Toward Safety and Security Enhancement by Car Robotics

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Preventive safety technology is very important to avoiding traffic accidents. Robotic technology, using sensors, actuators and microcomputers, is quite similar to preventive safety technology used to achieve drive assistance systems and autonomous stopping systems. Recently in JSAE, a new committee on Car Robotics started to investigate the new technology.

Key Words: *safety, car robotics, preventive safety, autonomous collision avoidance, driver model*

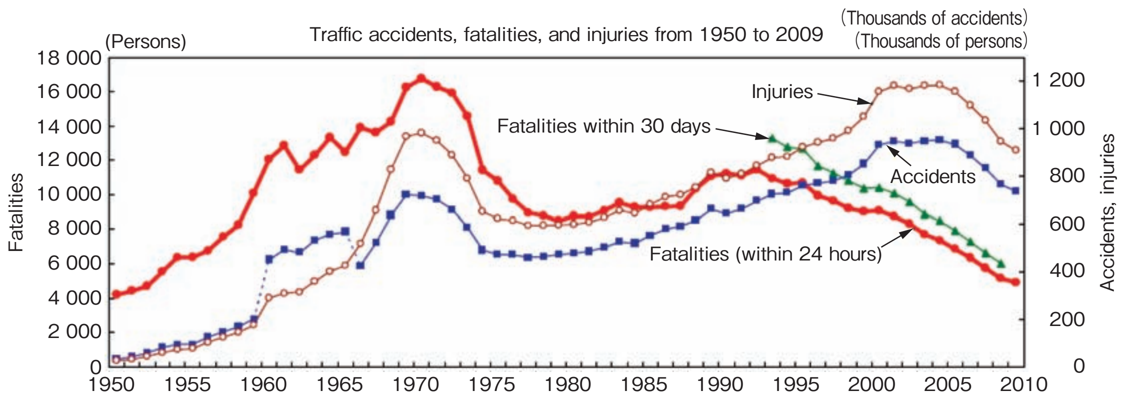
1. Introduction

In 2010, the number of traffic fatalities in Japan was 4 863, marking the tenth consecutive year of decline from the previous year. As shown in **Fig. 1**, traffic fatalities have fallen steadily over roughly the last two decades, and in the last few years, traffic injuries and accidents as well have begun to decline. Regarding traffic accidents, in addition to the obvious suffering of those directly involved as well as their families, a tremendous number of people are inconvenienced by the ensuing traffic jams, and the resultant annual economic loss has been calculated at several trillions of yen. In view of the great impact of traffic accidents, therefore, efforts in many areas have been made to reduce their occurrence, and Japan's responsible Cabinet member has announced a goal of reducing the number of accidents by half over the next 10 years with the aim of making Japan the world's safest country for driving.

The World Health Organization (WHO) reports that approximately 1.2 million traffic fatalities occur each year worldwide. In view of that, Japan has an obligation to spread to other countries the safety-related technology and experience it has accumulated thus far.

2. Aiming for a "Zero Traffic Accident" Society

While automobiles increase people's mobility and also provide pleasure and convenience, there are strong expectations that significant advances will be made in the 21st century to resolve various social problems related to automobile use, including safety problems, environmental



Notes1 Through 1959, minor accidents (injuries treated 8 days or less, property damage less than 20 000 yen) are not included
2 Accidents through 1965 include property damage accidents
3 Through 1971, Okinawa Prefecture is not included

Fig. 1 Traffic accident statistics

problems, energy problems, and even problems related to transportation for the increasing number of the elderly.

The author and others in the Engineering Systems Safety, Security and Risk Review Committee within the Science Council of Japan formed a "Subcommittee to Review Scientific Approaches to Achieving Zero Traffic Fatalities" in order to deliberate methods of eliminating traffic accidents, and in June 2008, this group published a report entitled, "Aiming for a 'Zero Traffic Accident' Society." In that report, the following four main approaches were proposed.

1) Expand utilization of driving recorders
2) Strengthen basic research on human factors
3) Strengthen R&D on preventive safety technology
4) Enhance traffic safety education

3. Fusion of Automobile Technology and Robot Technology

In his anthology I, Robot, Isaac Asimov provides the Three Laws of Robotics, a set of rules for robots such as "robots must not injure human beings" and "robots must obey orders given to them by human beings." Awareness of the critical role that preventive safety technology plays in the prevention of automobile accidents is growing, and as automobiles come to utilize robotics increasingly today, it is important to consider the rule that robots must not injure human beings, namely in that automobile robotics must protect human beings from traffic accidents. This has led to the formation by The Robotics Society of Japan and the Society of Automotive Engineers of Japan (JSAE) of a joint committee to carry out research on car robotics.

4. The Advance of Robotics in Automobiles

In recent automobiles, reportedly there are more than 100 sensors and actuators and more than 50 ECUs. According to a JSAE forum on "The Present and Future of Robot Technology," if we consider robot technology to be technology combining sensors, actuators and intelligence, much robot technology already is being utilized in automobiles.

Perhaps because awareness has been strong that automobiles basically are designed by machine specialists, the above technology conventionally has been positioned as car electronics and initially was applied mainly to accessories and electronic appliances. In recent days, however, awareness of the importance of mechatronics has grown to the point it is understood that without mechatronics, automobile electronic control and intelligence is not possible. As seen in the proliferation of car navigation systems and ETC, automobile technology today is evolving from individual technologies to network technology involving mobile communication systems.

5. Technology Supporting Intelligent Driving

Table 1 shows acronyms for typical driver assistance systems that have been developed until now. Basically, these are systems to control the vehicle's lateral movement, including side-slip prevention and lane departure prevention systems, and systems to control the vehicle's longitudinal movement, including systems to prevent rear-end collisions, mitigate the impact of collisions, and assist braking operation. **Figure 2** shows the concept of systems intended to assist the driver in avoiding rear-end collisions, which account for a high percentage of traffic accidents.

Table 1 Typical driver assistance systems

ESC	: Electronic Stability Control
LKAS	: Lane Keeping Assist System
LDWS	: Lane Departure Warning Systems
ACC	: Adaptive Cruise Control
FVCWS	: Forward Vehicle Collision Warning System
PCS	: Pre-Crash Safety System
CMS	: Collision Mitigation brake System

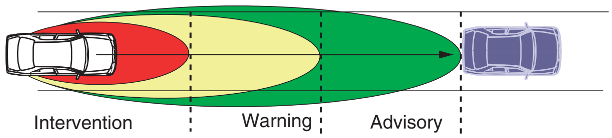


Fig. 2 Concept of driver assistance systems for rear-end collision avoidance

It is said that human error is often to blame for traffic accidents. Mistakes in human awareness, judgment, and operation, combined with dangerous driving conditions, can lead to near-misses, minor accidents, or major accidents. An image-capturing drive recorder as shown in **Fig. 3**, whose operation is triggered by sudden acceleration or deceleration such as during emergency braking, is extremely effective in recording real-world conditions and dangers during accidents. Also, because basic research on human factors is essential to the development of preventive safety systems, driving simulators such as that shown in **Fig. 4** are effective.

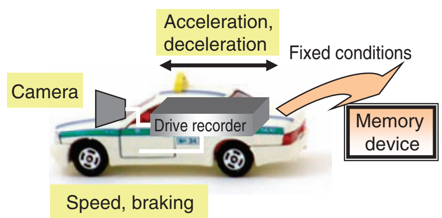


Fig. 3 Image-capturing drive recorder

CONTRIBUTION

Fig. 4 TUAT-driving simulator

6. From Passive Safety to Collision Mitigation

The movement speed of automobiles is much faster than that of robots, and the amount of damage that automobiles suffer in collisions is correspondingly larger. By rough calculation, given that the amount of kinetic energy in a collision is proportional the square of the speed, if we compare an electric wheelchair or mobile robot traveling 6 kph that strikes a wall to an automobile traveling 60 kph that strikes a wall, the automobile has 100 times the kinetic energy based on the ratio of the square of the speed, and if we assume the automobile's mass to be 10 times larger, its total kinetic energy is 1 000 times higher. Conventionally, the focus of collision safety technology has been devising means of absorbing this energy released during collisions in the safest way possible.

In recent years, a certain type of Pre-Crash Safety System (PCS) called the Collision Mitigating brake System (CMS) has been developed. When this system judges a collision to be unavoidable, it provides automatic braking to reduce the predicted collision speed and mitigate damage. It is expected that this technology will greatly reduce injuries and fatalities in collisions. In particular, the damage suffered by normal passenger cars in collisions with larger vehicles is severe, and the proliferation of CMS and similar safety systems is thought to be essential.

7. From Collision Mitigation to Automatic Stopping

CMS measures the speed of the host vehicle and the distance between it and the forward vehicle, and when the system judges danger to exist, it applies automatic braking independent of the driver. However, although this technology has the potential to be used for the purpose of avoiding collisions, its usage is limited to reducing collision speed and mitigating damage. The reason is that in Japan, there is debate over whether safety systems actually will lead to a reduction in traffic accidents if humans come to place too much confidence in them.

Incidentally, a Japanese-European carmaker very recently introduced to the market an automatic braking system able to avoid forward collisions completely during low-speed driving under 30 kph. In introducing this technology, however, more importantly than attempting to deal with any psychological problems of drivers having overtrust or distrust in such system, the carmaker must clarify sternly that "the vehicle is to be driven at the driver's responsibility" because weather conditions have the potential to affect the system's ability to stop the vehicle.

Moreover, judging from recent traffic accident statistics, reducing pedestrian and motorcycle fatalities resulting from traffic accidents and controlling the number of accidents both caused by and suffered by the elderly will be keys to achieving the goal of halving traffic fatalities over the next 10 years. Fatalities involving such vulnerable persons can occur even at very low collision speeds, and therefore systems able to stop automobiles completely can be expected to lead to a significant drop in the occurrence of such fatalities.

8. Individual Adaptation Service

The author and others participating in a project on "Mobile Sensing for Safety and Security" being promoted as part of Core Research for Evolutional Science and Technology (CREST), an undertaking of the Japan Science and Technology Agency (JST), are carrying out research in the area of integrated sensing with the aim of creating driving support systems adapted to the individual driving characteristics of each driver.

"Individual Adaptation Service" is a term referring to the concept of making a database of each driver's unique driving characteristics and habits and providing driving support specifically tailored to that individual's needs. Individual driving characteristics normally are evident particularly in accelerator pedal operation, and therefore in connection with such operation, the group is endeavoring to develop a continuously-logging drive recorder, carry out driving behavior modeling based on machine learning theory, etc. with the aim of achieving preventive safety automobiles that support with individual adaptability.

In order to develop individual and road environment individually adaptation service, our research group, focusing on accelerator and brake operation in each road environment, driver, and automobile situation, categorized road driving situations into the five situations shown in **Fig. 5** (F: Following a forward vehicle; B: Braking to avoid a collision; C: Cruising; D: Decelerating; S: Stopping) and is performing driving behavior modeling based on machine learning theory. Correspondence between each sensor's measurement data and driving situation label is formed, and by the sequential label

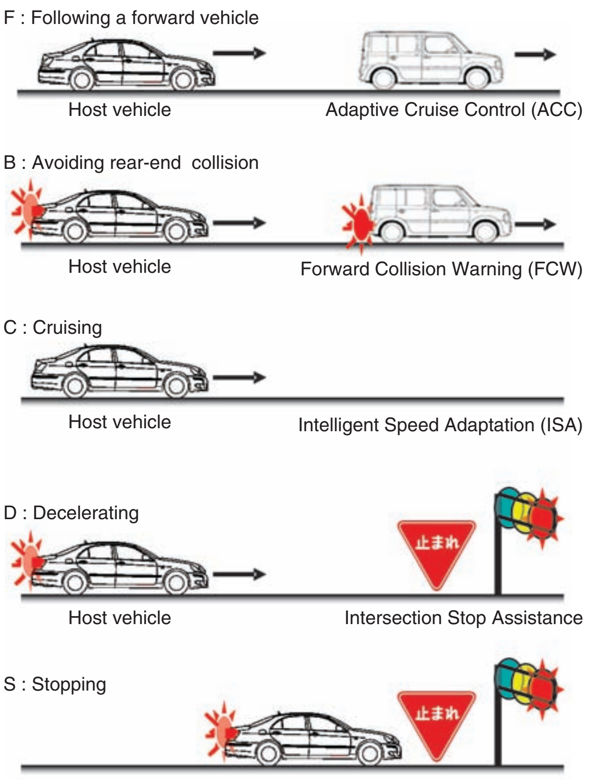


Fig. 5 Driving behavior modes of longitudinal control

boosting method, a driver model considering driving mode transition model as shown in **Figs. 6** and **7** is being developed. Our research group expects through this effort to contribute to the design of an advanced, highly usable driving support system.

9. Conclusion

Recently, the author has had great opportunities to visit not only European and North American advanced nations but also Vietnam, China, and New Zealand. Particularly in Vietnam, perhaps because public transport means are nearly nonexistent, the roads are overflowing with crowdy motorbikes, bicycles and pedestrians appearing to move in a chaotic pattern, which undoubtedly results in a great number of accidents. Certainly Japan has a duty to share with the world the safety-related technology and experience which has been accumulated thus far as an advanced country in order to provide other countries with solutions for social issues.

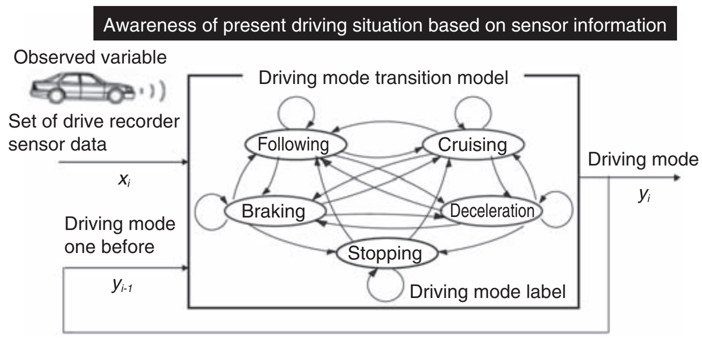


Fig. 6 Driver model based on driving mode transition

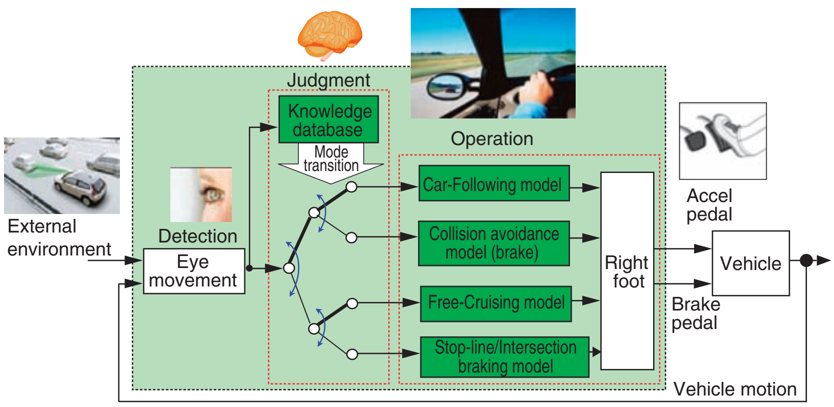


Fig. 7 Integrated driver model