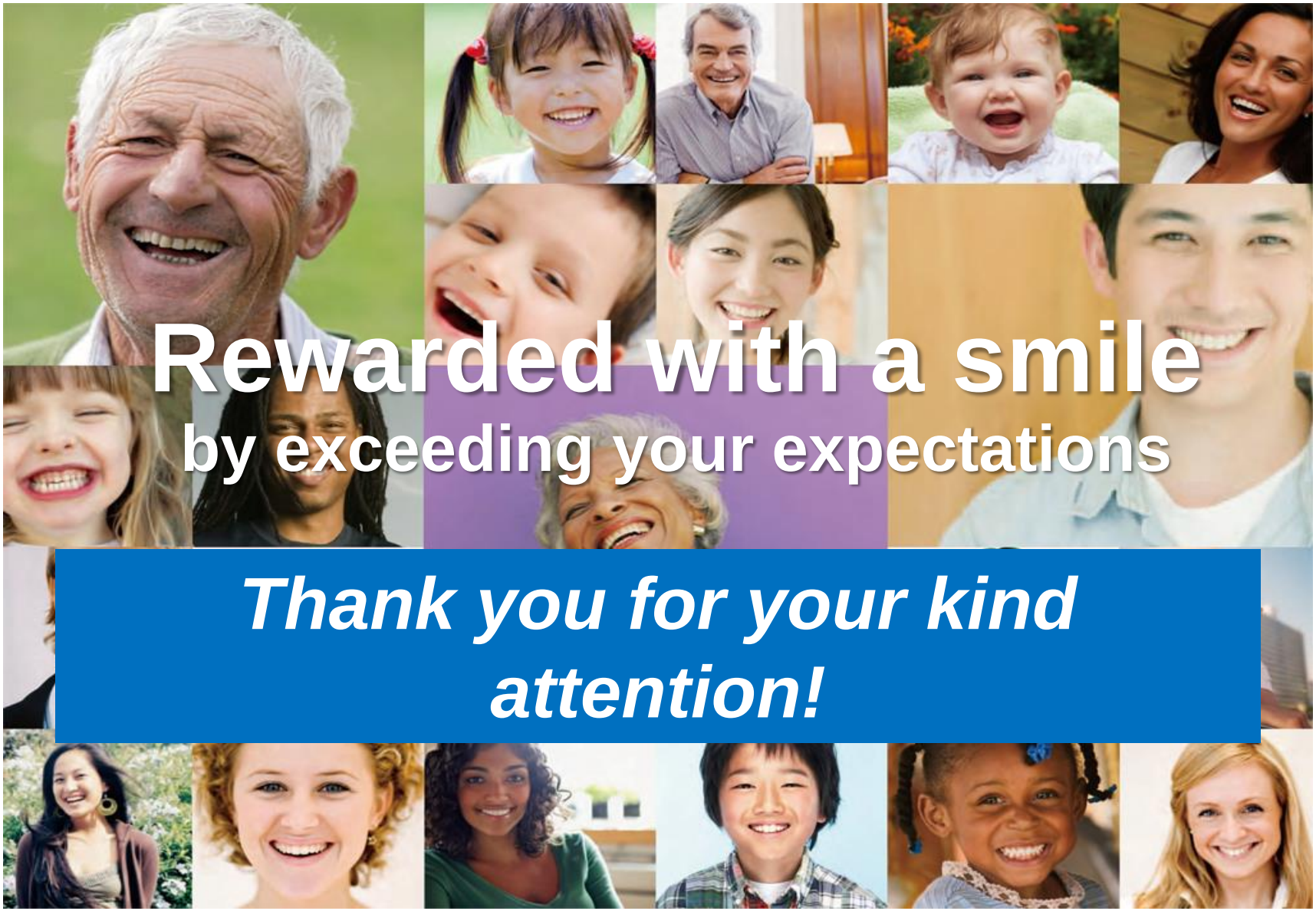
- Flash-memory for current systems
  - Retention period: over 20 years
  - Writing times: over 10^5 times
  - Computing power (inst-fetch/data-ope)
  - Sleep & wake up power reduction



Vehicle

Flash Memory Summit 2015

- New NV-memory for next-gen systems
  - Huge data storage for machine learning
    - Localized map model, sensor fusion model, motion planning, drive model, etc.
  - Random access speed
  - High reliability


Rewarded with a smile
by exceeding your expectations
Thank you for your kind attention!