Multi Angle Vision™ System to supplement Driver's Visual Field

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Multi Angle Vision

Abstract

Recently, the market needs has grown for the vehicle-mounted camera system to supplement driver's visual field, mainly those for back monitors. Moreover, the technologies for the system are advancing. Among them, one technology provides images of downward view from the sky (bird's eye view images) to drivers by using four fish-eye cameras, for easy parallel parking, etc. Products using this technology have been commercialized one after another.

The conventional system was useful only in limited scene because it could provide images of limited areas and from limited angles.

With "the 3-D virtual projection viewpoint conversion technology," we developed "Multi Angle Vision™," which is a surrounding monitoring system that combines video images into 3-dimensional images with the area near the vehicle displayed onto a plane representing the road, and the surrounding area distant from the vehicle onto curved surface.

This system is characterized by displaying images of the surroundings of the vehicle in 3-dimensional bird's eye view from any arbitrary angle according to driving scene such as parking, and greatly contributes to supplement driver's visual field. Moreover, the nighttime visibility is ensured for the right and left sides of the vehicle where visibility is poor when the illumination intensity is low, e.g. in the nighttime, by adopting a near infrared LED lighting system, which allows drivers to see entirely around their vehicles even in the nighttime.

1 Introduction

Recently, an increasingly popular system is the vehicle-mounted camera system that assists drivers in checking the surroundings of their vehicles that the drivers cannot see directly (to supplement drivers' visual field), by displaying camera images of the surroundings. In recent days, manufacturers have released new products one after another. Those products are equipped with the system that supplements the driver's visual field (system to supplement driver's visual field) by combination of two or more cameras, rather than by one camera, to reduce the blind zones in broader range. The technology for the vehicle-mounted camera system is advancing.

FUJITSU TEN has developed "Multi Angle Vision™," which is the world first system to supplement driver's visual field that can display 3-dimensional bird's eye view images of the entire circumference of the vehicle from various angles. This paper introduces the outline and element technologies of the Multi Angle Vision™.

2 Reasons for Development

2.1 Market Needs for Vehicle-mounted Camera System

Recently, the needs for the vehicle-mounted camera system, mainly back monitors, have been grown. For example, in February 2008, the U.S. congress passed the bill "Cameron Gulbransen Kids and Cars Safety Act of 2007," which requires securing rearward visibility behind the vehicle. In Japan, the vehicle- mounted camera system to supplement driver's visual field rapidly becomes popular with more than 4 million cameras to be mounted on vehicles shipped from factories in 1997. It is expected that a recent increase in women drivers and senior drivers will further enhance the needs for the vehicle-mounted camera system in the future.

Examples of Conventional Vehicle-mounted Camera Systems

- **Back monitor**

To supplement driver's visual field when a driver backs the vehicle by displaying camera images behind the vehicle, using a camera on the rear end of the vehicle

- **Blind corner monitor**

To supplement driver's visual field when a driver enters an intersection with poor visibility by displaying camera images ahead of the vehicle, using a camera on the front end of the vehicle

- **Bird's eye view image system**

To supplement driver's visual field when a driver parallel parks the vehicle by displaying camera images looked down from the sky above the vehicle, using four cameras on the vehicle

Moreover, many manufacturers have commercialized various types of products using the vehicle-mounted camera system, ranging from the system equipped with one camera such as a backside camera (back monitor) to the bird's eye view image system equipped with four cameras providing camera images looked down from the sky above the vehicle to show the road situation near the vehicle. The technology for the vehicle-mounted camera system is advancing as the market needs for the system is increasing.

2.2 Problems in Conventional System to Supplement Driver's Visual Field

During driving, drivers always have a feeling of uneasiness that there may be something around the vehicle. All the vehicle-mounted camera systems described in the previous section are intended to eliminate the uneasiness by providing camera images of zones that drivers cannot see directly. Generally, the following three are cited as factors giving uneasiness to drivers.

①**Vehicle body structure interrupting driver's visual field**
Vehicle body, pillars, etc.

②**Obstacles around vehicle interrupting driver's visual field**
Buildings, other vehicles, pedestrians, etc.

③**Characteristics of human eyes**
Unable to see entire 360-degree surroundings at one time

Actually, one or a combination of these factors exists and interferes with safe driving of drivers. Therefore, vehicle-mounted camera system is required to eliminate all these factors. However, the conventional system cannot sufficiently serve this purpose. For example, a back monitor or a blind corner monitor supplements the driver's visual field by displaying camera images of blind zones created by the vehicle body or an obstacle(s) around the vehicle, in the scenes where the driver is assumed to use the monitor system. However, those systems only provide partial images of the blind zones such as the area behind the vehicle or the area behind a wall. In terms of supplementing the characteristics of human eyes, those systems do not fulfill the purpose. Moreover, the bird's eye view image system can show road conditions around the vehicle at one time by providing camera images looked down from a higher position over the vehicle. However, the camera images are limited to the view from a predetermined fixed angle so that the images are only useful under limited scenes. As a result, conventional systems supplement the driver's visual field by displaying no more than partial images of blind zones around the vehicle only under limited scenes where each of those systems is supposed to support the driver, and do not achieve the comprehensive support including supplementing of the characteristics of human eyes.

In addition to elimination of those factors, it is important to take measures to improve cameras for better nighttime visibility. Compared to the bright daytime, it is more difficult to notice the existence of obstacles on the display in the nighttime when it is dark after the sun sinks because camera images captured by cameras are also dark (**Fig. 1**). It is required to improve the cameras so that they surely capture the images of obstacles

around the vehicle even under the dark environment.

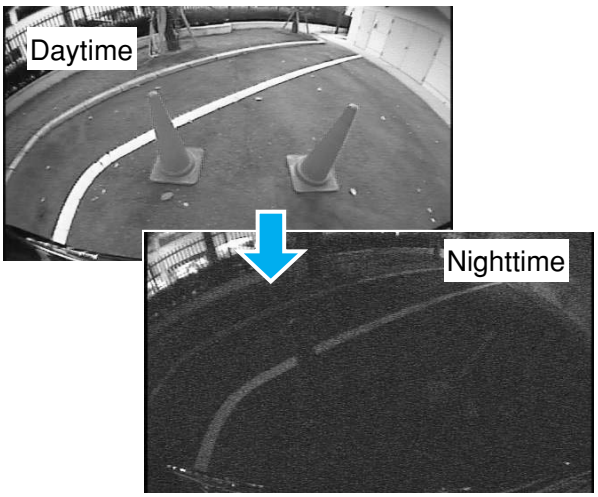


Fig.1 Difference in Camera Image Brightness between in Daytime and in Nighttime

This time we developed "Multi Angle Vision™," which supplements not only the driver's visual field to eliminate blind zones created by the vehicle body and/or obstacles around the vehicle but also the characteristics of the drivers' eyes. The Multi Angle Vision™ allows drivers to see entire 360-degree surroundings of the vehicle from various angles. Therefore, it is the system to supplement driver's visual field that is capable of supporting the visual field of users in total from when they get in their vehicles to when they drive the cars.

3 Element Technologies of "Multi Angle Vision™," System to supplement Driver's Visual Field

3.1 Outline of Multi Angle Vision™

The Multi Angle Vision™ is the world's first system that supplements the driver's visual field. Using an ECU, the system combines images around a vehicle captured by four cameras that are used only for this system and that mounted on the right side, left side, front end and rear end of the vehicle, and displays 3-dimensional bird's eye view images, to allow the drivers to see around the vehicle including blind zones.

This system includes four cameras dedicated for this system, an ECU, and an AVN. The images around the vehicle, captured by the four dedicated cameras, are aggregated in the ECU. The aggregated images are combined into an image on a real-time basis and projected on a 3-dimensional model using the "3-D virtual projection/point of view conversion technology [1]." The images are displayed on the AVN in accordance with the scene to supplement the driver's visual field (**Fig. 2**).

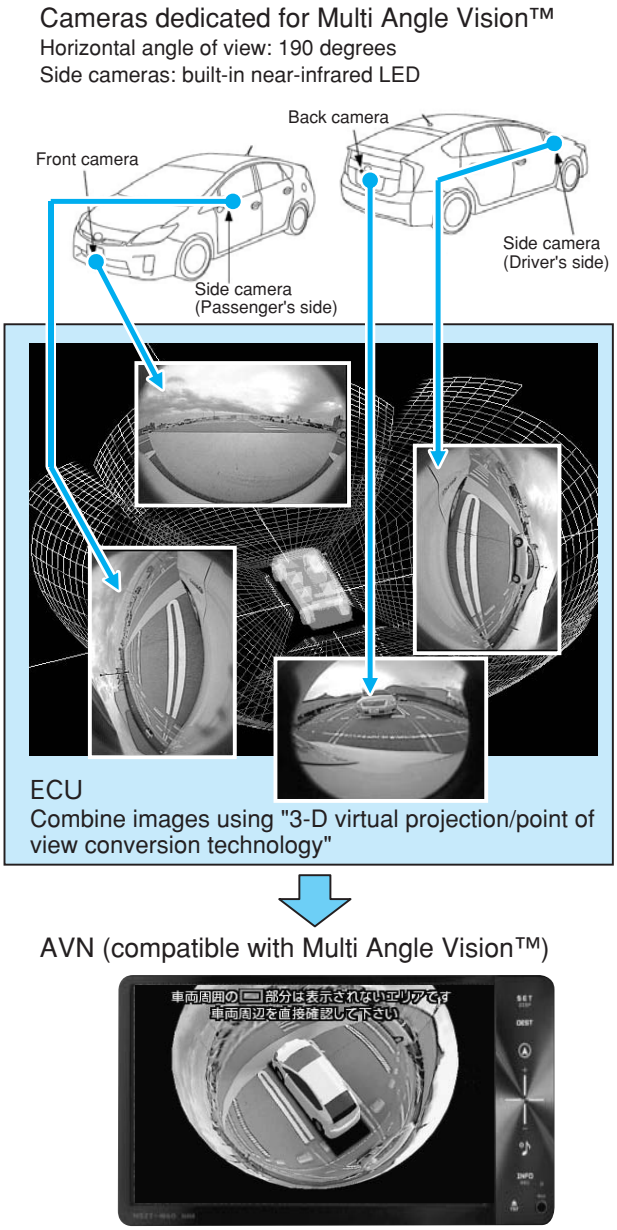


Fig.2 Outline of Multi Angle Vision™

The "3-D virtual projection/point of view conversion technology" allows this system to display bird's eye view images 360-degree around the vehicle from any arbitrary position in 3-dimension. For example, using this system, an image can be rotated around the vehicle of the driver to check the safety around the vehicle, as shown in **Fig. 3**. Moreover, unique images that cannot be achieved by the conventional system can be displayed. An example of those images is the one showing the vehicle viewed from behind the vehicle, as shown in **Fig. 4**. The images below are a couple of other image examples able to be displayed by the system (**Fig. 5 and Fig. 6**).

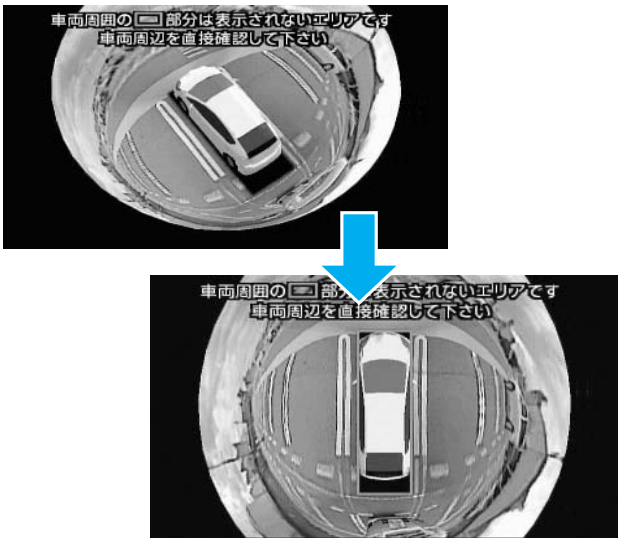


Fig.3 Image Used for Check Surroundings of Vehicle

Fig.4 Image Used for Check at Intersection with Poor Visibility

Fig.5 Image Used for Parking

Fig.6 Image Used for Parking on Verge of Road

On the other hand, the cameras of this system must be mounted with extreme accuracy. In order to make sure of the mounting of the cameras at the accurate positions, "calibration" is performed to correct tiny errors made during the mounting of the cameras so that misalignment of combined images does not occur.

Moreover, we developed "near infrared LED lighting system" in order to enhance the visibility of camera images of obstacles around the vehicle in the nighttime. This improvement enhances the visibility of camera images captured in the nighttime and enables the system to supplement the driver's visual field in the daytime and nighttime.

Furthermore, the system equipped with functions to meet the future expansion of models of vehicles, such as a slot for a SD card on the ECU to read in data for upgrading.

The outline and the structure of the Multi Angle Vision™ are mentioned above. The following sections will explain the key element technologies for the Multi Angle Vision™: 3-D virtual projection/point of view conversion technology; calibration; and the technology for enhancing nighttime visibility using near infrared LED lighting system.

3.2 Technology for Showing Surroundings All around Vehicle from Arbitrary Viewpoint

The camera images from four cameras mounted on the vehicle are combined using the "3-D virtual projection/ point of view conversion technology." The "3-D virtual projection/point of view conversion technology" is the technology that projects an image on a 3-D model and then converts the projected image into the image viewed from an arbitrary viewpoint. Using this technology, our newly developed system is able to show images substantially different from the one created by conventional systems using conventional technologies.

The conventional bird's eye view image system converts camera images from the four cameras, on a 2-D plain surface to combine them into bird's eye view images. Therefore, objects around the vehicle are stretched in those images. Another disadvantage of the conventional system is that it is only capable to display downward images viewed from a certain viewpoint over the vehicle. That means that the system is only useful to show certain areas and for certain scenes **(Fig. 7)**.

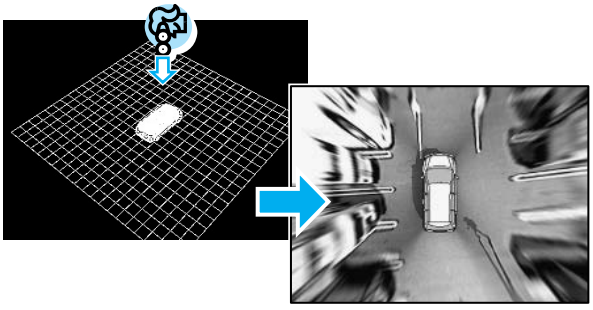
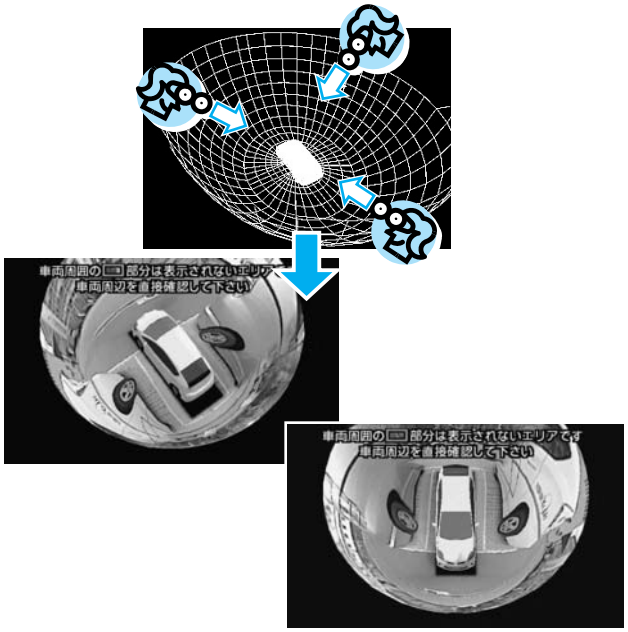


Fig.7 Image Example Projected on 2-D Model

On the other hand, our new system combines camera images on the 3-D model where the area near the vehicle is designed to be projected on the plain surface of a road and the area distant from the vehicle on a curved surface (**Fig. 8**), which can prevent objects around the vehicle from being stretched out of shape and can provide drivers with camera images of an area wider than the one provided by conventional systems. In addition, by including a LSI capable of fast arithmetic processing, this system can computes an image from a viewpoint, in real time. Therefore, besides the conventional bird's eye view images viewed from the sky over the vehicle, images around the vehicle viewed from various angles can be provided to drivers, and the driver's visual field can be supplemented in many scenes.



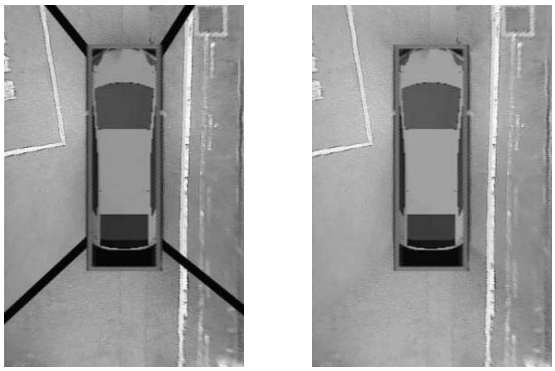
Possible to check area around vehicle from various angles

Fig.8 Image Example Projected on 3-D Model

3.3 Seamlessly Combined Camera Images

The calibration is performed to correct misalignment of combined images caused by a tiny error in position of the cameras when the system is mounted. Calibration is a technology that automatically computes the mounting information (position and angle) of each of the cameras mounted on a vehicle by capturing the camera images of markers around the vehicle by those cameras, and then combines the camera images seamlessly while automatically adjusting tiny misalignment caused on the combined images in accordance with the computation results.

This technology enables the system to combine the camera images seamlessly and to eliminate borderlines between camera images captured by the cameras although those borderlines are conspicuous between the camera images combined by conventional systems (**Fig. 9**).



Conventional　　Multi Angle Vision™

Fig.9 Examples of Borderlines between Camera Images

The calibration adopts the method that eases restrictions relating to work space, work time and equipment. For example, the markers are allowed to be placed at arbitrary positions if the cameras can capture the markers. Therefore, it does not have to secure work space used only for the Multi Angle Vision™. The application used for the work is installed in the ECU. The work can be performed using the AVN so that there is no need to prepare special equipment (such as a PC).

3.4 Supplementing of Drivers' View in Nighttime

In the nighttime, the camera images captured by the cameras are dark and visibility becomes lower. In the case of a vehicle-mounted camera system with cameras respectively mounted on the front end, back end, right side and left side of a vehicle, the cameras on the front and back ends can capture relatively bright images due to the lighting system originally installed on the vehicle. However, the images captured by the side cameras are dark because there is no lighting system to light the sides of the vehicle (**Fig. 10**).

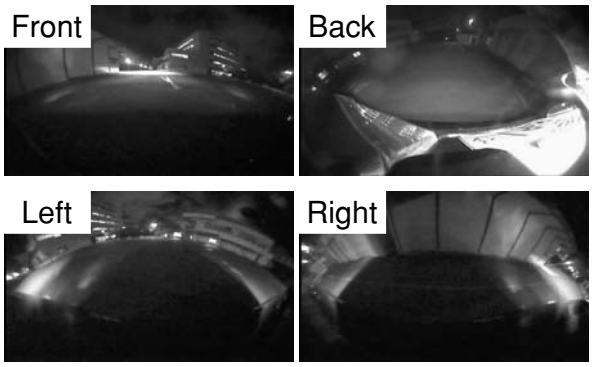


Fig.10 Camera Images Captured in Nighttime

Combining the camera images on which the sides of the vehicle are dark only produces combined bird's eye view images with the dark sides of the vehicle. Therefore, a lighting system is required to develop to ensure the visibility of the side cameras. The following are the three points that we addressed to develop a lighting system for the side cameras.

①Use of invisible near infrared light as light source
Near infrared light is adopted as a light source because it is invisible and does not prevent driving of the drivers of the vehicle and other vehicles.

②Camera sensing near infrared light
IR cut filters, which block near infrared light, are removed from the cameras.

③Entire side areas lit by lighting system
In order to ensure visibility all around the vehicle even in the nighttime, extensive entire side areas are set to be lit (**Fig. 11**).

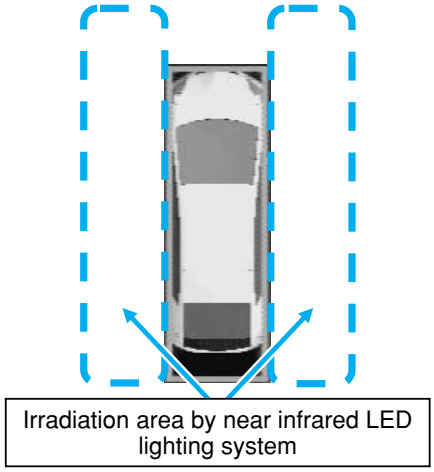


Fig.11 Irradiation Area by Near Infrared LED Lighting of This System

By ensuring a certain level of nighttime visibility of side cameras, we achieved the supplementing of the driver's visual field to see the entire circumference of the vehicle in the daytime and in the nighttime by taking these measures (**Fig. 12**). Moreover, since being able to light the entire side areas, the lighting system can be used not for some specific camera images but for any camera images during driving (**Fig. 13**).

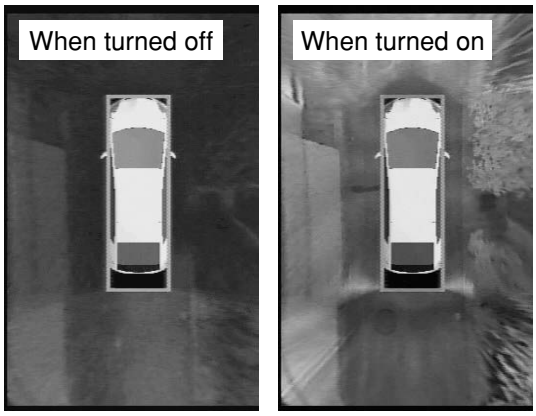


Fig.12 Difference in Brightness of Bird's Eye View Images between with Lights on and with Lights off

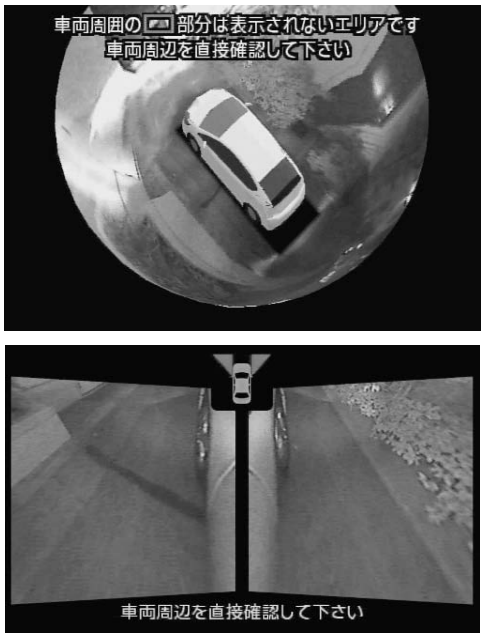


Fig.13 Example Images with Lighting System on in Nighttime

4 Screen Design from a Driver Viewpoint

4.1 Easy-to-understand Images according to Scene

The images are designed to display such that drivers easily understand and use the on various scenes. For example, for checking scenes of the sides of the road in front of the vehicle, the blind corner monitor of this system displays an image of the vehicle viewed from behind the vehicle as well as an image equal to the image displayed by a conventional system. As a result, when turning right or left at an intersection with poor visibility, the driver can simultaneously check the scene of the sides of the road in front of the vehicle and a rear wheel of the vehicle to prevent a person/a thing from being caught under the rear wheel (**Fig. 14**).

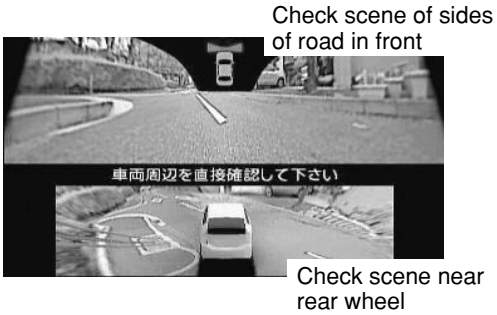


Fig.14 Images Used for Turning Left at Intersection with Poor Visibility

Moreover, this system is equipped with the function of changing viewing angle of the bird's eye view image, according to a choice of the driver, when he/she parks the vehicle, utilizing the characteristic of this system that can converts the image on the 3-dimensional model to the one viewed from an arbitrary viewpoint. This system provides three choices of angles that drivers can select an angle between those choices if desired (**Fig. 15**).

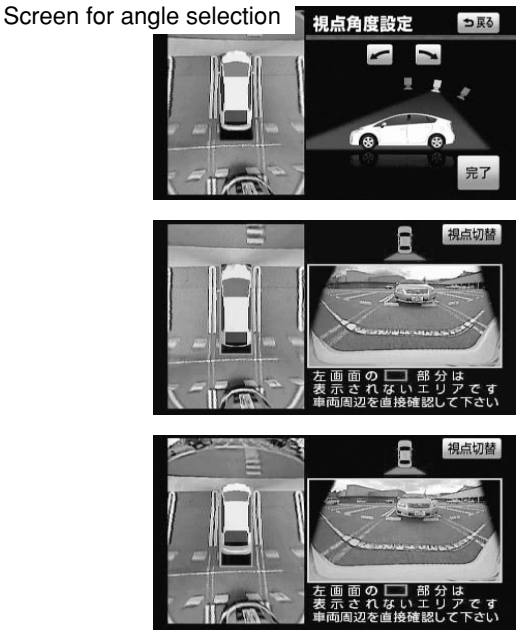


Fig.15 Images at Different Viewing Angles

4.2 Matching of Vehicle CG to Mounting Vehicle

Furthermore, this system is equipped with the function with which the driver can change the model and the color of the vehicle CG located in the center of the bird's eye view image to match with the real vehicle mounting the system. As a result, although vehicles vary in size and shape, this system is capable of displaying the scene around the vehicle faithfully in accordance with the size and the shape of the vehicle (**Fig. 16**). Furthermore, with this function, the color of the vehicle CG on the image also can be changed to provide a sense of reality to the driver.

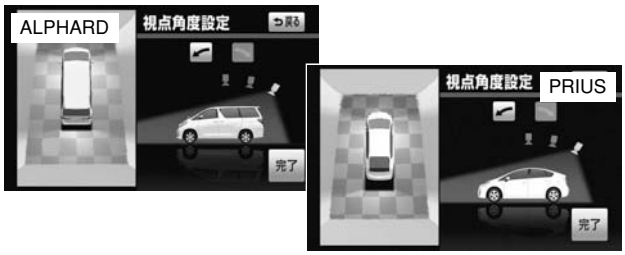


Fig.16 Example of Vehicle CGs according to Vehicle Model

5 Conclusion

We have developed "Multi Angle Vision™," which comprehensively supplements the field of view of drivers in the daytime and in the nighttime, using the "3-D virtual projection/point of view conversion technology" and the "technology for enhancing nighttime visibility using near infrared LED lighting system." The Multi Angle Vision™ has been commercialized as an option to be installed at car dealers (dealer option) for ALPHARD, VELLFIRE and PRIUS of TOYOTA MOTOR CORPORATION since May 2010.

We think that this system can provide safety to drivers in various driving scenes and can contribute greatly to the safety in the car society. We would like to make an effort to enhance safety precautions and assistance in parking in addition to the supplement of the field of view of drivers, in the future.

Reference:

1) SHIMIZU Seiya, et al, "System Giving Wraparound View of Vehicles", FUJITSU, Vol.60, No.5, pp.496-501 (2009)

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