

Introduction of HONDA ASV-2 (Passenger cars)

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ABSTRACT

In response to the Advanced Safety Vehicle Project Phase 2 (ASV-2) proposed by the Ministry of Transport, we have addressed the two topics below with reference to the results from analysis of actual traffic accident conditions. After selecting effective technologies, we fabricated test vehicles for each of the objectives and moved forward with the research.

- Safety-enhancement through the reduction of both driver operating burden and rear-end collision damage through driving and operational support using CCD camera, radars, and related technology (Honda ASV-2, Vehicle 1).
- Enhancement of visual recognition to thereby provide information on the presence of motorcycles and pedestrians through information and visual support using communications and control devices, infrared cameras, and other technology (Honda ASV-2, Vehicle 2).

Research is proceeding on installation and implementation of each system, taking the basic approach of developing systems that will not interfere with driving operations. The test results on these systems have shown that they can be expected to produce accident-reducing effects. Minister of Transport approval was granted and road tests are being conducted on some of these technologies.

1. Introduction

The Advanced Safety Vehicle Phase 2 (ASV-2) Development Promotion Project proposed by the Road Transport Bureau of the Ministry of Transport has been implemented as a 5-Year Project starting from fiscal year 1996 with the participation of 13 domestic manufacturers. The ASV project aims to increase the intelligence of vehicles by utilizing electronics and other new technologies that are advancing rapidly, and to research and develop vehicles to enhance safety. Technical items have been set for a total of 32 systems in the following six fields: (1) Prediction and collision avoidance safety technology, (2) Accident evasion technology, (3) Fully automatic driving technology, (4) Collision avoidance technology, (5) Reduction of secondary effects from collisions, and (6) Automobile infrastructure technology. Each participating company was left to its own devices in dealing with each of the items. In Phase 2 the project was expanded to include trucks, buses and motorcycles in addition to the automobile research initiated in Phase 1 (implemented from 1991 to 1995).⁽¹⁾ In addition, joint proving tests (Smart Cruise 21) with the Advanced Cruise-Assist Highway Systems (AHS) promoted by the Ministry of Construction are scheduled for the end of this year.

2. Background

The types of accidents that would be most effective to research and the technologies needed to avoid accidents served as the starting points for safety research for the Honda ASV. Fig. 1 shows the transition in the number of fatalities and casualties over the last ten years.⁽²⁾ This graph shows that the casualties are still increasing, and it is thought that research and development on collision avoidance technology will become even more important for reducing traffic accidents in the future.

Fig. 2 shows the percentage of traffic accidents according to the parties involved. These graphs show that collisions between automobiles account for 50% of accidents involving casualties. Likewise, 50% of fatal accidents involve vulnerable parties such as pedestrians, motorcycles and bicycles.

Analyzing this data in greater detail shows that the number one cause of accidents between vehicles is rear-end collisions, accounting for 30% of the total, while most single vehicle accidents involve colliding with objects or the vehicle leaving the designated lane due to driver recognition or judgment errors. On the other hand, 70% of accidents resulting in the death of vulnerable parties occurred at night, with most occurring while pedestrians were crossing streets.

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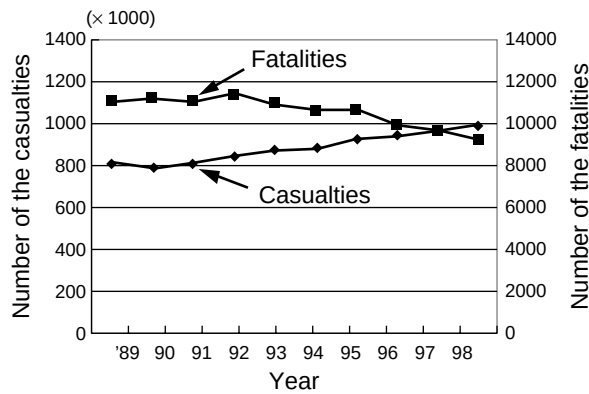


Fig.1 History of fatalities and casualties in traffic accidents

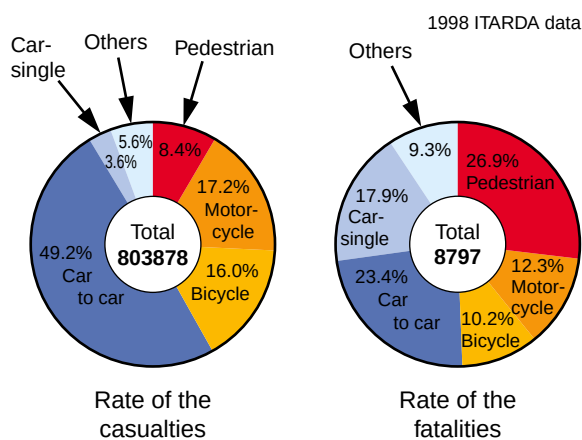


Fig.2 Percentage of the traffic accident details

In addition, 70% of motorcycle accidents are accounted for by intersection collisions and collisions involving vehicles making a cross-traffic turn (right-turn in Japan, left-turn in America) in front of an oncoming motorcycle.

Based on the above, we selected the following three topics:

- (1) The tracking of vehicles in front, as a way of reducing rear-end accidents between vehicles.
- (2) The avoidance of departure from a lane, as a way of reducing single vehicle accidents.
- (3) The detection of pedestrians at night and motorcycles at intersections, etc., as ways of reducing traffic accidents involving vulnerable parties.

Experimental vehicles were divided by topic as follows to allow research to proceed in an efficient manner.

- Honda ASV-2 experimental vehicle 1: Research on driving support
- Honda ASV-2 experimental vehicle 2: Research on improving recognition of vulnerable parties

Fig. 3 shows the experimental vehicles that were fabricated for the purpose of the research.

Research proceeded while bearing in mind the fact that "increasing human comfort reduces driver load," and the following themes were set as goals for the realization of our objectives:

- (1) Establishing guidelines for the development of new safety technologies
- (2) Real world tests
- (3) Verifying user compatibility
- (4) Improving system reliability



Fig.3 HONDA ASV-2

3. Technologies Applied to the Honda ASV-2 Experimental Vehicle 1

3.1. Outline

An analysis of traffic accident data revealed that the major factors involved in traffic accidents were human factors such as driver carelessness and/or errors in judgment. Therefore, the following three functions were incorporated into experimental vehicle 1:

- (1) Honda Lane Keep Assistance System (HLKAS), a system to help drivers keep their lane position and help avoid departure from a lane.
This system uses a CCD camera to recognize the lane markers and makes lane keep assistance.
- (2) Adaptive Cruise Control (ACC) with Stop & Go System, an ACC system with tracking control for congested traffic situations.
This system uses a millimeter-wave radar sensor to track the vehicle in front and keep the appropriate distance between the two cars during operation from start to stop.
- (3) Honda Collision Velocity Reduction System (HCVRs), a system for reducing rear-end collision velocity.
This system applies the brakes sharply to reduce the vehicle's collision velocity when the system has judged that a collision with the vehicle in front is likely.

Note that the system combining (1) HLKAS and (2) ACC⁽³⁾ is named the Honda Intelligent Driver Support System (HIDS)⁽⁴⁾. This is the first such domestic system to receive the approval of the Minister of Transport. Expressway running tests are currently underway with the aim of achieving actual application and use.

3.2. System Configuration

Fig. 4 shows the installation location of components used to achieve the above three functions in experimental vehicle 1, and Fig. 5 is a block diagram of the system's control. The CCD camera is positioned at the top of the windshield and the millimeter-wave radar is placed inside the front bumper

to detect the lane markers and the vehicle in front. The electric power steering (EPS) system, throttle actuator, electronically controlled master power (E-M/P) cylinder system, etc., are activated to control lane position and distance between vehicles.

3.3. Honda Lane Keep Assistance System (HLKAS)

This system provides the following lane keeping assistance: it recognizes the lane markers on the roadway by processing the images obtained from the CCD camera⁽⁵⁾, establishes the target point that the vehicle should reach along the target route to keep itself in the center of its own lane, and calculates the angular difference between the target point and the vehicle's predicted position. The system then calculates the optimum steering assist torque to steer the vehicle toward the target point, and controls the current supplied to the vehicle's EPS system to steer the vehicle

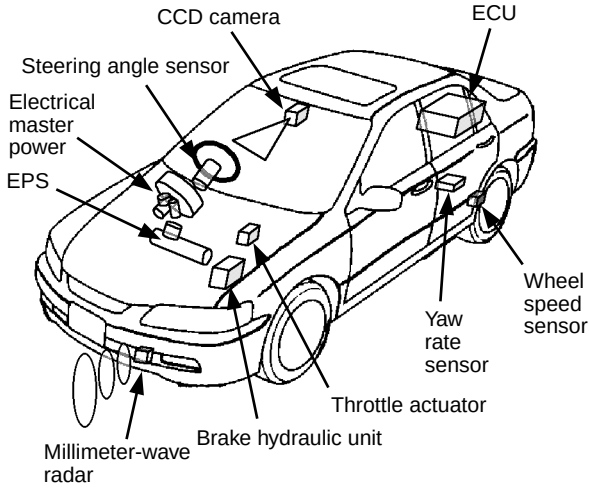


Fig.4 Configuration of ASV-2 experimental vehicle 1

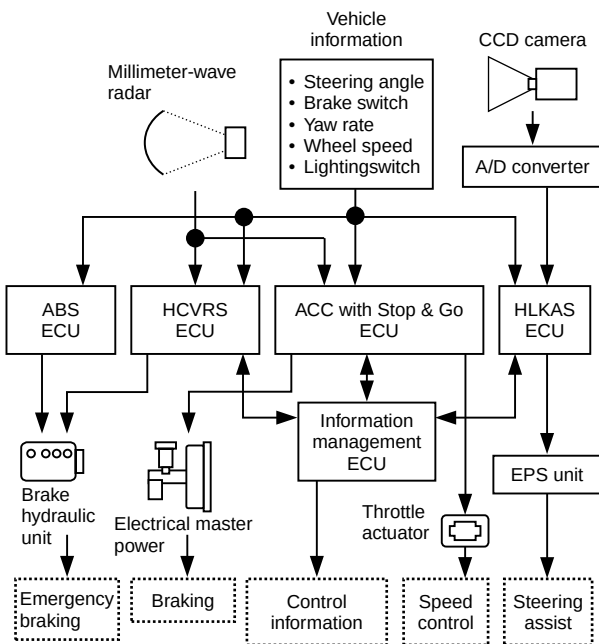


Fig.5 Block diagram of ASV-2 experimental vehicle 1

and keep it in its own lane. The system also provides a warning when the vehicle departs from the lane recognized by the system.

3.3.1. Lane Keeping Control Algorithm

As indicated by the geometric model shown in Fig. 6, the basic approach to controlling vehicle lane keeping consists of two functions.

The first function, feed-forward torque T_f , has the objective of stabilizing the vehicle for steady-state cornering. Steady-state cornering is made possible by calculating, the steering torque which will generate cornering force C_f that is optimal for centrifugal force $m \cdot V^2/R$ based on the road radius R , which is determined by image processing, and by steering the vehicle at this steering angle.

The second function, feedback torque T_b , has the objective of allowing stable cruising in the center of the lane. Cruising in the center of the lane is made possible by reducing the vehicle deviations to zero (in lateral position Y_d and vehicle heading angle θ_h) from the target route.

By generating a steering torque that optimally corrects these deviations, it is possible for the vehicle to follow the target route. Simultaneously, the appropriate steering torque is also generated to stabilize the vehicle-heading angle whenever this angle is suddenly altered by external disturbances such as road unevenness or crosswinds.

The combined torque of these two elements is calculated as lane keep assistance torque T_a , and lane keep control is performed for the vehicle.⁽⁶⁾

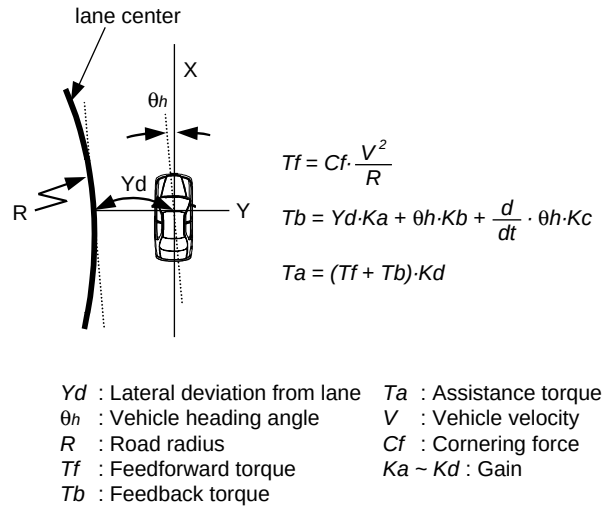


Fig.6 Geometric model

3.3.2. Driver Torque Interface Structure⁽⁷⁾

Within the EPS system, changeover between the driver's torque and the HLKAS torque is done as shown in Fig. 7-a to prevent steering wheel torque interaction with the driver. This is done by lowering the HLKAS torque in response to the amount of the torque input when the driver intentionally provides steering input during HLKAS control as shown in MAP1 in Fig. 7-b. At the same time, steering with little torque fluctuations is realized by restoring the assist characteristics of conventional power steering where there is no control system as shown in MAP2 in Fig. 7-b.

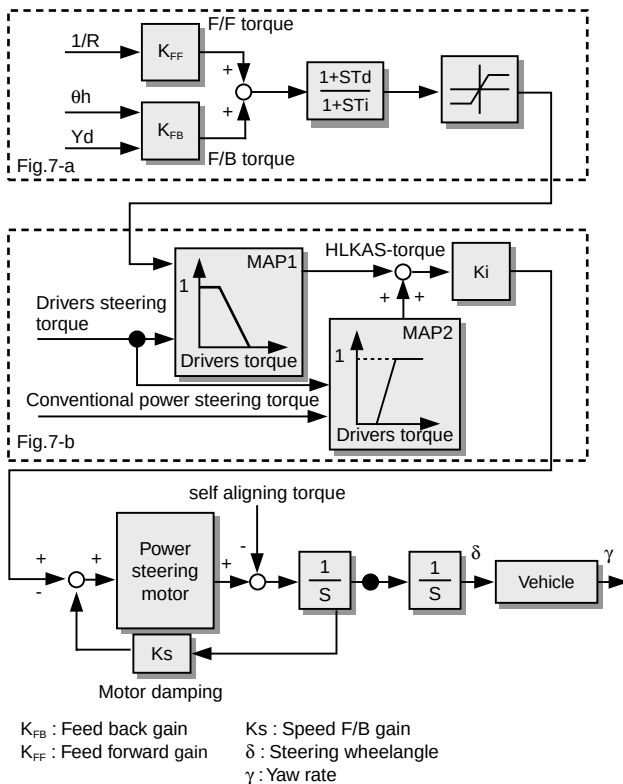


Fig. 7 Block diagram for HLKAS control

3.3.3. Steering Torque and Steering Angle Frequency Test Results

We compared the steering characteristics for a vehicle in which the system was installed with a conventional vehicle with no control system (using the travel data obtained from the lanes on the Tohoku Expressway, with a cruising speed of 100 km/h and a travel distance of approximately 50 km). Fig. 8 shows a comparison of the steering torque distribution. These results revealed that the high steering torque change frequency was reduced by HLKAS compared with a conventional vehicle without the control system. In addition, Fig. 9 shows a comparison of the steering angle distribution. This figure shows that HLKAS has a higher frequency near the steering angle center and smaller fine adjustment steering angles compared with a conventional vehicle without the system, thus confirming that HLKAS reduces the driver load.⁽⁸⁾

3.4. ACC with Stop & Go System

This is a driver load reduction system that assists drivers in keeping a set distance from the vehicle in front. In congested traffic, for example, the system decelerates the vehicle and, if necessary, stops the vehicle automatically. In this way, it keeps track of the vehicle ahead under a wide range of driving speeds, thereby reducing the driver load. Using a millimeter-wave radar sensor, the system detects the driving conditions of the vehicle traveling ahead, it senses the condition of the vehicle in which it is installed using the vehicle speed sensor and yaw rate sensor, and in this way focuses on its relative position to the vehicle ahead in the same lane. If the distance between the two vehicles becomes too short, the system reduces the vehicle's speed primarily

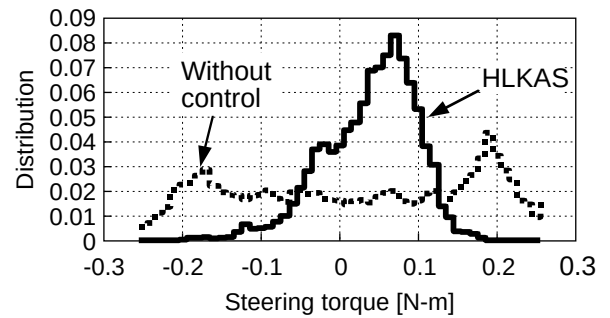


Fig. 8 Normalized steering torque distribution

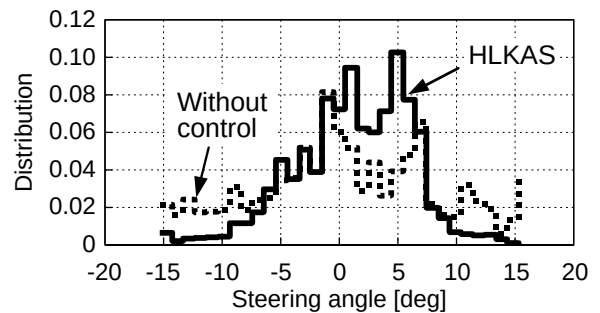


Fig. 9 Normalized steering angle distribution

by releasing the throttle. If this speed reduction is not sufficient, it further reduces the speed using the main brakes. In this way, the appropriate distance between the vehicles is maintained. At the same time, warning devices are used to alert the driver. Conversely, when the vehicle in front is traveling faster and the distance between the vehicles is becoming progressively greater, the system functions as a regular cruise control.

3.5 Honda Collision Velocity Reduction System (HCVR)

When the distance from the vehicle in front is progressively decreasing, this system urges the driver to exercise caution by way of a warning sound. If the driver fails to respond and proceeds to close in on the vehicle in front to the point where the distance between the vehicles is dangerously short, the system sounds a warning and begins braking. This encourages the driver to avoid the vehicle ahead by steering and applying the brakes. Furthermore, if the system judges that a collision is unavoidable, it reduces the collision velocity using the emergency brake which assists the driver's braking operation in order to reduce the severity of impact damage.

4. Technologies Applied to the Honda ASV-2 Experimental Vehicle 2

4.1. Outline

An analysis of traffic accident data revealed that poor visual identification of the vulnerable parties in traffic accidents is a significant factor in pedestrian accidents occurring at night and collisions with motorcycles at intersections.

In view of the above, the following three functions were incorporated into experimental vehicle 2:

- (1) Honda Night Vision System, a system which uses infrared cameras to detect pedestrians walking at night.
- (2) Active Headlight System, a system which synchronizes with steering angle, etc. to illuminate the path of the vehicle and thereby secure the driver's field of view during the night.
- (3) Inter-Vehicle Motorcycle-Automobile Communication System, a system to help enhance driver awareness through communication via systems installed in both motorcycles and automobiles.

4.2. System Configuration

Fig. 10 shows the installation location of the components of the system that performs the above three functions in experimental vehicle 2, and Fig. 11 is a block diagram of the system's control. The two infrared cameras installed inside the front grille detect pedestrians while the

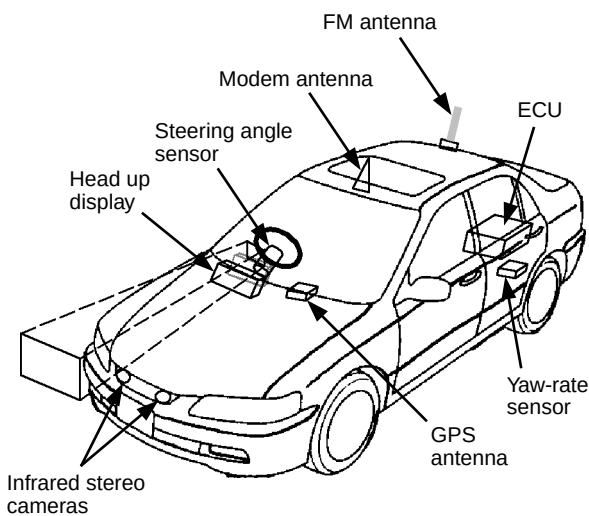


Fig.10 Configuration of ASV-2 experimental vehicle 2

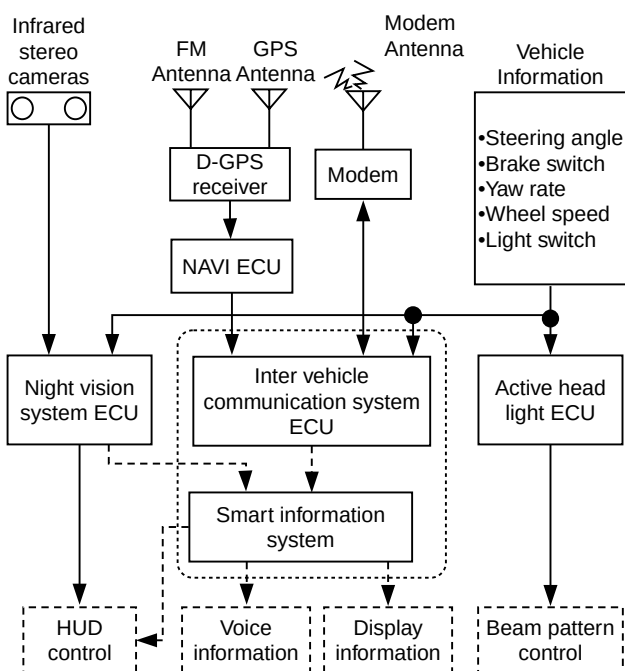


Fig.11 Block diagram of ASV-2 experimental vehicle 2

communication modem antenna on the roof enables communication with motorcycles in the vicinity of the vehicle. Depending on the conditions, warning sounds are emitted and images are shown on the head-up display (HUD) and navigation screen. The HUD has color image functions and is capable of displaying images during the day or night. The light distribution control of the Active Headlight System is coupled with the operation of the steering wheel.

4.3. Honda Night Vision System

This is a visual identification assistance system with the main objective of reducing accidents involving pedestrians walking at night. It helps the driver be aware of the presence of pedestrians using voice guidance and highlighted infrared images of pedestrians on the HUD. Fig. 12 shows the system's operating condition when the system supplies such information.

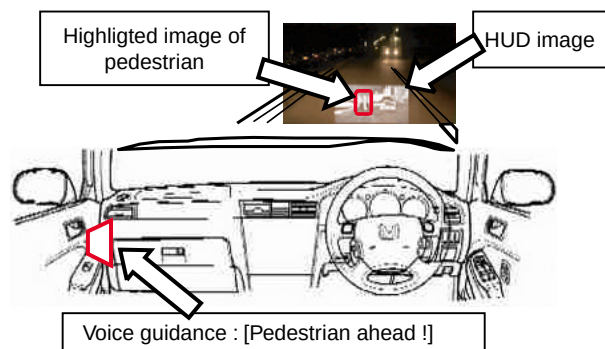


Fig.12 Example of HUD image and voice guidance

4.3.1. Pedestrians about which Information Should be Provided

As shown in Fig. 13, this system aims to inform drivers of pedestrians walking on roadways or attempting to cross streets at night at a distance whereby the vehicle will be able to stop in time.

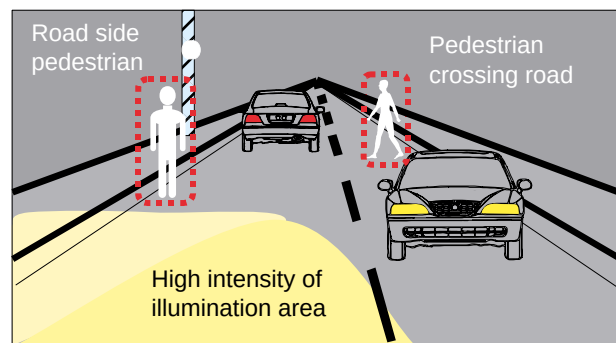


Fig.13 Example of detected pedestrians

4.3.2. Pedestrian Detection Method⁽⁹⁾

Pedestrians and other high-temperature objects are highlighted in white on the infrared camera image. However, shape differentiation with other high-temperature objects is difficult. Therefore, this system uses stereoscopic images and processing to calculate the distance to the objects. Then it identifies the objects and judges the possibility of collision

based on the speed by obtaining the relative moving vectors from the changes occurring over time. Fig. 14 shows the processing flow.

4.3.3. Pedestrian Presence Information Range

The area for which information is provided was set broader than the high intensity illumination area of the headlights as shown in Fig. 15, and the system operates to provide information at a vehicle speed of 40 km/h or higher. In addition, the lateral range was set at 12 degrees or less for entering objects, and the vehicle lane width for approaching objects. Information is provided 3.5 seconds before the estimated collision time as calculated from the steering evasion success rate and stopping distance with respect to the advance information provision time.⁽¹⁰⁾

4.3.4. Verification of Effects

This system incorporates voice guidance and highlighted frame displays of pedestrian areas as a means of compensating for poor visual identification of pedestrians.

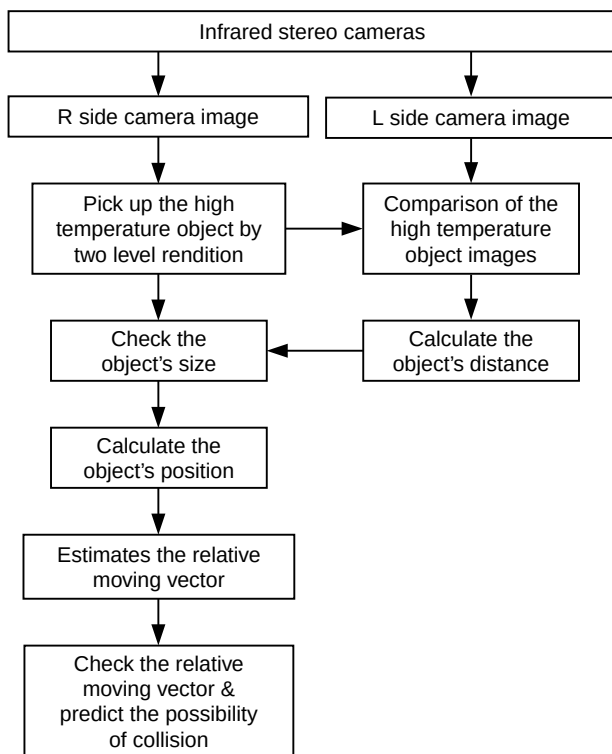


Fig.14 Pedestrian detection processing flow

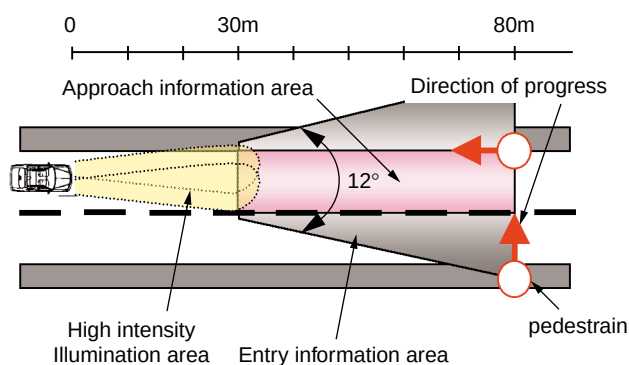


Fig.15 Pedestrian detection area

We compared the effectiveness of these functions with constant displays of images for verification purposes.

(1) Test method

As shown in Fig. 16, a number from 0 to 9 that changed at 1.5-second intervals was displayed on the screen in front. By having the test drivers read off these numbers, their ability to keep their eyes "on the road" was restricted to reproduce a state of visual attention resembling actual driving conditions. Images simulating driving were then shown on the HUD. When the test drivers identified a pedestrian crossing the road in the image, they were instructed to press a switch either on the left or right of the steering wheel, depending on the direction in which the pedestrian appeared, and their response time was measured. A total of 10 test drivers consisting of 8 males and 2 females ranging in age from their twenties to fifties was selected for the test.

The test patterns compared this system with a system which only displayed a constant image as shown in Table 1. Pedestrians crossed the road 10 times in the travel images shown over a 5-minute period.

(2) Test results

Fig. 17 shows the results obtained from measuring the average response time of the test drivers. When test drivers were placed in the near-driving state of visual attention in the forward direction, the system yielded a response time approximately 50% or less compared with the image displays alone. This proved that the system's voice guidance and highlighted displays are effective in improving the visual identification of pedestrians.



Fig.16 Measuring conditions

Table 1 Test pattern

	Image only	HONDA night vision
Voice guidance	×	○
Highlighted image of pedestrian	×	○
HUD Image	A	P

○ : Available A : All the time
 × : Not Available P : Pop-Up

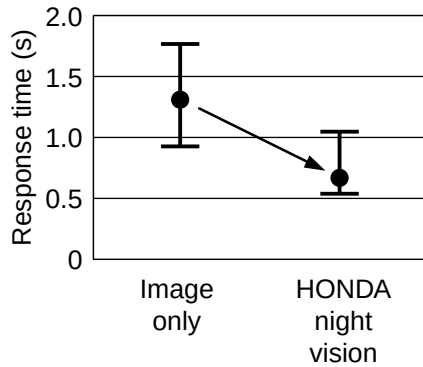


Fig.17 Comparison of response time

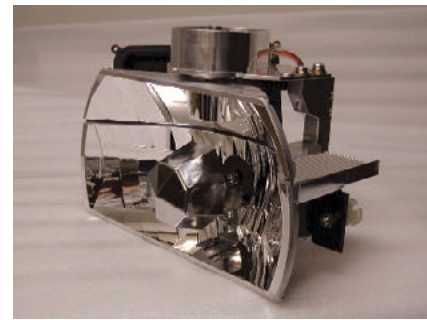
4.4. Active Headlight System

At intersections or curves, this system moves the upper reflectors of the headlights according to the steering angle and vehicle speed, and it produces light distribution appropriate to the roadway conditions. Fig. 18 shows a comparison of the light distribution with normal headlights. By enabling the driver to gain an accurate grasp of the roadway conditions and by having the effect of drawing the driver's visual attention into the curves, the system helps drivers to drive more safely and it enables pedestrians to be identified sooner.

Fig. 19 shows the internal configuration of the active headlights and their operating modes. The upper reflectors are rotated up to 40 degrees outward and up to 20 degrees inward by a stepping motor which is mounted at the rear. The ratio of the light distribution between the upper moving reflectors and lower fixed reflectors is approximately 4:6.

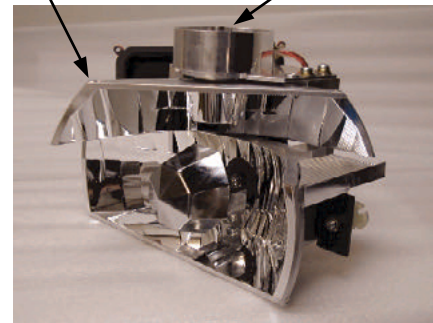
4.5. Inter-Vehicle Motorcycle-Automobile Communication System

This communication system, which is installed on both motorcycles and automobiles, exchanges information on, for example, the types, positions, speeds and directions of the respective vehicles, thus assisting the awareness of each of the drivers. In this way, it helps to reduce failures to spot the other vehicle and it decreases the number of errors in judging approach speed and relative distance. As shown in Fig. 20,



Straight driving condition

Upper reflector Stepping motor



Turning driving condition

Fig.19 Active head-light mechanism

it prevents intersection collisions and cross-traffic turn (right-turn in Japan and a left-turn in America) collisions which are the most typical accidents involving motorcycles and automobiles.

Fig. 21 shows an outline of the system. The vehicle's own position is determined by a navigation system using a high-accuracy GPS, and information such as the vehicle speed and turn signal operation is obtained from the vehicle. The modems installed on both vehicles then perform two-way communication based on this information. When the system judges that a collision is likely at an intersection, it displays the symbol, etc., of the other vehicle on the navigation or head-up display and alerts the driver by voice announcements and warning sounds. The details of this system are presented separately.⁽¹¹⁾

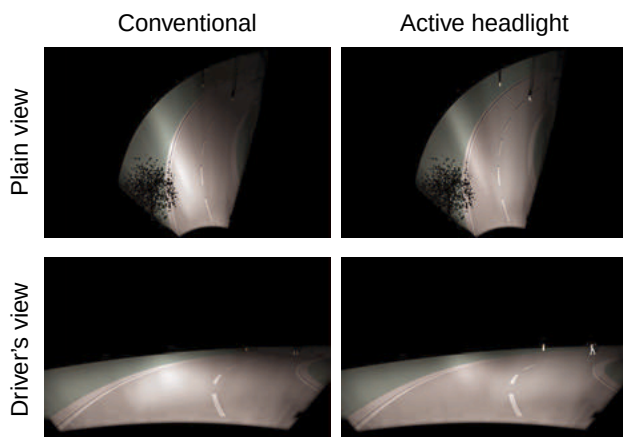


Fig.18 Comparison of vehicles with and without control

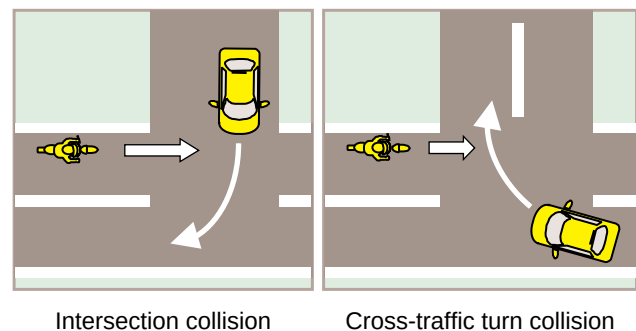


Fig.20 Typical traffic accidents between automobile and motorcycle

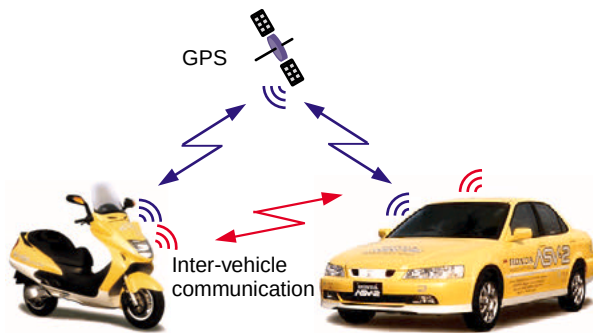


Fig.21 Inter-vehicle communication system

5. Conclusion

In response to the ASV-2 project, we have conducted research on advancing driving operation assistance and enhancing the identification of vulnerable parties in traffic accidents, and we fabricated experimental vehicles to validate the objectives of each of our research projects. As a result, we were able to validate the functions and performance of the various systems installed in the experimental vehicles. Moreover, we conducted validation tests and confirmed the effectiveness of these systems on reducing accidents.

Research is currently proceeding for some of these technologies with the aim of achieving actual application and use.

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