Parking Assist System

● Kazuhiro Sakiyama ● Toshihiro Shimizu ● Kazuya Sako

Abstract

Traffic accidents have become a major social problem as their frequency has risen alongside the increased numbers of cars and drivers. In recent years the introduction of ITS (Intelligent Transport Systems) technology has been seen as a promising means to solve this problem. One type of ITS technology is " safe driving support systems ". The authors have engaged in product planning of an onboard system of this kind that makes use of " image sensors " - sensing technology that captures the situation around the vehicle - and are working to turn such a system into a commercial product. Specifically, a new type of system has been devised that employs onboard cameras to lighten the burden on the driver by providing easily-comprehended displays of pictures of the scene behind the vehicle plus other information necessary to aid driving. This is the " Parking Assist System ", which features numerous added-value functions enhancing convenience for the driver and thus goes beyond conventional products such as the " back eye camera ", which enhanced safety only.

This paper describes the new system's functions and configuration together with the specifications required of its major components, and further discusses its utility as determined by effectiveness validation tests of the system on board an actual vehicle.

1. Introduction

The recent increase in the number of traffic accidents that has resulted from an increase in the number of automobiles and drivers, is becoming a major problem. Intelligent Transport Systems (ITS) technology is attracting attention as a means of solving this problem.

We have applied ITS technology to safe-driving support systems. These safe-driving systems can be divided into the following three categories[1]:

- Advanced cruise-assist Highway System-information (AHS-i) systems, which support safe driving by providing information about driving environments and issuing hazard warnings
- AHS-control (AHS-c) systems, which control power output, braking, and other driving operations
- AHS-automatic (AHS-a) systems, which help automate driving

Focusing on the AHS-i system, we have been working on a plan to fabricate car-mounted AHS-i system products using image sensors. We have developed a prototype system that will be covered in this paper.

2. Purpose

2.1 Technological Trends in Imaging System Application

Most image sensors are based on charge-coupled devices (CCDs), which have long been in use in video cameras. Recently, extensive efforts have been made to develop very small, low-power-consumption Complementary Metal-Oxide Semiconductor (CMOS) devices for installation in mobile equipment. Most of these devices that are currently available are installed in domestic electric appliances. However, but their picture quality is still lower compared with that of CCDs.

Table 1 Performance comparison between CCD and CMOS image sensors

		CCD	CMOS
System	Power consumption	Good (300 mW)	Very good (30 mW)
	Supply voltage	Poor (3 sources)	Very good (single source)
	On-chip system	Poor	Very good
	Cost	Good	Good
Characteristics	Sensitivity	Very good	Good
	Smear	Good (-90 dB)	Very good (-140 dB)
	S/N	Very good	Good
	Dynamic range	Good	Good

Car-mounted rear-view cameras, which were based on CCDs and intended to help the driver see the rear view when driving backing a vehicle, were first installed around 1970 on large buses and trucks. Their use quickly spread because they were found to be useful on home delivery service vehicles, which often have to use narrow roads. Thereafter, rear-view cameras began to be installed on camping cars, and RVs (minivans and vans).

Currently, a variety of image sensor systems are being developed not only for rear-view cameras, but also for ITS products aimed at AHS.

2.2 Our Efforts

We initially began studying developing an image-sensor-equipped product as a part of warning and visual assistance systems capable of issuing warnings and providing visual information. This study was part of our efforts to lead the industry in offering information-providing system products that will support safe driving. This product should provide not only rear-view camera-related, or other visual-assistance-related functions, but should also provide car-mounted functions that can display information needed to assist in driving and, as a consequence, be able to offer additional value added.

Table 2 Driving support systems from automobile manufacturers

Manufacturer	Company A	Company B	Fujitsu TEN
Name	Back View Monitor	Back Guide Monitor	Parking Assist System
Release	November 1999	January 2000	—
Display function	Vehicle width lines and distance lines • Link to rear and corner sensors	• Vehicle width lines and distance lines • Projected path lines • Steering angle (for parallel parking)	• Vehicle width lines and distance lines • Projected path lines • Steering angle (for parallel parking) • Link to rear and corner sensors
Performance comparison			
Image	Monochrome	Monochrome	Color
Visibility at night	Poor	Poor	Good

Automobile manufacturers offer products similar to those indicated in Table 2, as options. Since we began our development activities, we have focused on offering a system that can provide information that is understandable to anyone and that can be used with ease, so that even novices and unskilled drivers can take advantage of the information that the system provides. To this end, we have designed equipment and functions with emphasis on safety features and ease of handling. Such equipment includes color cameras that provide good visibility for ease of detection of objects at night, and whose displays can be readily understood at a glance. Recently, we have also added the concept of Universal

Design (*1) to our product designs so as to offer more easy-to-handle car-mounted systems that can be used by a wide variety of drivers, including physically disabled people.

*1 Universal Design: Design of products and environmental elements that can be of use to anyone without any modification or special additional design. Universal Design is based on the idea that products, as marketed, should be barrier-free to all.[2)]

3. Overview of the Parking Assist System

3.1 Functions

The Parking Assist System assists the driver in steering and checking the rear to ensure that the area is clear when backing the vehicle.

When a driver puts a vehicle in reverse so as to enter a parking space, the Parking Assist System displays the two types of information given below:

- An image taken by an image sensor (affixed to the rear roof of the vehicle), that includes views that cannot be seen by the driver simply by turning around and looking toward the rear
- Superposed vehicle travel direction information, which varies with the steering angle. The driver backs the vehicle while steering it so that the curve indicating the direction of the vehicle (projected path lines) matches the path to the parking space. This allows anyone to park in a parking lot easily and safely.

Fig.1 shows a sample display. The rear end (1) of the vehicle is seen at the bottom of the display. The translucent area (2), around the center of the display is between the projected path lines which indicate what path the vehicle will take (within 3.5 meters from the rear end of the vehicle) and the width of the vehicle. The two straight lines in magenta (3) are the lines drawn by extending the left and right sides of the vehicle in the backward direction. When these lines are parallel with the white lines defining the parking space, the vehicle is parallel with the sides of the parking space. The red line (4) indicates the distance from the vehicle rear end. The driver can use this line as a guide for stopping the vehicle. In addition to the above information, text is displayed at the left bottom to ask the driver to watch the surroundings.

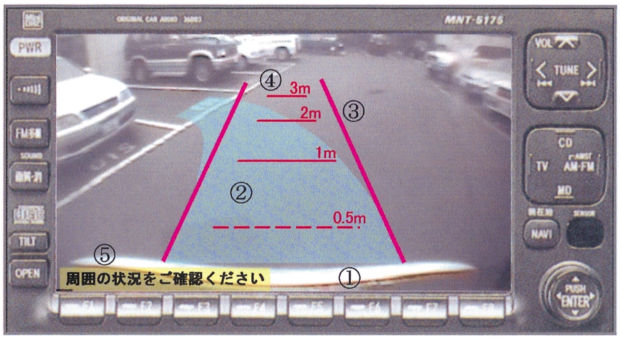

Fig.1 Sample display: Ordinary parking

For parallel parking, a blue blinking parallel parking line (6) is displayed to indicate where to change the steering direction, in addition to the information about the direction of vehicle travel. The parallel parking line display works together with a hazard switch.

The driver stops the vehicle so that it is by the side of, and parallel with a vehicle that is parked in the parking space just in front of the parking space the driver want to park in. The driver then completely turns the steering wheel and then backs the vehicle. When the parallel parking line overlaps the edge of the road or white line indicating the shoulder, the driver fully turns the steering wheel in the opposite direction and moves the vehicle until the vehicle becomes parallel with the line indicating shoulder. In this manner, anyone can park in parallel with ease by observing the displayed simple, easy-to-read information.

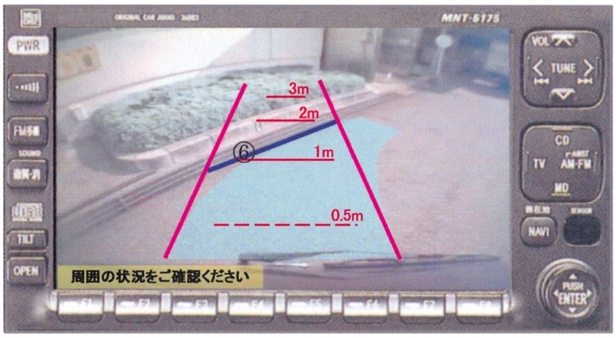

Fig.2 Sample display: Parallel parking

3.2 System Configuration

The Parking Assist System consists of three main types of units as follows:

1) Image sensors

Image sensors are installed on the vehicle roof end or rear spoiler to take pictures, including those of scenes that cannot be seen by the driver simply by turning around and looking toward the rear.

2) Steering sensor

The steering sensor senses the turning of the steering wheel shaft in order to detect the steering angle of the vehicle on a real-time basis by counting the number of turns the steering wheel shaft has made.

3) Built-in AV unit (drawing and display unit)

The AV unit receives the steering angle signal from the steering sensor and vehicle signals from the speed sensor and back sonar, and then judges the vehicle status from the received signals. The AV unit then displays drawing data regarding the direction in which the vehicle is currently travelling, together with the image taken by the image sensor, to depict the scene viewed from the vehicle rear. This drawing data is superposed on the image.

Fig.3 shows the Parking Assist System installed on a vehicle.

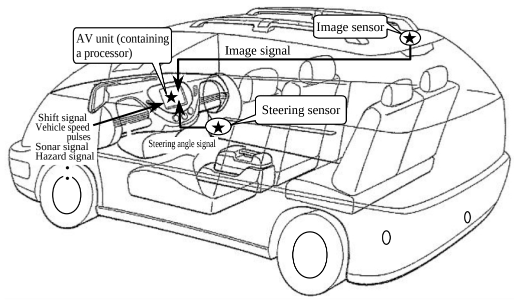

Fig.3 Parking Assist System installed on a vehicle

3.3 Image Sensor

Table 3 gives the specification for the image sensor used in our prototype.

The image from the image sensor is a rear-view mirror image that is carried on an NTSC signal, and that mimics what the driver would normally see when viewing a typical rear-view mirror in a vehicle.

A CCD is used because of the advantages it offers in terms of high picture quality. However, since conventional CCD cameras cannot obtain good images when the light intensity is insufficient (for example, during nighttime use), we have adopted a specially designed CCD that features a number of benefits, including enhanced white balance adjustment and an improved optical filter. The new CCD can take images similar to those images visible to the naked eye at night. Night visibility has thus been highly improved.

Table 3 Image sensor specification (for the prototype)

Pickup device	250,000-pixel (available) color CCD with a horizontal resolution of 300 TV scanning lines (at center)
Lens	Focal distance f = 1.8 mm F value 1:2.8 Angle of view: 86 degrees (vertical) 114 degrees (horizontal)
Circuit specification	Minimum object illumination: 5 lx or more (at F2.8) White balance: Fixed Sensitivity adjustment: Automatic Electronic shutter: 1/60 to 1/100,000 Automatically variable
Power requirements	10.5 to 16.0 V
Dimensions	44 mm wide x 27 mm high x 35 mm deep Net weight 90 grams

3. 4 Steering Sensor

Fig.4 shows how the steering sensor works. The brush moves as the steering shaft rotates. Accordingly, the resistances between terminals 1, 2, and 3 vary. The angle of steering shaft rotation is sensed as a voltage, which is then converted to a digital value. This digital value is subjected to various adjustments and compensations to obtain the angle data.

Table 4 gives the specification for the steering sensor used in our prototype.

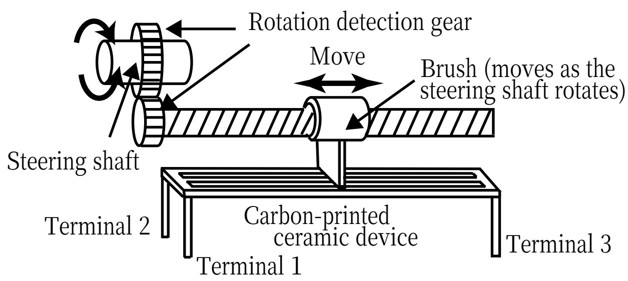

Fig.4 Principle of steering sensor

Table 4 Steering sensor specification (for our prototype)

Output signal	Analog signal (0 VDC to supply voltage) Accuracy: 0.1 V for a steering angle of 30 degrees
Mechanism	Combination of feed screw and slide resistor Conversion ratio (distance corresponding to steering angle): 0.42 mm for 30 degrees
Gear ratio	2.5
Steering range	Up to two turns in each of clockwise and counterclockwise directions
Sensitivity	A shaft rotation of at least 15 degrees can be sensed.
Power requirement	10.5 to 16.0 V
Dimensions	28 mm diameter x 55 mm long (main sensor unit) Weight 400 grams

3.5 Display

Since the display is designed to follow the concept of Universal Design, it has been designed to be simple and easily to understand for any driver.

The area between the projected path lines is a translucent grid so that the driver can clearly see the rear view. Because of linkage with the vehicle speed and the back sonar, the color of this area changes to orange when the vehicle begins to move, and to red when the back sonar senses something and becomes active. Also, the boundary of the colored area is 2 meters from the rear end of the vehicle when the vehicle begins to move and 0.5 meter when the back sonar reacts to an obstacle. In this way, the display provides a varieity of functions to warn the driver about possible hazards. Fig.5 and 6 show the displays the driver will see under the above two conditions.

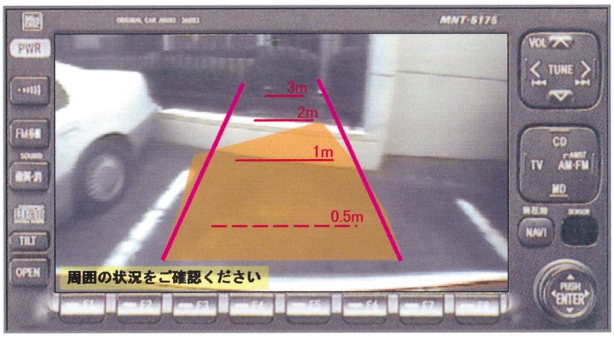

Fig.5 Display seen when the vehicle begins to move

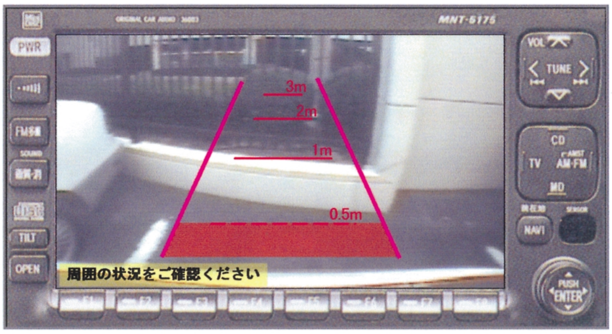

Fig.6 Display seen when the back sonar reacts with something

For enhanced safety, the area between the projected path lines is widened by about 20% of the actual vehicle width on either side -- about the width of one wheel tire -- in order to reduce the risk of running into obstacles.

As described above, the display is designed to offer in an effective manner useful information to the driver when the driver is parking. This information will help the driver perform a variety of parking operations, including those involving parallel parking.

4. Effects of the System

4.1 Experiment for Evaluating the Effects of the System

To verify the functions and performance of the system, we chose subjects from within the company (eight office work employees who had not driven a system-equipped vehicle), and asked them to drive an experimental vehicle for the purpose of evaluation tests).

The evaluation conducted at this time was divided into two categories: objective evaluation and subjective assessment. The objective evaluation included comparisons made concerning the amount of time required to park a vehicle, and observation of the condition of the tested vehicle. The subjective assessment was based on the NASA-TLX subscales in order to analyze the effects of the system on driver load reduction in terms of a number of factors, including understandability and ease of use. For reference, the NASA-TLS assessment subscales[3] are shown in Table 5 and the questionnaire and check sheets are shown in Fig.7.

Table 5 NASA-TLX assessment subscales

Subscale	Score	Explanation
Mental Workload (MD)	Low/High	What degree of mental and intellectual activity was required? (These activities include thinking, decision-making, calculating, remembering, and observing.)
Physical demands (PD)	Low/High	What degree of physical activity was demanded? (The activities include pushing, pulling, turning, and acting.)
Temporal demands (TD)	Low/High	What degree of temporary pressure did you feel in terms of the tasks, the frequency of the tasks, and the speed required to fulfill the tasks?
Performance (OP)	Low/High	What degree of performance did you feel you achieved when you attempted to fulfill the target set by the experimenter or by yourself?
Effort (EF)	Low/High	How much effort did you have to exert to achieve the target performance level?
Frustration (FR)	Low/High	To what degree were you pleased, satisfied, relaxed, and relieved during the tasks?

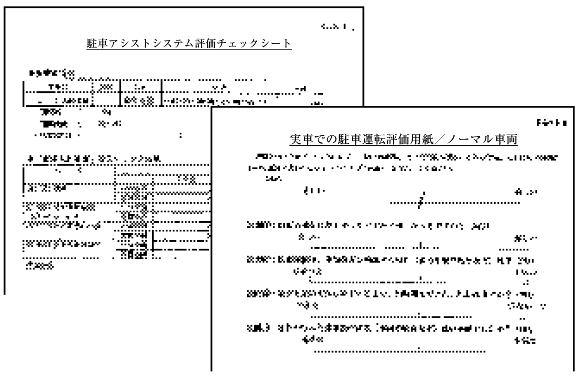
駐車アシストシステム評価チェックシート
実車での駐車運転評価用紙／ノーマル車両

Fig.7 Questionnaire and check sheet

When selecting the subjects, we were careful to avoid bias on gender, age, and driving experience in order to evaluate the target system performance represented by "what would be understandable to anyone and what would be able to offer useful information." The selected subjects were asked to drive actual vehicles into a garage and park the vehicles in parallel with other vehicles. Their driving performance was then evaluated.

4.2 Evaluation Results

Fig.8 and 9 show the results of comparing the amount of time required to park a normal vehicle, and the amount of time required to park a vehicle equipped with the Parking Assist System (ordinary parking in Fig.8 and parallel parking in Fig.9).

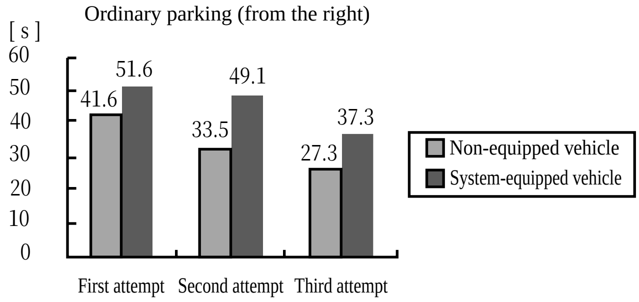

Fig.8 Comparison of time required for ordinary parking

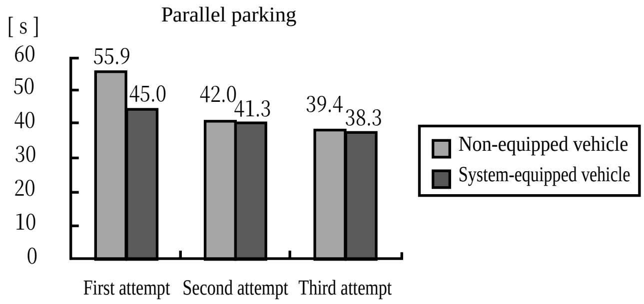

Fig.9 Comparison of the time needed for parallel parking

The above results indicate that the system is somewhat advantageous for parallel parking, which people are not so much used to (do not often perform). In contrast, for parallel parking, the normal vehicle required a lesser amount of time as compared with the amount of time required using the assisted vehicle. Fig.10 shows the results of the subjective assessment using the NASA-TLX subscales.

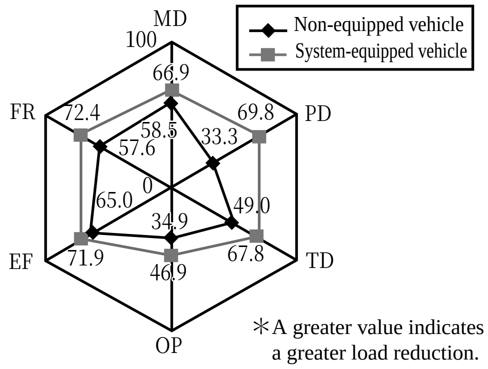

Fig.10 Subjective assessment results

For each type of vehicle, the difference in the AWWL (average weakened workloads) values calculated from the results of NASA-TLX assessment is as follows:

◯ AWWL: 14 points

Non-equipped vehicle: 55.4

System-equipped vehicle: 69.4

The system installed on the vehicle showed a reduction in the loads placed on the driver. The Physical Demands (PD) reduction stood out in particular. This is, because, for example, the driver did not have to twist in the driver's seat a get a look at the rear of the vehicle. Although the objective evaluation results indicate that the time required to park the system-equipped vehicle was longer as remarked above, the Temporary Demands (TD) were relatively low. This suggests that the driver was mentally relieved because it was possible to check for obstacles in the rear without difficulty. Some subjects' comments that follow support this reasoning:

- My neck wasn't stiff because I didn't have to look back.
- I had a good view of the rear.

All the subjects remarked that the system was easy to handle and that the display easy to read. Their comments include the following:

- The system is good because it is easy to operate.
- I was able to see how wide the vehicle was and when to turn the steering wheel.

The system proved to meet the target we had initially set.

4.3 Research on the Usefulness of the System

In addition to the above evaluation and assessment, we asked 117 people to drive a vehicle equipped with the Parking Assist System and answer questions about the usefulness of the system and the readability of the display. Fig.9 and 10 show the results obtained.

The above results indicate that the system with its functions and performance was proved to be useful to a wide range of drivers, including novices and aged people.

5. Afterword

This paper has introduced a safe driving support system based on image sensors. We believe that

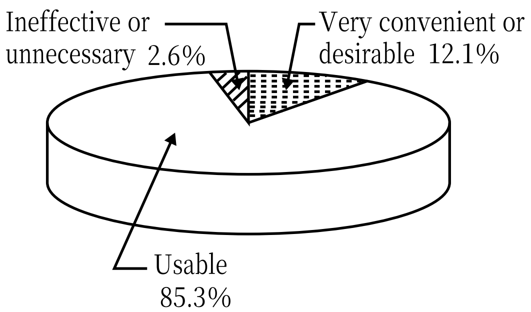

Fig.11 Questionnaire result 1: Usefulness of the system

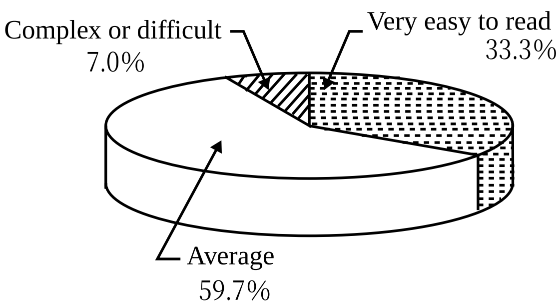

Fig.12 Questionnaire result 2: Readability of the display

specifications and designs based on the concept of Universal Design will be indispensable for not only systems intended to provide the new functions discussed in this paper, but also existing car-mounted equipment.

For systems related to safe driving, including the system discussed in this paper, efforts for putting the system into practical use should be made along with processes for gaining the acceptance and consensus of society in general. We plan to make the system more advanced while engaging in exchanges of relevant information with people from the automobile industry.

In the future, we shall endeavor to develop sensing systems that will satisfy requirements for enhanced safety and accuracy and that will eventually lead to AHS and other automatic driving systems. We shall also make efforts to develop products for car-mounted systems, equipped with an interface that will allow a broad range of driver to understand the functions of the system without difficulty, and ensure a high degree of safety and comfort through the performance of simple operations.

Bibliography

1) Highway Industry Development Organization: ITS Handbook (November 1999)
2) Satoshi Furuse: What is Universal Design (December 1998)
3) The Faculty of Human Sciences, Osaka University: Web pages about human behavioral sciences (September 1999)

Authors

Kazuhiro Sakiyama

Employed by Fujitsu TEN since 1991
Engaged in developing digital signal processing systems.
Engaged in developing ITS-related systems
Currently in the ITS Planning Department

Toshihiro Shimizu

Employed by Fujitsu TEN since 1997
Engaged in planning ITS-related systems.
Currently in the ITS Planning Department

Kazuya Sako

Employed by Fujitsu TEN since 1978
Engaged in developing car audio, sound field control, noise reduction, voice processing, and other DSP applied technologies.
Currently manager of the ITS Planning Department