IMPROVEMENT OF VISIBILITY FOR VULNERABLE PARTIES IN TRAFFIC ACCIDENTS

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ABSTRACT

More than half of fatalities in traffic accidents in Japan are the vulnerable parties in such accidents (pedestrians, motorcycles, bicycles). In most of these accidents, the cause is collision involving automobiles. Therefore, reasoning that early detection of such vulnerable parties would lead to a reduction in accidents, we conducted research on the following three systems:

・ Honda Night Vision System

For night-time detection of pedestrians using infrared cameras.

・ Active Headlights

For assuring night-time field of vision by directing illumination in the direction of vehicle travel through lights coupled with steering wheel turn and so on.

・ Inter-Vehicle Motorcycle-Automobile Communication System (IVCS)

Notifies drivers of each other's presence by providing information through communications systems installed on both vehicles.

The results from research on these systems show that their use can be expected to have a positive effect in reducing the occurrence of accidents.

These systems have been installed on experimental vehicles under the Advanced Safety Vehicle Project Phase 2 (ASV-2). This project was proposed by the Ministry of Land, Infrastructure and Transport of Japan and is being participated in by thirteen domestic automobile manufacturers.[1] [2] [3]

1. INTRODUCTION

Honda has conducted research and development on hoods and bumpers with shock-absorbing construction for ASV Phase 1 vehicles as a measure to protect the vulnerable parties in traffic. Measures for when collisions occur with these unprotected vulnerable parties should of course be taken, but it seems even better from the perspective of the protection of those vulnerable parties to reduce the very occurrence of such collisions themselves. Consequently, we carried out research with the objective of earlier detection of vulnerable parties for the Phase 2 Honda ASV-2. Analysis of actual traffic accidents was taken as the point of departure in determining our research topics.

According to this analysis, the majority of accidents involving pedestrians take place when pedestrians are crossing streets at night. The causal factors in automobile drivers at those times include looking away to the side, absentmindedness, and other such failures to pay attention to safety.

In the case of motorcycle accidents, the majority occur as crossing collisions and collisions involving right-hand turns made in front of oncoming vehicles. The causal factors in automobile drivers at those times include misperception of the speed of the motorcycle, failure to pay attention to the motorcycle, and so on. Figure 1 presents data on accidents in Japan.

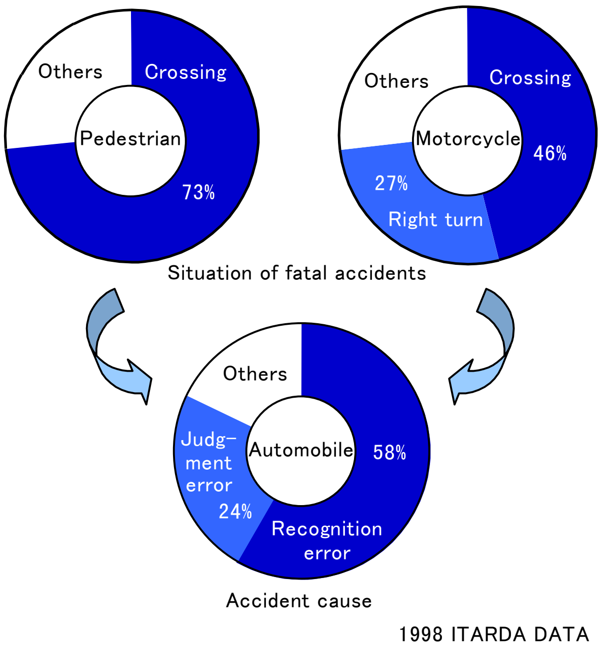

Fig. 1 Breakdown of accidents.

From the above, we determined that:

・ A system to notify the driver of the presence of pedestrians crossing the street at night would be an effective measure against accidents involving pedestrians.

・ A system to notify the drivers of motorcycles and automobiles of each other's presence would be an

effective measure against accidents involving motorcycles.
Our research and development was conducted accordingly.

2. TECHNOLOGY FOR IMPROVING VISIBILITY

2.1. Overview

The traffic accident data analysis results showed clearly that the low visibility of vulnerable parties is a factor both in night-time accidents involving pedestrians and in motorcycle collisions in intersections.
The Honda ASV-2 was consequently equipped with the following three functions:
(1) Honda Night Vision System
This system uses stereoscopic infrared cameras to detect pedestrians. When it appears possible that the vehicle may collide with a pedestrian, the system informs of the danger by voice guidance and display of a visual image on a head-up display (HUD).
(2) Active Headlight System
This headlight system allows easier and earlier detection of pedestrians in intersections or other areas and more accurate perception of road conditions by shining the headlights toward the curve or intersection toward which the car is moving.
(3) Inter-Vehicle Communication System
Motorcycles and automobiles equipped with communications systems exchange information with each other. In cases when collision in an intersection is possible, the system informs the driver using both voice guidance and visual symbols indicating the presence of the other vehicle. In an automobile, the visual information is shown on an HUD or navigation display. On a motorcycle, it is shown on a head-up indicator (HUI).

2.2. System Configuration

Figure 2 shows the configuration of the installed system, while Figure 3 shows a system control block diagram. Pedestrians are detected by the two infrared cameras installed inside the front grille. The light distribution control for the active headlight system is coupled with the operation of the steering wheel. The inter-vehicle communication system uses the communication modem antenna on the roof to communicate with motorcycles in the vicinity, and provides warning information using sounds and images. The images are displayed on the head-up display and the navigation screen. The HUD has color capability and is capable of displaying images both day and night.

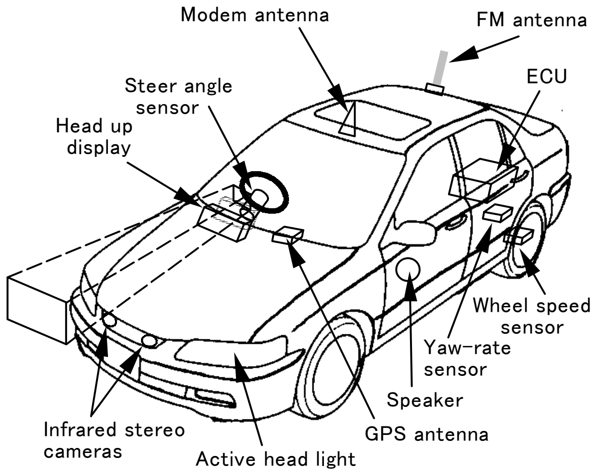

Fig. 2 Configuration of ASV-2 experimental vehicle.

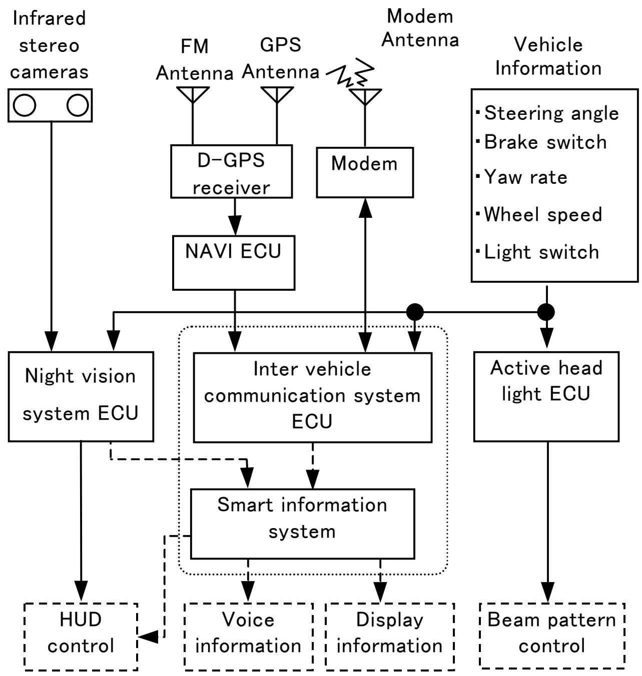

Fig. 3 Block diagram of ASV-2 experimental vehicle.

3. HONDA NIGHT VISION SYSTEM

This is a visual identification assistance system for night-time that automatically initiates voice guidance and images to prompt driver caution when the system detects the presence of any pedestrians in the vehicle's cruising lane or judges that intrusion into that lane by a pedestrian is possible. The system is also capable of highlighting pedestrians in the infrared image by displaying a red frame around them. Figure 4 shows an example of the information provided by this system in operation.

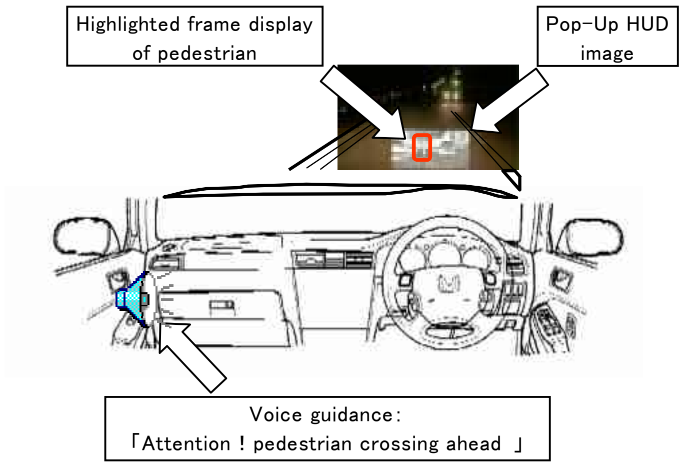

Fig. 4 Example of HUD image and voice guidance.

3.1. Pedestrian Detection Method

As shown in Figure 5, the system provides information about pedestrians on the roadway or pedestrians moving toward the street to cross it. The objective is to allow such objects to be easily evaded by ordinary braking after they have been detected. The images of pedestrians or other high-temperature objects captured by the infrared cameras are displayed in white, and it is difficult to distinguish pedestrians from other high-temperature objects by their shape. Therefore, this system uses stereoscopic image processing to calculate the distance, position, and size of high-temperature objects. The system next derives the relative moving vectors from the vehicle speed and changes occurring over time. Two areas, designated approach and entry areas, are established, and the system predicts the possibility of a collision by determining whether any objects have entered these areas. Figure 6 shows the processing flow. [4]

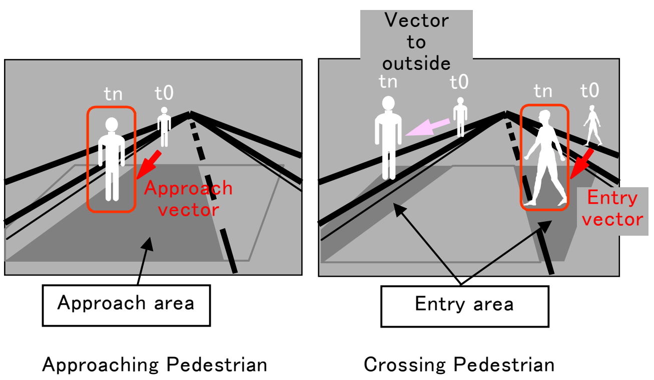

Fig. 5 Principle of pedestrian detection.

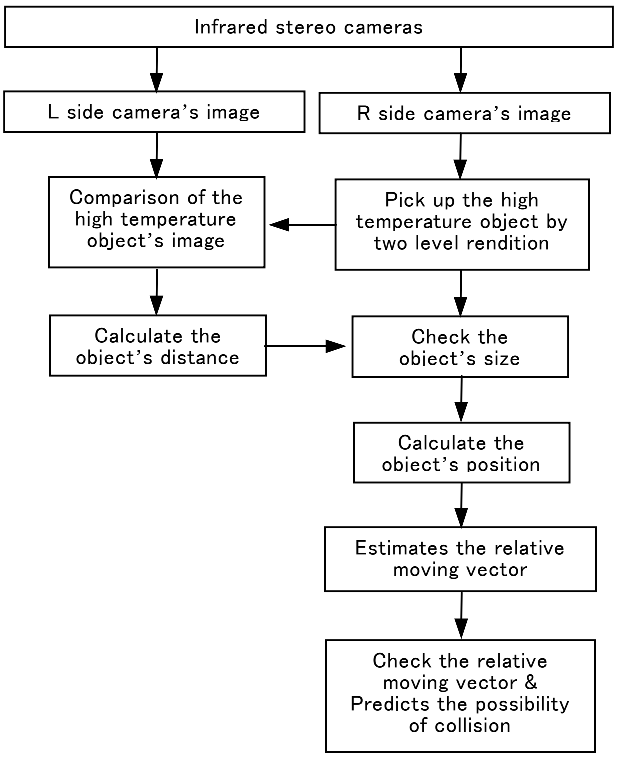

Fig. 6 Processing flow of pedestrian detection.

3.2. Area for Provision of Highlighted Pedestrian Information

As shown in Figure 7, the area for provision of information is set to extend past the high intensity illumination area of the headlights. Information provision will operate at vehicle speeds of 40 km/h or greater. As for the lateral area for detecting objects to the side, the entry area is defined within a line extending outward at an angle of 12 degrees. The approach area is the width of the vehicle lane. The timing for provision of information was set to be 3.5 seconds before the estimated time of collision, based on the vehicle stopping distance and the evasion success rates by the steering operation for times at which information is provided in advance.

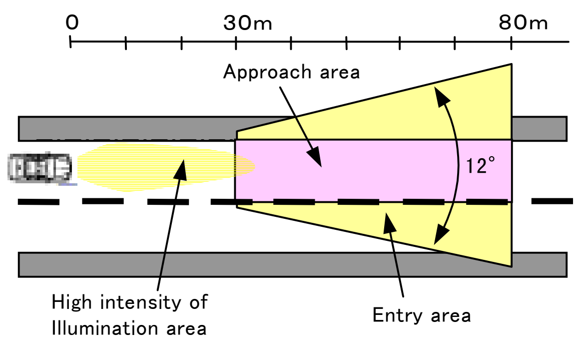

Fig. 7 Detection area of pedestrian.

3.3. Verification of Effects

This system is equipped with voice guidance, displays that are highlighted using red frames, and pop-up functions as methods for improving pedestrian recognizability. We verified the effectiveness of these functions by comparing them with a simple image display only.

3.3.1. Test Method

As shown in Figure 8, numbers from 0 to 9 are displayed on screens to the front and the side at 1.5-second intervals. The test subjects are caused to read off these numbers in order to restrict the direction of their gaze and so reproduce a state of visual attention that is close to actual driving conditions. In this state, they are shown images of driving scenes on the HUD. When the test subjects identify a pedestrian crossing the road in the image, they are expected to press a switch either on the left or right side of the steering wheel according to the side from which the pedestrian appeared. Their response time and the number of correct response are measured. The driving scene images are made to show pedestrians crossing the road ten times within a five-minute period. Eight men and two women were selected for a total of ten test subjects spanning age groups from their twenties to their fifties.

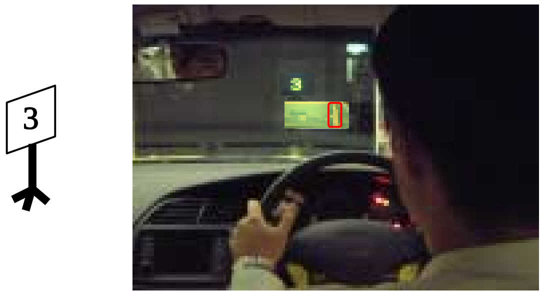

Fig. 8 Measuring conditions.

Table 1 shows the test items.

Table 1 Test pattern

Items \ Screen	Ahead				Left	
	1	2	3	4	5	6
Voice guidance	—	○	—	—	—	○
Highlighted flame	—	○	○	—	—	—
HUD Image	A	P	A	P	A	A

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

3.3.2. Test Results

The test results are shown in Figure 9. The mean response time when looking at the screen to the front was shorter by 50% or more with this system, compared to times with simple image display only. The distribution of measured values for the mean response time spreads upward because of the scores for some older test subjects. The number of correct response to recognize pedestrians when looking at the screen to the side was similarly improved about 15%. This confirms that the voice guidance, displays highlighted with red frames, and other system elements are effective in improving the visual identification of pedestrians.

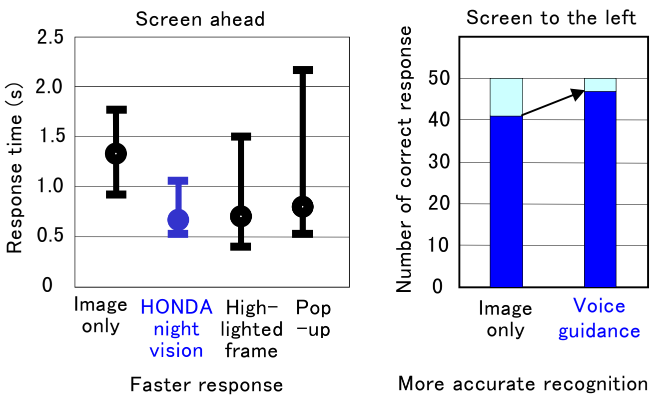

Fig. 9 Test results.

4. ACTIVE HEADLIGHT SYSTEM

As shown in Figure 10, for locations such as curves and intersections, the system moves the upper reflectors of the headlights in accordance with the angle to which the steering wheel is turned and the speed of the vehicle, and produces the distribution of light that is appropriate to road conditions. The system enables the driver to gain an accurate grasp of the road conditions and acts to draw the driver's visual attention into the direction of the curve. In this way, it can helps drivers to drive with greater stability and makes it possible to identify pedestrians earlier.

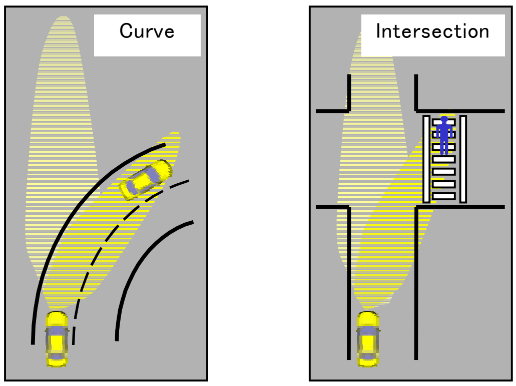

Fig. 10 Concept of Active Headlight System.

4.1. Mechanism and Operation

Figure 11 shows the internal mechanism and operating modes of the active headlights. The movable upper reflectors are turned in the horizontal plane by stepping motors installed behind the headlights. They can turn up to a maximum of 40 degrees toward the outside and 20 degrees toward the inside. Limiting the angle of turn toward the inside to 20 degrees makes it possible to cover the area between the illumination that is directed straight forward and the illumination that is directed toward the outside, which would otherwise be dark. The ratio of light distribution between the movable upper reflectors and the stationary lower reflectors is approximately 4:6. With this ratio, and with only the upper reflectors being moved, it is possible to limit the dazzle effect on oncoming vehicles. The illumination that is directed straight forward by the stationary lower reflectors assures a constant amount of light that is just as adequate as that from conventional headlights.

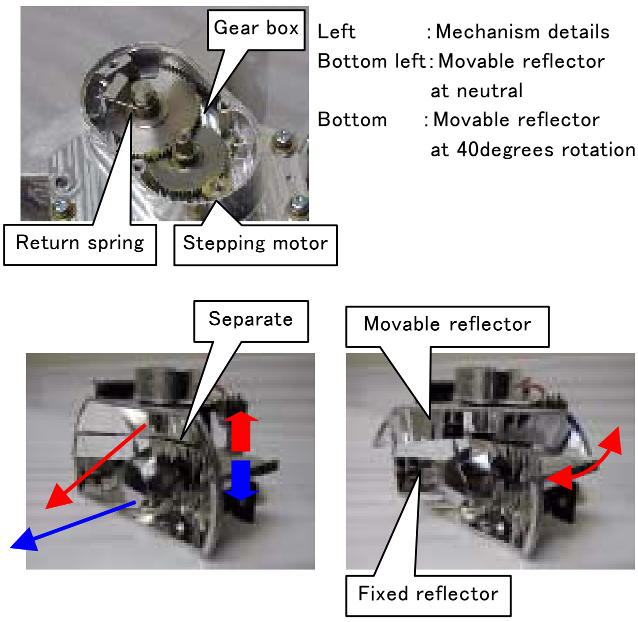

Fig. 11 Active headlight mechanism.

4.2. Setting Light Distribution Conditions

In setting the light distribution, we conducted sensory evaluation tests and road tests with actual vehicles on a variety of curves at different speeds. The results showed that the optimum configuration, regardless of vehicle speed, is to illuminate the position that the vehicle will reach in approximately two seconds. We took into consideration the distance and speed at which safe stopping is possible after discovery of an obstacle, as well as the amount of illumination and other factors, and determined the optimum angle of rotation for the reflectors coupled to the steering wheel angle.

We also improved visibility when changing lanes on ordinary roads and pedestrian detection time in intersections by providing for an additional 10-degree angle of control when the turn signal indicator switch is used. When driving in curves or other such locations, the response to minor adjustments of the steering wheel could cause shaking (chattering) of the headlight beams. Measures were taken to prevent this by building in hysteresis properties that establish a dead zone for steering wheel movements of 10 degrees or less. This has made smooth, stable cruising possible. Figure 12 shows a comparison of the road illumination intensity distribution of conventional headlights and active headlights when in operation.

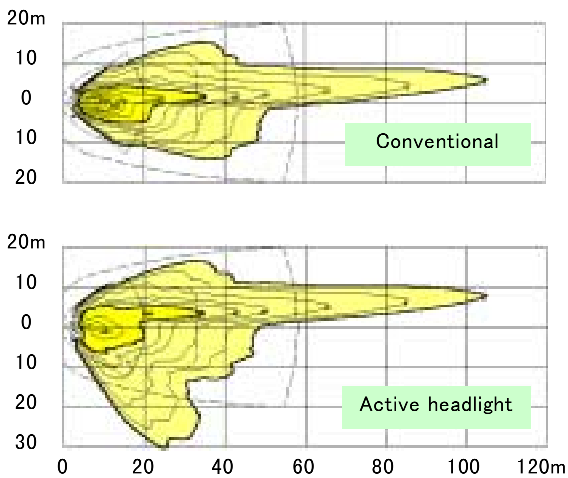

Fig. 12 Comparison of illumination intensity distribution.

4.3. Verification of Effects

Figure 13 shows the results of tests conducted with actual vehicles to verify the improved avoidance and ease in discovering obstacles that are conceivable results of the use of active headlights. [5]

The test was conducted by driving around in a circle 30 m in radius at a set speed of 40 km/h, with the driver making evasive steering movements upon detection of a pylon along this course. The time margin upon detection of the pylon (calculated from the distance to the pylon at the time of detection) and the amount of evasive steering movement made at that time were measured. The test was conducted under three different conditions: At night with active headlight control, without control, and during the day.

According to the results of this test, the mean detection time was approximately 1.3 seconds in advance without control and approximately 1.9 seconds in advance with control, meaning an additional 0.6-second margin was gained that brought the detection time up nearly to the 2-second level achieved in daylight. Measurement of the amount of evasive steering movement similarly showed that the steering angle with control was smaller than it was without control. This eliminated the kind of overshooting that was particularly conspicuous in the test without control, and it is apparent in the graph that the shape of the curve is much closer to the curve for steering in daylight.

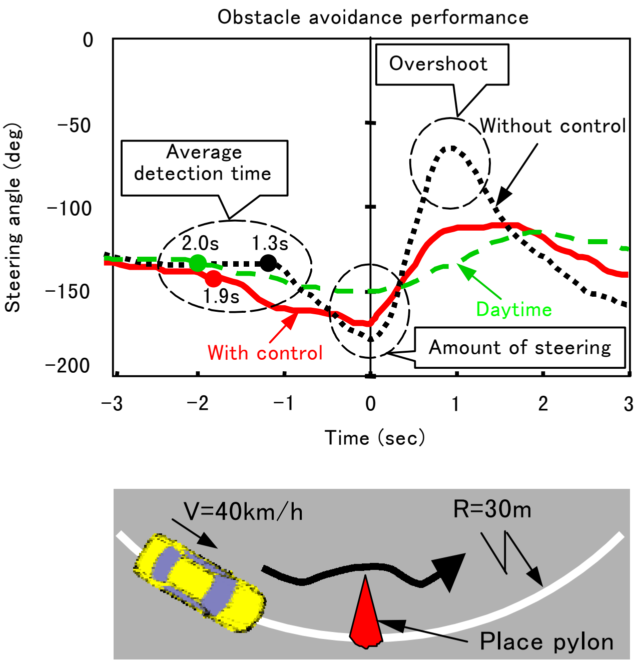

Fig. 13 Test results.

5. INTER-VEHICLE COMMUNICATION SYSTEM

This is a communication system installed on both motorcycles and automobiles to exchange information on the types, positions, speeds, and directions of the respective vehicles. When the system judges that a collision is likely inside an intersection, it displays the icon or other visual symbol of the other vehicle on the navigation or head-up display, and also informs the driver by voice guidance. In this way, the system helps to reduce failure to detect the other vehicle and reduces the number of errors of judgment regarding its distance and approach speed. This prevents crossing collisions and right-hand turn collisions, which are typical of accidents involving motorcycles and automobiles. Figure 14 shows the operating mode of this system when it is providing information.

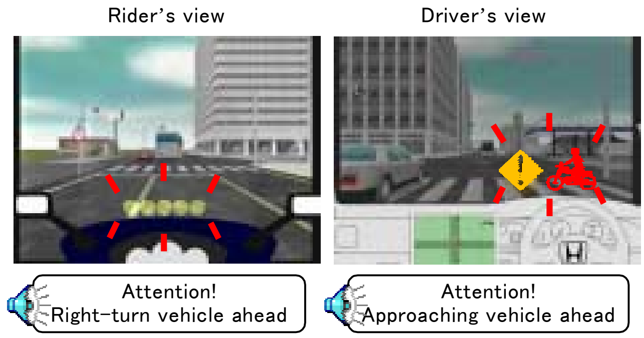

Fig. 14 Example of display and voice guidance.

5.1. System Features

As shown in Figure 15, the system is made up of the control ECU that controls vehicle information and communications, an inter-vehicle range-finder and communication unit, and a human-machine interface (HMI). Virtually identical systems are used in both the motorcycle and automobile.

The main items of information for inter-vehicle communications include the IDs (motorcycle and automobile type identification), present positions (latitude and longitude), vehicle speeds, estimated positions, position of the next intersection, time until the next intersection, the number of vehicles receiving the information, conditions (brakes, turn signals, etc.) in its own vehicle, and so on. All this data is sent and received by the vehicles concerned.

Motorcycles in particular require lightweight equipment, so this system provides motorcycles with intersection position information obtained through communications with automobiles rather than using a navigation system of its own to provide map data. The system determines whether the motorcycle is approaching the same intersection as the automobile based on the automobile vector and the vector of its own movement calculated from its position and direction.

The system automatically varies the data updating period to suit the speed of its own vehicle, proximity to the intersection, and other conditions. The system is configured as a self-supporting distributed network centered on intersections.

Major features of the system are the development of an automatic estimated positioning algorithm that uses a high-accuracy GPS (D-GPS) to determine the location of its own vehicle, and the use of a spread-spectrum inter-vehicle range-finder and communications modem that implements procedures to isolate counterpart vehicles (providing information) while also conducting inter-vehicle communications and range-finding to determine the distance between vehicles.

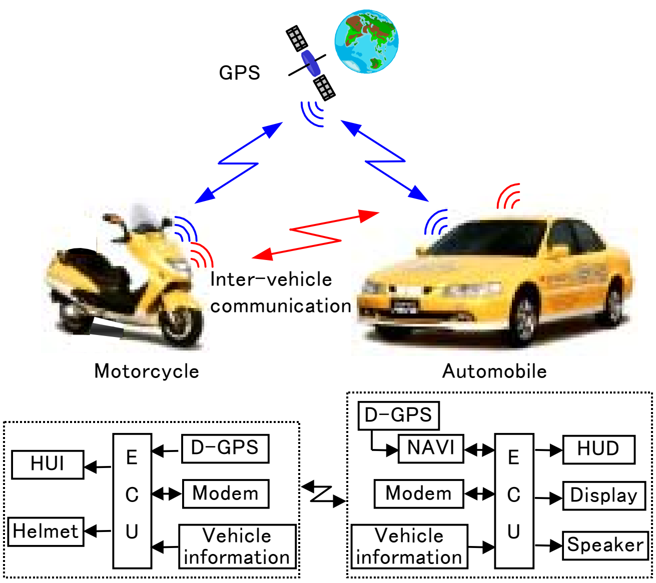

Fig. 15 Inter-vehicle communication system.

5.1.1. Vehicle Estimated Positioning Algorithm

Figure 16 presents an overview of the vehicle estimated positioning algorithm. When a vehicle transmits its own position to other vehicles after arithmetically processing data received from a GPS satellite, the process typically takes about one to two seconds. Consequently, the vehicle position at the time it is received by other vehicles is already one to two seconds old. Therefore an algorithm was developed to estimate the up-to-date position of the vehicle from the GPS position data, vehicle speed, acceleration, and yaw rate. As a result, the system can estimate its position in real-time while minimizing that discrepancy.

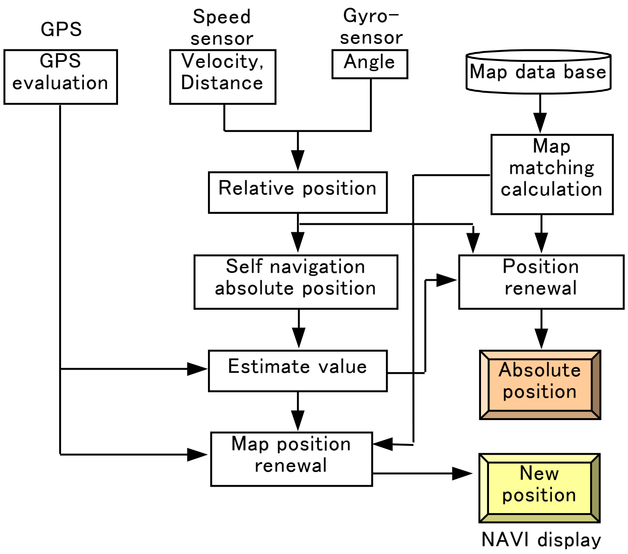

Fig. 16 Estimated positioning algorithm.

5.1.2. Example of Isolating Counterpart Vehicles and Providing Information

Figure 17 shows the flow of information provision. When the vehicle reaches a point 200 m before an intersection, it detects other motorcycles and automobiles in the vicinity of the intersection. Those other vehicles that may possibly intersect this vehicle's future path are isolated from the travel vectors of this and the other vehicles and shown on the navigation display. When this vehicle moves still closer to the intersection, the system projects the word "intersection" on the HUD. Then, a few seconds before reaching the intersection, the system displays the symbol shown in this figure and provides a voice guidance only if there are any vehicles that meet the path intersection conditions. These conditions are derived from the times at which other vehicles will reach the intersection and the times at which this vehicle and those other vehicles will approach each other.

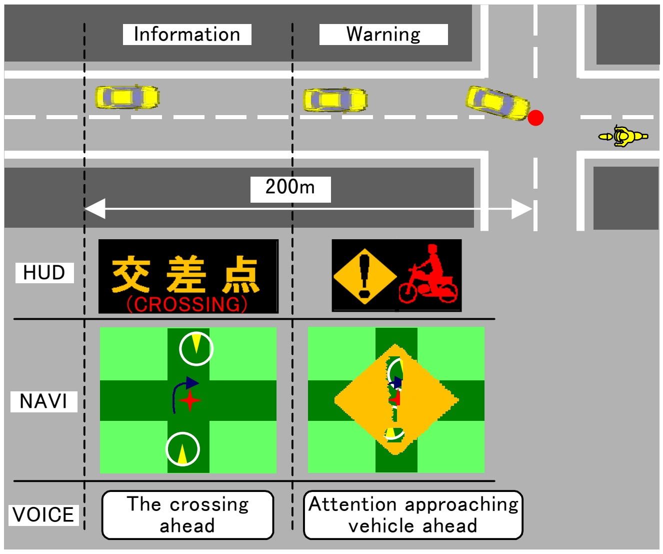

Fig. 17 Flow of information offer.

5.1.3. Inter-Vehicle Range-Finder and Communications Modem

The accuracy of radio waves from GPS satellites is often compromised by interruption of their broadcasting from overhead when they are received between high-rise buildings, under bridges and elevated roadways, and other such locations, as well as by multi-path effects and so on. The spread spectrum (SS) communications used by this system for inter-vehicle communications not only has excellent anti-noise performance, but is also known for its capability to measure the time taken for a signal to reach it and return. Therefore, the system is able to measure its distance from another vehicle while communicating information with that vehicle, thus making it possible to conduct high-precision inter-vehicle range-finding and communications without any need to add further new equipment. This SS inter-vehicle range-finder and communications modem was installed both on motorcycles and on automobiles, and carrier sense multiple access (CSMA) was used for communications control. [6]

6. CONCLUSION

Measures to be taken when collisions occur with unprotected vulnerable parties in traffic should of course be implemented. From the perspective of the protection of those vulnerable parties, however, it seems even better to reduce the very occurrence of such collisions themselves. Consequently, we carried out research to improve the visual recognizability of vulnerable parties as a means of ameliorating their involvement in accidents, and completed experimental vehicles (Honda ASV-2) equipped with these three systems. These vehicles were used to conduct proving tests of the impact of those systems, and their effectiveness in accident reduction was verified. Verification of the functions and basic performance of the systems installed on these vehicles was also accomplished. We are presently pressing forward with research directed toward the practical application of some of this technology.

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