NOTE

New Multi Angle Vision™ System

Tadashi KIDENA
Kazumasa KAMEDA
Minoru FUJIOKA
Koei KIYO
Fumitaka FUSHIMI

1 Introduction

Recently, various systems for helping drivers drive more safely and comfortably have been adopted for cars. The technologies especially for systems using cameras to support the drivers' field of view (FOV) have been advanced. Systems that use two or more cameras, rather than one camera for providing a rearward view, have been commercialized one after another to support the FOV for a wider range.

In 2010, FUJITSU TEN developed and commercialized the world's first FOV support system, Multi Angle Vision™, which uses "the 3-D virtual projection view point conversion technology." We herein introduce new element technologies that we have developed this time for further improvement of the drivers' FOV.

2 Background of the Development

2.1 Market Trend of Vehicle-mounted Camera Systems

Back monitors for supporting FOV have been the mainstream trend in the vehicle-mounted camera system market, and the market has grown mainly in Japan. However, "Cameron Gulbransen Kids Transportation Safety Act (KT Safety Act)," which mandates rear-view cameras on motor vehicles, will take effect in North America in 2013. Therefore, the market is also growing there. At the same time, the systems with enhanced FOV support functions have been introduced to reduce the drivers' burden (surrounding monitoring systems) in the Japanese market.

We launched the development of a new system for the purpose of adding functions, such as a guiding line function and an image enlarging function, to the Multi Angle Vision™, which has already been mass produced, to improve the convenience for users, and of reducing time required to adjust the optical axes of the cameras in vehicle production lines for better productivity.

3 Details of System

3.1 System Outline

Fig. 1 shows the configuration of the system.

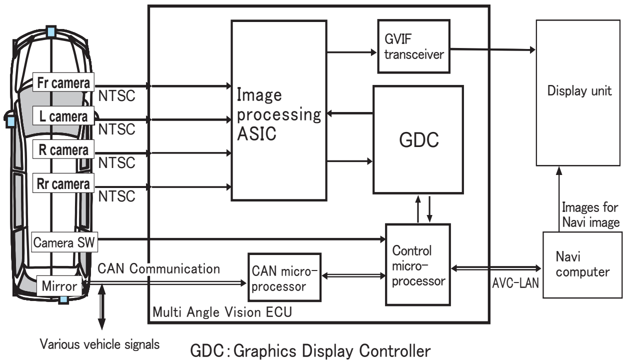


Fig.1 System Configuration

Images captured by four vehicle-mounted cameras on the vehicle are transmitted to the ECU via the NTSC signal and are processed by the image processing ASIC that was developed this time. The processed images are further processed by the GDC (Graphics Display Controller) and then are output via the GVIF to be displayed on the display unit. Moreover, signals for necessary vehicle information, such as the shift position, are received by the ECU via CAN communication.

3.2 Additional Functions for Screen

3.2.1 Guiding Line Indication

In addition to Multi Angle Vision™, which realized the FOV support of 360-degree surrounding of the vehicle, the function of indicating guiding line for assisting drivers to park cars is equipped this time.

Fig. 2 shows the indicated guiding lines for moving forwards and moving backwards.

The equipped guiding line indication function indicates: "expected course line (①)" which is a popular function of showing the line on the screen in the back up camera mode; "outside corner course line (②)" which shows an expected course of the vehicle outside corner difficult for the driver to check although it is the front area of the vehicle; and "inner wheel course line (③)" which shows a course of the inner wheel of the vehicle moving forwards.

With those lines indicated on the screen, the driver can park the vehicle more easily and more safely, in various parking scenes, such as parking into a garage, parallel parking, and front-end parking, by trying to place those lines in the parking space on the screen.

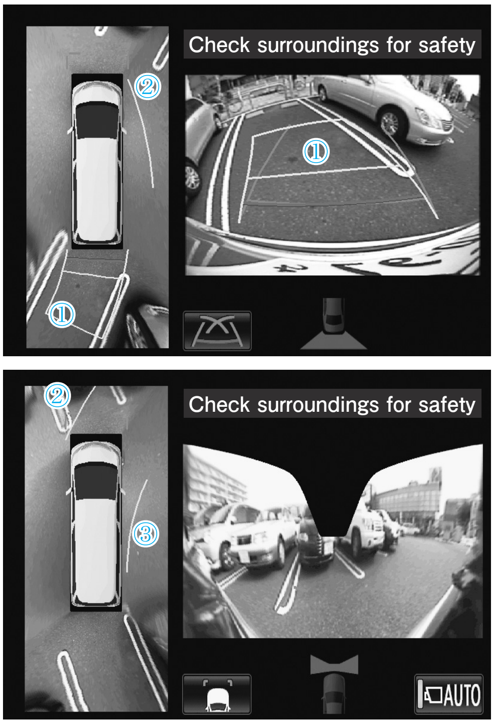


Fig.2 Screens Showing Guiding Lines for Parking

3.2.2 Enlarged Image Display

In order to improve visibility at the time of parking or driving the vehicle out of a parking space, we added the function of enlarging the overhead view image on the screen. **Fig. 3** shows the display of enlarged images.

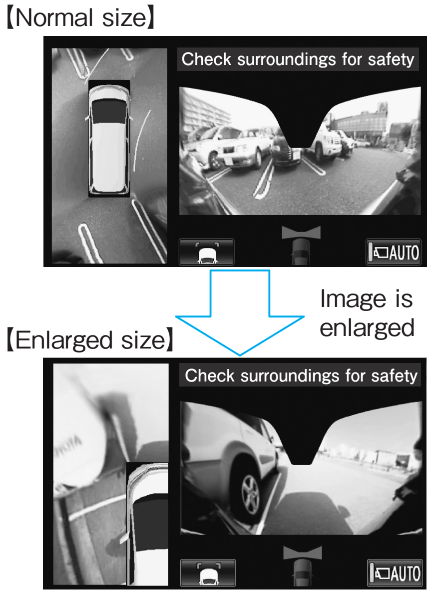


Fig.3 Display of Enlarged Image

The issue to be solved in the development of displaying enlarged images was how to show three-dimensional (3-D) protruding objects, such as a bumper of a vehicle parked in the vicinity of the vehicle on which the system is mounted (host vehicle), in the enlarged image. In the case of the conventional method of showing an overhead view as shown in **Fig. 4**, the image captured by the camera is projected on a plane assumed as the road surface. Therefore, the 3-D objects, such as a bumper, seem to be located farther than their actual positions. In the enlarged image, an area closer to the host vehicle is enlarged and displayed so that there was a possibility that the host vehicle unintentionally came too close to the object.

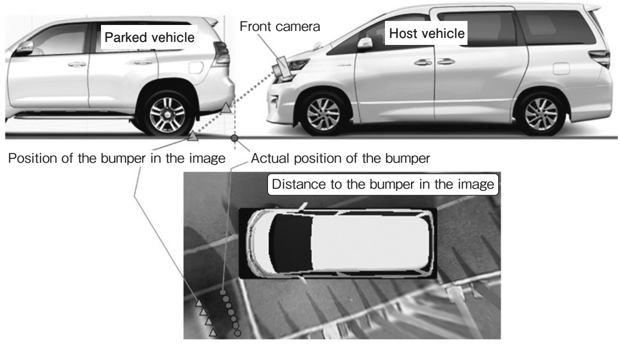


Fig.4 Projected Position of 3-D Object (Bumper)

To solve the problem, we improved the 3-D model used for the projection of the captured images, from the "bowl-shaped" model used for Multi Angle Vision™ to the "upside-down bowl-shaped" model, as shown in **Fig. 5**, for this system to compress the image of the area very close to the host vehicle projected on the new 3-D model when the model is looked down straightly. As a result, this system is capable of displaying those 3-D objects at substantially the same positions as their actual positions, in the overhead image.

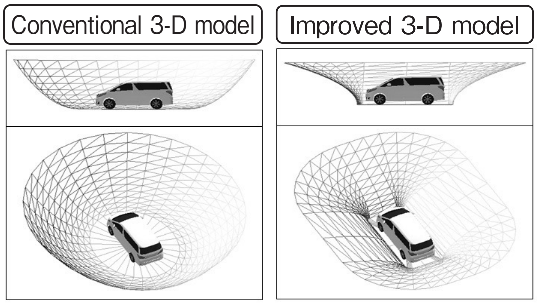


Fig.5 Improvement of 3-D model

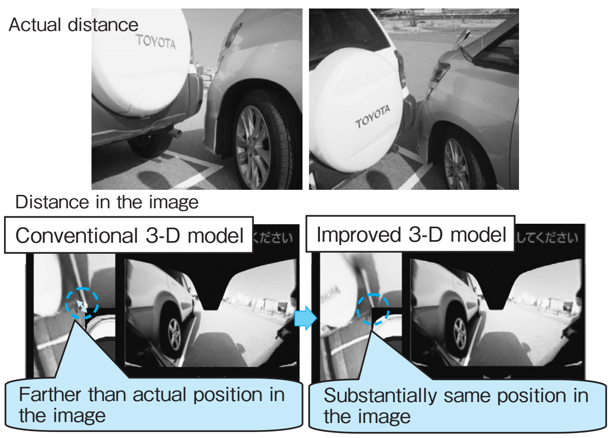


Fig.6 Examples of Displayed Image

Thus, providing images that show the appropriate distances to objects, as shown in **Fig. 6**, the system allows the driver to keep safe distances to them and improves visibility by the enlarged images.

4 Elemental Technologies

4.1 Outline of Image Processing ASIC

Fig. 7 illustrates the block diagram of the image processing ASIC and its peripherals developed this time.

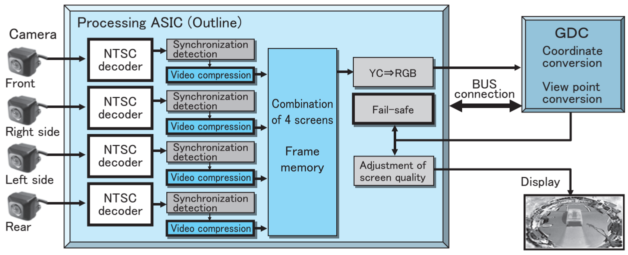


Fig.7 Block Diagram of Image Processing ASIC and Its Peripherals

4.1.1 Built-in NTSC Decoder

The NTSC decoder separates a NTSC signal into a luminance signal and a chromatic signal via three-line 2-D YC separation filter and then performs the matrix conversion processing to output digital RGB data from the YUV signal. Conventionally, four general-purpose video decoder ICs have been mounted. However, from this system, the functions of the decoder ICs are built in the ASIC to reduce the surface area for the mounted devices. As a result, the mounted area was drastically reduced from conventional 639 mm^2 to 139 mm^2.

4.1.2 Built-in Fail-safe Function

In compliance with KT Safety Act, this system is required not to display frozen images on the screen in order to help the drivers avoid making wrong decisions. Therefore, we added a frozen image detection function to the ASIC to detect the frozen images caused by factors beyond the scope of the assumption of the GDC. It is designed to enhance the speed of the frozen image detection by using this circuit that can determine presence of a frozen image in compressed data by coding the video signals.

4.2 Outline of Automatic Optical Axis Adjustment (Calibration) Technology

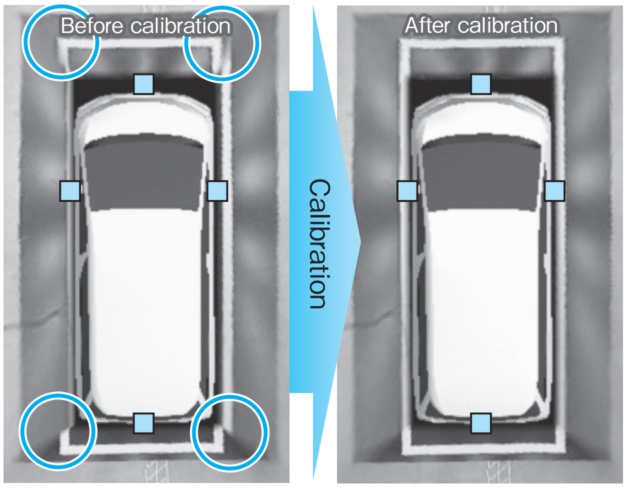
4.2.1 Multi Angle Vision™ Calibration

Multi Angle Vision™ Calibration refers to a technology that corrects image conversion data based on an assumption of angles of cameras that are actually mounted on the vehicle and that recognize locations of target markers placed around a vehicle.

4.2.2 Necessity of Calibration

The Multi Angle Vision™ generates the image conversion data based on the angles of the four cameras mounted on the vehicle and displays combined images. However, due to an error caused in production lines where the cameras are mounted or for other reasons, there are cases where an angle of the mounted camera differs from a design value. If the design value is applied to the images without taking the difference into account, the images captured by the cameras are misaligned at seams, as shown in the left drawing in **Fig. 8**, and the combined image becomes unnatural.

Therefore, it is necessary to correct the images based on the angles of the mounted cameras calculated by the calibration. This time, we have achieved a new automatic adjustment (calibration) technology for the optical axes of the vehicle-mounted cameras and the technology can be used in assembly lines of vehicle manufacturers.



(○ : Misalignment of images, □ : Points of mounted cameras)

Fig.8 Before and After Calibration

4.2.3 Use of Multi Angle Vision™ Calibration at Vehicle Assembly Factories

We worked to meet the following three challenges in order to make the calibration usable in assembly lines of vehicle manufacturers.

(1) Space-saving

A space was not prepared newly for the adjustment work, but the adjustment had to be performed with minimum equipment in the existing assembly lines. Therefore, we studied the situation of the vehicle assembly lines and performed computer simulation beforehand to determine a minimum space for placing the markers. Moreover, we determined to place the target markers at the four corners of a vehicle standing vertically from the ground, rather than laying them on the ground, to save space. Due to those space-saving efforts, it becomes possible to perform the calibration in the existing lines.

(2) Shorter adjustment work time

The conventional method required much time for calibration because many positioning points for the calibration were determined manually by workers looking at screens showing images obtained by the cameras. However, we developed a technology that automatically detects intersection points in patterns of the target markers placed at four corners of the vehicle, from the images captured by cameras, using the high-accuracy image recognition technology. Further, we also developed a technology that automatically assumes the angles of the mounted camera based on the plural detected points.

As a result, as compared with the conventional calibration method, the calibration time was drastically reduced, for example, the detection time to approx. one-sixtieth and entire adjustment time to approx. one-fifth.

(3) Process with minimum adjustment equipment

The ECU includes all application software used for the calibration illustrated in **Fig. 9**, and the calibration can be performed via the display unit of a device, such as a car navigation device. Thus, we achieved the process that requires only target markers for adjusting the optical axes of the cameras.

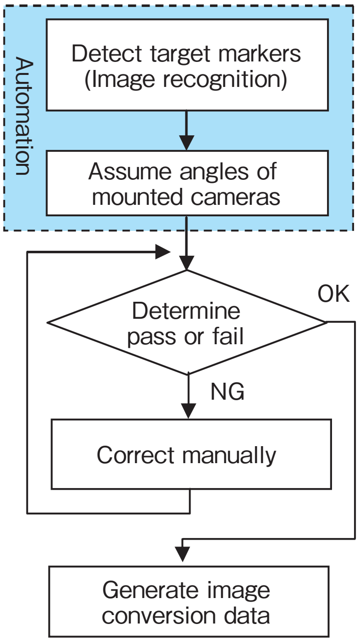


Fig.9 Flowchart of Calibration

We appreciate a great deal of cooperation of design departments of the vehicle manufacturers and staff members of the vehicle factories, for identifying the requirements and solving problems to use the technology in the assembly lines.

This newly developed calibration technology enables: to accurately calculate the angles of the mounted camera in a small space in a vehicle factory in short time; to correct the conversion data of the images captured by each camera; and thus to accurately and continuously combine images of the vicinity of a vehicle (white lines, etc) because the misalignment at the seams between the images is corrected.

5 Conclusion

We successfully commercialized the system in which user convenience, the fail-safe function, and the productivity of the adjustment work of optical axes of cameras are improved by "the additional functions for screen," "the newly-developed image processing ASIC," and "the technology of the automatic adjustment (calibration) of optical axes of cameras." Fortunately, the system was adopted by TOYOTA MOTOR CORPORATION for a high-class sedan Crown (scheduled to be sold from December 2012). We will further improve the system to support drivers' field of view. At the same time, we will develop technologies leading to preventive safety and parking assistance system. Moreover, we would like to contribute to spreading the field-of-view support systems not only to high-end cars but also to lower price cars by developing systems of which prices are so reasonable that more consumers can use those systems.

6 Acknowledgment

Lastly, we would like to extend our cordial appreciation to FUJITSU LABORATORIES LTD.'s senior researchers Mr. Kawai and Mr. Mizutani, who provided cooperation and support for us by supplying the core technology of calibration, etc. and to others who also helped us, for developing this system.

Reference

Page 12 - page 18, No. 36, FUJITSU TEN TECHNICAL JOURNAL in English version

Profiles of Writers

Tadashi KIDENA
Project General Manager of System Engineering Dept, AS Engineering Group.

Kazumasa KAMEDA
Team Leader of System Engineering Dept, AS Engineering Group.

Minoru FUJIOKA
Sensor Development Dept, AS Engineering Group.

Koei KIYO
System Engineering Dept, AS Engineering Group.

Fumitaka FUSHIMI
PF Development Department, SS Engineering Group.