# Adaptive Driver-assistance Systems

Tatsuya Yoshida
Hiroshi Kuroda
Takaomi Nishigaito

*OVERVIEW: An ACC (adaptive cruise control) system and a pre-crash braking system have been put into practical application. By automatically controlling the distance to a preceding vehicle, the ACC system helps to reduce driver fatigue. And by measuring the relative speed and distance of the preceding vehicle, the pre-crash braking system takes control of the brakes in the event that a collision is unavoidable in order to mitigate the impact during the collision. Although current adaptive driver-assistance systems are mainly applied for highway driving, even driving on public roads will become safer through technologies for coordination with information from surrounding infrastructure and through navigation systems and technologies for driving-environment recognition. Aiming to contribute to the reduction in traffic accidents, while applying our know-how acquired in the industrial and railway fields, Hitachi Group is developing driving-environment recognition technology, driving-control technology, and actuator technology that all attain high reliability at low cost.*

## INTRODUCTION

IN Japan in recent years, although the general trend in the death toll due to traffic accidents has been a gradual decline, it still exceeds around 8,000 people every year. Moreover, there is an increasing trend in the number of traffic accidents, which stands at around a million every year. Since a large proportion of traffic accidents is caused by the driver (namely, human error), adaptive driver-assistance systems — which stop human-error accidents before they occur or alleviate damage by taking control of the vehicle just before an accident occurs — have been actively developed, and some systems have already been implemented.

An adaptive driver-assistance system ensures safe driving by assisting the driver in the following ways: reducing driver fatigue and maintaining driver performance by supporting a driver's "recognition," "judgment," and "actuation" actions; displaying warning signs in the case that errors in these actions are judged to be dangerous; and taking control of the vehicle in the case that the driver is unable to avoid a collision.

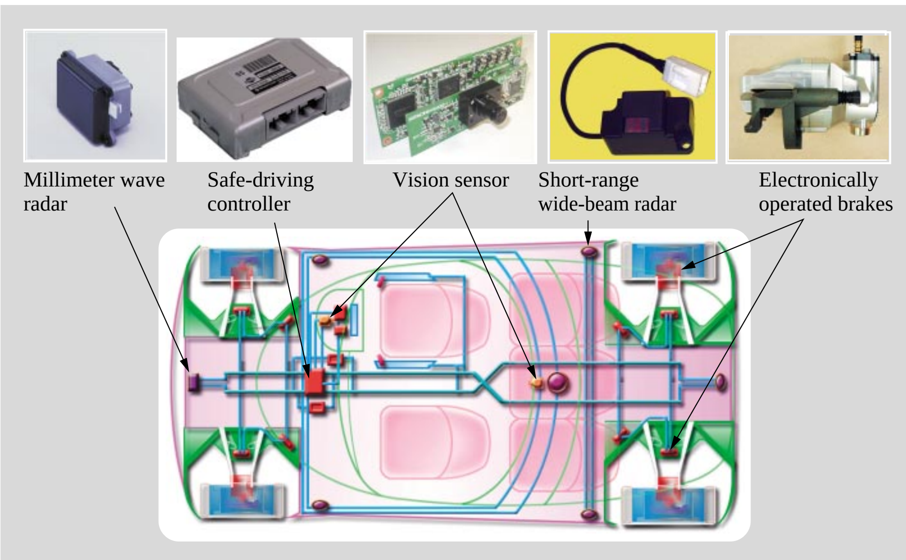


*Fig. 1—Main Components Forming Adaptive Driver-assistance System of Future.*
*With environmental-recognition devices — such as millimeter wave radar and vision sensors — arranged at the front, back, and sides of the vehicle, the conditions of the driving environment in all directions can be detected. These devices receive information from the surrounding infrastructure and navigation systems, which is then used by the safe-driving controller to electronically control the engine throttle, braking, and steering. This information is exchanged via a network mounted inside the vehicle.*

In the following sections of this paper, development trends concerning adaptive driver-assistance systems are reviewed, the current status of Hitachi Group's development work on these systems is introduced, and the future outlook for such systems is outlined (see Fig. 1).

## TRENDS IN DEVELOPMENT OF ADAPTIVE DRIVER-ASSISTANCE SYSTEMS

On the initiative of the Ministry of Land, Infrastructure and Transport, Government of Japan, plans for implementing "ASVs (advanced safety vehicles)" are being promoted, and R&D (research and development) on various kinds of adaptive driver-assistance systems — aimed at supporting accident avoidance and automatic driving — is being advanced.

To reach what is considered the ultimate form of adaptive driver-assistance systems, namely, "autonomous driving," various challenges need to be overcome.

Forecasted trends in the development of adaptive driver-assistance systems are shown in Fig. 2. There are two kinds of adaptive driver-assistance systems: those that support driving in relation to the longitudinal direction of the vehicle, and those that support driving in relation to the lateral direction.

As an example of such a longitudinal-direction adaptive driver-assistance system, ACC, which controls the distance between vehicles, is already being fitted by several vehicle manufacturers. In 2003, TOYOTA MOTOR CORPORATION, Honda Motor Co., Ltd, and Nissan Motor Co., Ltd, launched "pre-crash braking systems"— aimed at reducing damage caused by collisions — in quick succession. In the near future, expanding the current range in which vehicle speed can be controlled (i.e. currently starting from around 40 km/h under Japanese restriction) to cover lower speeds is thought likely to lead to the development of so-called "stop-and-go systems.*"

As examples of lateral-direction adaptive driver-assistance systems, LDWS (lane-departure warning systems) and LKS (lane-keep support) systems are also being fitted by several vehicle manufacturers. And in the future, it is considered that, together with further development of lane-recognition technology, these systems will be expanded for public road use.

From now on, control through cooperation between longitudinal- and lateral-direction adaptive driver-assistance systems will lead to the development of crash-prevention systems, and the application of information received from car-navigation systems and road-side infrastructure will lead to the appearance of adaptive driver-assistance systems with even higher performance. It is thus anticipated that these developments will lead toward the realization of autonomous driving.

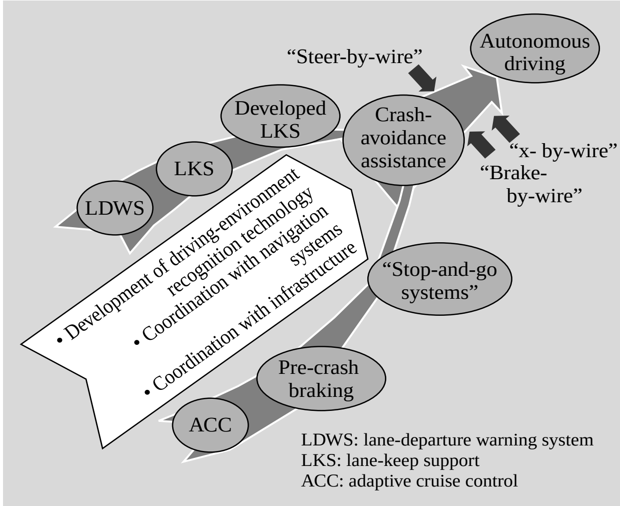


*Fig. 2—Trends in Development of Adaptive Driver-assistance Systems.*
*Together with advances in environmental-recognition technology and actuation technology, the realization of autonomous driving is approaching.*

## ADAPTIVE DRIVER-ASSISTANCE SYSTEM

### Status of Developments at Hitachi Group

Integrating technologies from various fields within Hitachi Group, we have been actively developing adaptive driver-assistance systems for several years.[1–4)]

The current status of the systems that Hitachi has commercialized is shown schematically in Fig. 3. In 2001, a control unit and brake booster for ACC systems were introduced. Later, vision sensors for LKS systems were launched commercially for use in ACC systems in trucks, and following the addition of a pre-crash braking system for passenger-vehicle ACC, a millimeter wave radar system for ACC was launched onto the market in 2003.

The configuration of the ACC system fitted with the pre-crash-braking function is shown in Fig. 4.

### Adaptive Cruise Control System

ACC (adaptive cruise control) — a longitudinal-direction driver-assistance system — alleviates the load

* Stop-and-go systems: ACC systems that extend the speed range to stop so that the systems can be used in congested stop-and-go driving conditions.

on a driver in operating a vehicle by assisting with the operation of the accelerator and brakes. It uses a radar to measure the distance to the vehicle in front, and then automatically adjusts the speed of the vehicle so as to maintain the distance set by the driver. And in the case that there is no vehicle traveling in front, it is controlled at a pre-set speed in "constant-speed mode."

Hitachi Group has developed and commercialized all the components that compose an ACC system, namely, environmental sensors (millimeter wave radar) for the "recognition" function, an ACC control unit for the "judgment" function, and powertrain and braking control systems for the "actuation" function.

As regards development of ACC systems, so-called "hardware-in-the-loop" technology is used to perform virtual running tests before operation validation using actual vehicles and to speed up development of sub-system control systems. As regards this technology, a computer for determining vehicle-operation parameters is combined with a production-model controller and an actuator (i.e. hardware). To achieve a virtual running test, a control loop incorporating actual conditions simulated in real-time is then formed.

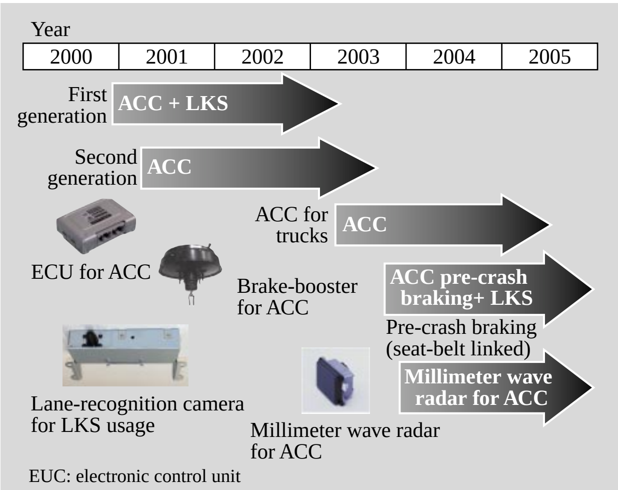


*Fig. 3—Status of Product Commercialization Regarding Adaptive Driver-assistance Systems Developed by Hitachi Group.*
*Hitachi Group has been commercializing adaptive driver-assistance systems since 2001.*

## Pre-crash Braking-control System

The pre-crash braking-control system uses a radar to measure the distance to the preceding vehicle and determine its relative speed. In the case that there is a danger of a collision with that vehicle, the driver is warned by a buzzer. In the case that the driver's avoidance action is judged inappropriate to avoid a collision, and a crash is thus inevitable, the system applies the brakes in order to reduce the impact of the collision. Since the component parts of this system are the same as those for the ACC system, the two systems are often fitted as a complete set.

Moreover, in the case that a collision is unavoidable, the pre-crash seat-belt function engages simultaneously with the pre-crash braking-control and tightens the seat belts in order to restrain the passengers a second before the collision and reduce any injuries they might suffer.

In addition to developing the above-mentioned ACC systems, Hitachi Group is also developing the seat-belt drive units for the pre-crash seat-belt-tightening function.

## Lane-keep Support System

LKS (lane-keep support) is a lateral-direction support system that assists the steering of the driver by means of an electric power-steering system so that the vehicle does not deviate from the lane it is running in. It does this by recognizing the white lines marking the lane by means of processing data from images captured by vision sensors on the sides of the vehicle.

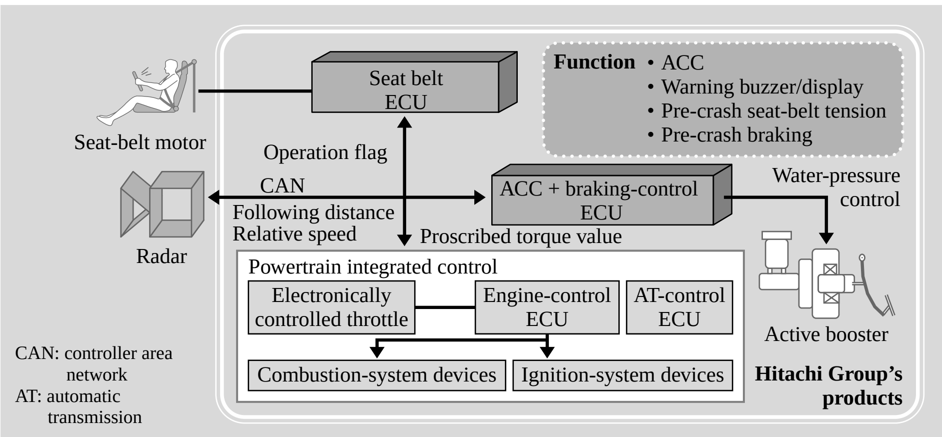


*Fig. 4—Configuration of ACC System Fitted with Function for Pre-crash Braking.*
*In regards to the ACC system for the "Cima" model launched by Nissan Motor Co., Ltd. in 2003, a function for pre-crash braking to limit the collision damage was added.*

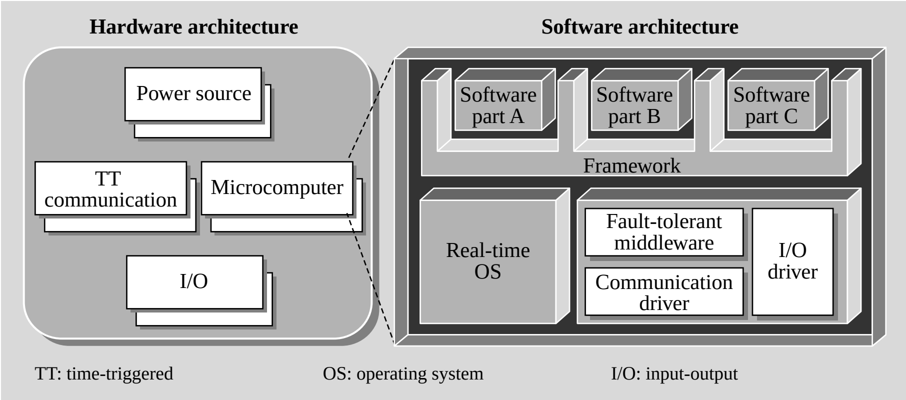


*Fig. 5—Example Configuration of High-reliability Controller.*
*With many years of experience in the industrial and railway fields, Hitachi Group has been making great efforts to develop high-reliability controllers. As regards the automotive field—to meet the challenge of reducing costs—we are applying our know-how acquired from those other fields in order to develop technologies that can deliver high reliability at low cost.*

Hitachi Group is developing the vision sensors for the “recognition” function and the electronic steering system for the “actuation” function.

## FUTURE OUTLOOK

A horse senses the rider’s intentions and, while judging the surrounding conditions, avoids obstacles in order to ensure its own safety as well as the rider’s. Similarly, in the case of an adaptive driver-assistance system, responding to the sudden appearance of another vehicle, pedestrians, or animals, a group of sensors (such as the above-mentioned vision sensors) recognizes the surrounding circumstances; a controller evaluates the driver’s intention at the same time as it determines the appropriate evasive action; steering control avoids spinning or skidding while suspension control adjusts the downward force on the tires; and independent control of the left and right brakes assists the evasive action and controls the vehicle speed. The result of these actions is that crash avoidance is completed safely. In regards to the establishment of future adaptive driver-assistance systems, as well as electronizing the operation of the actuators, improving the reliability of the sensors and controllers is a key issue. It is thus thought that the trend toward making best use of the integrated technologies developed in the Hitachi Group will continue. An example of such a vital technology — which will realize functions analogous to man and horse as one — is the “x-by-wire” system being developed by Hitachi Group.

In addition, an HMI (human-machine-interface) technology that enables the vehicle and driver to cooperate in a natural form (so intervention of the adaptive driver-assistance system does not cause any sense of discomfort to the driver) and that can cooperate with infrastructure is thought to be an important part of the evolution process toward autonomous driving.

### x-by-wire Technology

The “x-by-wire” system being developed by Hitachi Group represents the first generation of autonomous driving. As for the first generation, it is necessary that the vehicle faithfully follows the driver’s intentions. Consequently, as regards realizing actions “by-wire”— namely, cutting out the mechanical linkage between the input devices such as brake panel and steering wheel and actuators — a key issue is improving the reliability of the actuators and controllers. It is also important to improve the reliability of the sensor recognition technology, which connects to the decision making process. (Actuator and sensor recognition technologies are outlined in a separate article in this issue.)

An example configuration of a high-reliability controller is shown in Fig. 5. Duplicating the hardware ensures that the controller can continue to operate as a whole unit even if one part of it is damaged. The software architecture is configured in such a way that application software resources are utilized as software components and the reliability of communication and I/O is ensured in the middleware layer. As a result of this layered configuration, previously accumulated software resources can be utilized, and the reliability of the whole software configuration can be easily ensured.

In regard to the evolution from the first to the second generation of x-by-wire systems, it is considered necessary to guide vehicles to safer direction by means of autonomous decision making. To achieve this, it is necessary to improve vehicle control by integration of individual by-wire systems to expand cooperation with humans (namely, extracting the driver’s intention) and the control domain under conditions that give no discomfort to the driver.

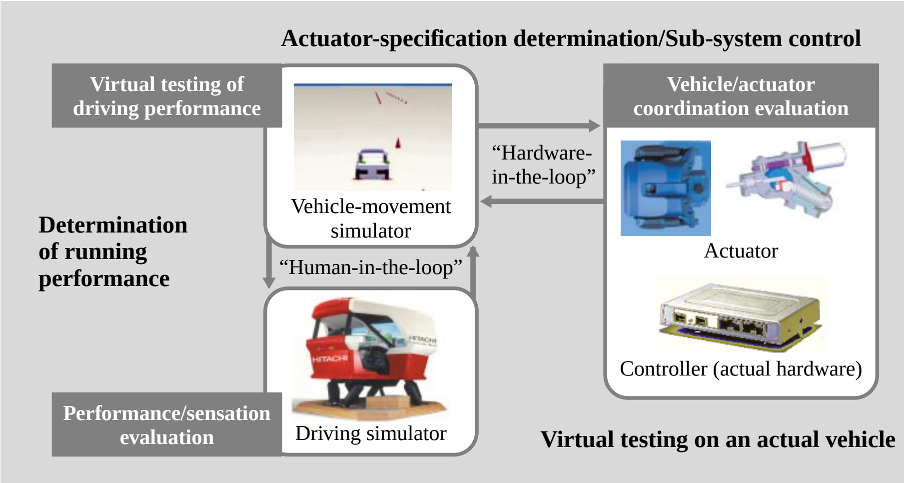


*Fig. 6—Configuration of Virtual-vehicle System.*
*Without having to run an actual vehicle, this simulation technology can be used to efficiently develop control systems and human interfaces that are in accord with the driver's sensitivity.*

## Simulation Technology

Aiming to establish human-interface technology and x-by-wire systems, Hitachi Group is developing a virtual vehicle simulator (which combines a driving simulator and a vehicle-movement simulator) that evaluates the driver sensations by means of a "human-in-the-loop" system (see Fig. 6). Taking into account a driver's sensibility and body characteristics, this simulator is used to determine the running performance. The appropriate actuators and control systems to meet this performance are then developed.

## CONCLUSIONS

After reviewing the current state of development regarding adaptive driver-assistance systems, this report explained the status of Hitachi Group's developments concerning these systems and then went on to summarize their future outlook.

It is expected that adaptive driver-assistance systems will contribute to the reduction of traffic accidents; moreover, if the aging of society is taken into consideration, it is thought that such systems will become even more essential features of vehicles in the future.

The key factors in realizing these systems are driving-environment recognition technology and high system reliability. At Hitachi Group — with an eye on future infrastructure improvements and developments in HMI technology — we will be striving towards the realization of adaptive driver-assistance systems that will assure driving safety.

## REFERENCES


(1) S. Kuragaki et al., "An Adaptive Cruise Control Using Wheel Torque Management Technique," SAE Transactions, 98060 (Feb. 1998).

(2) J. Takezaki et al., "Adaptive Driver-assistant Systems," Hitachi Hyoron **82**, pp. 599-604 (Sep. 2000) in Japanese.

(3) H. Kuroda et al., "Vehicle Control and Information Systems," Hitachi Hyoron **84**, pp. 541-546 (Aug. 2002) in Japanese.

(4) M. Ichinose et al., "Development of Hardware-In-the-Loop Simulator for Adaptive Cruise Control System," Proceedings of AVEC '02, 20024513, pp. 207-212 (Sept. 2002).


## ABOUT THE AUTHORS


Tatsuya Yoshida

*Joined Hitachi, Ltd. in 1978, and now works at the Advanced Technical Center, the Automotive Systems. He is currently engaged in the development of vehicle driving control systems. Mr. Yoshida is a member of Society of Automotive Engineers of Japan, Inc. (JSAE), and can be reached by e-mail at tatsuya.yoshida.sr@hitachi.com.*

Hiroshi Kuroda

*Joined Hitachi, Ltd. in 1984, and now works at the 1st Electronic Device Design Department, the Engine Management System Division, the Automotive Systems. He is currently engaged in the development of vehicle driving control systems and millimeter wave radars. Mr. Kuroda is a member of The Institute of Electrical Engineers of Japan (IEEJ), The Institute of Electronics, Information and Communication Engineers (IEICE), and can be reached by e-mail at hiroshi.kuroda.gy@hitachi.com.*

Takaomi Nishigaito

*Joined Hitachi, Ltd. in 1986, and now works at the Mechanical Engineering Research Laboratory. He is currently engaged in the development of vehicle dynamics control systems and engine control systems. Mr. Nishigaito is a member of JSAE, Japan Society of Mechanical Engineers (JSME), and can be reached by e-mail at tn@gm.merl.hitachi.co.jp.*