Support System to inform Driver of Approaching Objects

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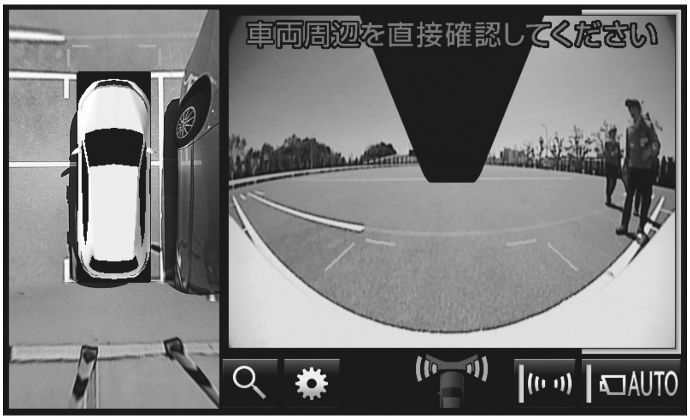


Abstract

One of major factors of accidents happened in a parking lot is collision with an approaching vehicle or a pedestrian, but such an accident is difficult to be prevented by conventional vehicle-mounted camera systems which aim to supplement driver's visual field only by displaying Images.

Then we have developed a new system which detects an approaching vehicle or a pedestrian in the area near driver's vehicle in the traveling direction and informs the driver of possible danger.

The image processing technology of the new system to detect approaching objects is based on optical-flow technique and reduces the calculation amount by about 99.7% by controlling the number and distribution of feature points on images. Moreover, the technology reduces the memory amount by about 92.2% by comparing the image at the present time with micro regions nearby feature points extracted from an image at a different time. Incorporating this technology into the existing vehicle-mounted camera system enables the low-cost development in a short time.

Furthermore, this system also resolves some problems caused when the system is mounted on vehicles, such as "unwanted detection at night time," "excessive detection in the distance" and "background detection at turning."

1 Introduction

A vehicle-mounted camera system which supplements a driver's visual field around a vehicle and eases driver's strain has become popular rapidly. Especially a system which displays the images of a rear-mounted camera is well known. Recently, in order to expand the coverage area, a system which displays the surrounding images of the vehicle by using not only one camera but multiple cameras appears on the market.(1)(2) Moreover, attention is also drawn to a cognition support system which does not only supplement driver's visual field but also makes the driver aware of the situation of the surroundings.(3)

We have developed a "support system to inform driver of approaching objects" which support driver's cognition, using an approaching-object detection technique(4) to detect approaching objects. This paper introduces the developed system, element technologies, and approaches to mounting the system on vehicles.

2 Background of Development

2.1 Trend of Vehicle-mounted Camera System

There is a growing need for vehicle-mounted camera systems focusing on a rear-view camera, as shown in the enforcement of "Cameron Gulbransen Kids and Cars Safety Act (KT Safety Act)" which mandates a vehicle to be equipped with a rear-view camera in the US.

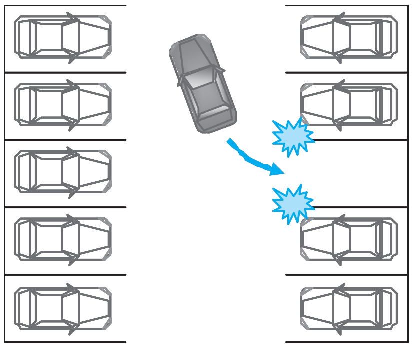
With the advancement of technology, many systems have been commercialized. Among them are a system which uses multiple cameras, rather than a rear-view camera, a system which displays the camera images viewed from the sky above a vehicle by image processing technique.

In 2010, FUJITSU TEN has also developed and commercialized "Multi Angle Vision™" System which displays the 3-dimensional image showing 360 degrees around a vehicle by using four cameras mounted on the vehicle and which supplements driver's visual field.(1)(2)

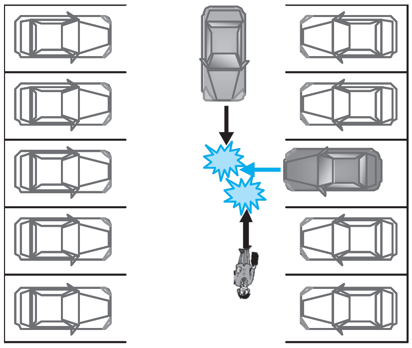
As the next step of such a vehicle-mounted camera system which displays the images showing 360 degrees around a vehicle and which supplements driver's visual field, the need for a system which supports driver's cognition by making a driver aware of the condition around the vehicle is also increasing.

2.2 Need for Supporting Driver's Cognition

Approximately 30% of auto accidents occur in parking lots and most of them fall into two patterns shown in **Fig. 1**.(5)



(a) Collision with vehicle parked on either side



(b) Collision with approaching vehicle, pedestrian, etc.

Fig.1 Accident Patterns in Parking Lot

A minor accident with a parking vehicle shown in **Fig. 1(a)** occurs in the blind spots which a driver has difficulty to check. These blind spots can be checked by using the vehicle-mounted camera system described in the previous section because it supplements driver's visual field. However, a minor accident with a vehicle, a pedestrian, or another approaching object, as shown in **Fig. 1(b)**, may occur by driver's oversight of objects approaching from the direction opposite to the traveling direction, because, for example, he/she pays more attention to the traveling direction. This accident can be hardly prevented by conventional vehicle-mounted camera systems which are designed only to display images aiming to supplement driver's visual field.

Therefore, in order to prevent such a driver's oversight, we have developed the "support system to inform driver of approaching objects," which supports driver's cognition by informing a driver of approaching objects such as vehicles or pedestrians near his/her vehicle in the traveling direction.

3 System Outline

3.1 Assist Scene

The "support system to inform driver of approaching objects" is designed to reduce close calls or accidents by informing a driver of approaching objects which are overlooked easily, when the driver moves his/her vehicle from a parking lot or the like.

When a vehicle leaves from a parking lot as shown in **Fig. 2**, the right and left side of the driver's visual field tend to be blind spots. Moreover, the driver potentially overlooks approaching vehicles or pedestrians since the driver moves his/her vehicle while checking the surrounding areas. Therefore, objects located in and approaching the vicinity in the traveling direction of the driver's vehicle, from right or left, are set as the targets to be informed.

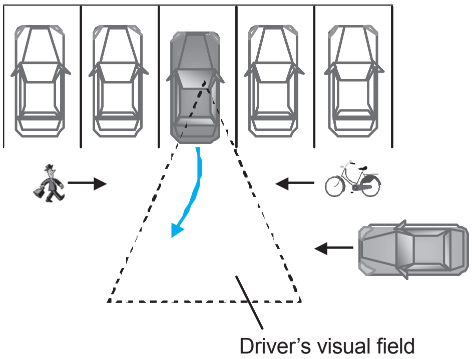


Fig.2 Example of Assist Scene (In Case of Backing out of Lot)

3.2 System Configuration

We could develop the "support system to inform driver of approaching objects" in a short period and at low cost by incorporating it into the Multi Angle VisionTM system, which has been already commercialized.

The configuration of the system is shown in **Fig. 3**. First, the image processing ASIC in the system detects approaching objects in the camera images of two cameras on the front and rear ends out of four front, rear, right and left cameras. Next, the control microcomputer determines the conditions of the vehicle from the vehicle information such as vehicle speed obtained through CAN. Only when the vehicle condition satisfies the operating conditions of vehicle speed, steering angle and so on, the system informs the driver of approaching objects by a frame on the display image, as shown in **Fig. 4**, and sound.

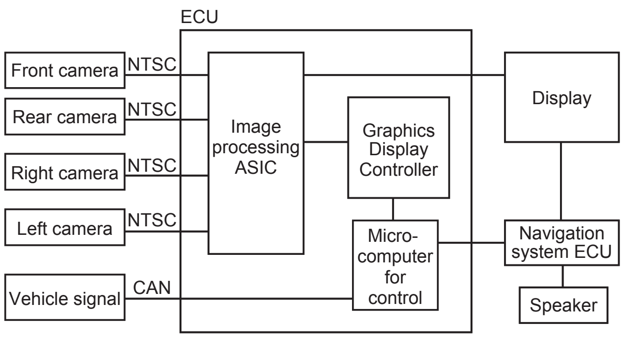


Fig.3 System Configuration

Fig.4 Example of Informing Means

4 Element Technology

Approaching-object detecting method co-developed with FUJITSU LABORATORIES LTD. is used as the image processing technology for detecting approaching objects. The method is based on the optical-flow technique which detects the movement of each pixel on two images captured at two different times. **Fig. 5** shows the detection process flow diagram.

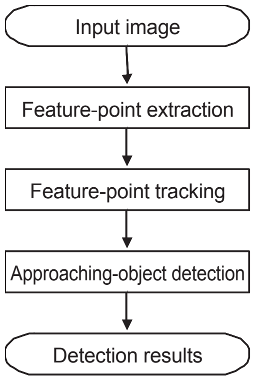


Fig.5 Processing Flow of Approaching-Object Detection Method

(1) Feature-point extraction

If the calculations of optical flow (hereinafter referred to as flow) are performed for the entire area of the input image, a huge amount of calculation is needed. However, as for the input image of the system shown in **Fig. 6**, flow calculations for the upper area and the bottom area are not necessary because objects intended to be detected does not appear in the both areas showing the sky and the body of the system-installed vehicle. Therefore, the central area where approaching objects appear is set as a monitored area.

As compared with the objects such as vehicles and pedestrians, the areas of the sky, road surface, etc. in the monitored area have so low contrast that the calculation accuracy of the flows is low. Also, the calculation of flow for such areas results in consuming calculation amount unnecessarily. Therefore, by extracting a corner of an object as a feature point,[6] calculation accuracy of the flow is increased and calculation amount of the flow is reduced.

As shown in **Fig. 7**, when the maximum number of the feature points is reduced to 1,024 points, the calculation amount of the flow can be reduced by about 99.7%, as compared with the calculation amount performed for the entire area of an input image.

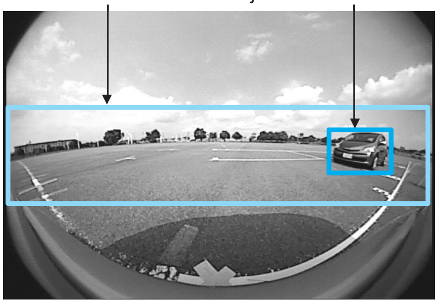


Fig.6 Example of Setup of Monitoring Area and Approaching-Object Detection

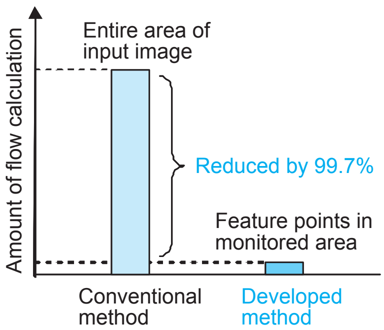


Fig.7 Calculation Amount of Optical Flow

(2) Feature-point tracking

Next, the flows of the extracted feature points are calculated and the feature-point tracking is performed. The system is assumed to be used mainly in a parking lot and the objects to be detected are vehicles, pedestrians, and others which are approaching at low speed. The movements of these objects are small on the image as compared with objects approaching at high speed. In order to detect the small movement on the image, the conventional optical-flow technique needs a lot of memory amount because it requires to retain multiple past images. The method[4] developed by FUJITSU LABORATRIES LTD. satisfies both of reduction of memory amount and detection performance by the flow calculation which compares the feature points in micro regions nearby extracted from the past time frame with the same feature points extracted from the present time frame.

As shown in **Fig. 8**, the method can reduce the memory amount by about 92.2% in comparison with the conventional method, even in the case of the tracking of 32 frames to get high performance.

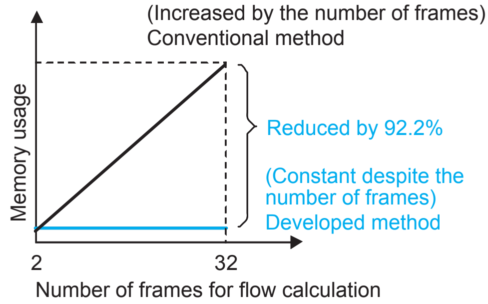


Fig.8 Amount of Memory Needed for Optical Flow Calculation

(3) Approaching-object detection

The system is required to detect the objects approaching the vicinity in the traveling direction of the driver's vehicle, from right or left. These objects move from the outside toward the center on the image. Contrarily, objects moving away and the background move from the center toward the outside on the image. Therefore, by grouping the feature points of which flows move inward relative to the image center, the areas of the objects to be detected are specified and approaching objects are detected as shown in **Fig. 6**.

We have incorporated the function of the approaching-object detection method into the image processing ASIC shown in **Fig. 3**. As described above, the reduction of memory amount eliminates a need for external memories and achieves low cost. Also, the reduction in the calculation amount enables to complete the detection process for each of 30 frames input per second so that there is no negative influence on the detection performance, and thus no delay in providing informing caused by the delay in the detection process.

5 Approach to Mounting System onto Vehicle

5.1 Challenge

We had to overcome the challenges below in order to make sure that the approaching-object detection method works appropriately in specific scenes assumed to be challenges for the method installed on a vehicle.

(1) Unwanted detection is annoying when it works in the dark such as nighttime.
(2) Excessive detection is annoying when it detects distant moving objects not to be detected.
(3) Detection of the background which is not an approaching object is annoying when driver's vehicle is turning.

5.2 Practical Approach

Solutions to these challenges were studied to install the method into vehicles.

(1) Solution to annoyance at nighttime

The system is designed to be used when the driver moves out of a parking space, but it works when he/she is going to park the vehicle into a parking space as well. The driver sometimes turns on the hazard lamps to park the vehicle. In the dark, such as nighttime and indoor parking lots, because of light-dark changes caused by the blinking hazard lamps and high-sensitive noises generated by the increased camera gain, the feature points are tracked inward and unwanted detection increases, as shown Fig. 9. Since the unwanted detection increases in the dark below a specific illuminance level, it is possible to temporarily stop the system based on the information obtained from an illuminance sensor. However, the convenience of the system decreases. Therefore, we studied a new solution to the unwanted detection in the dark. The reasons for the unwanted detection in the dark are the illuminance change and/or the noises that cause the feature-point tracking. Therefore, as the solution to that, we determined to use the block-matching method[7] which is less affected by the illuminance change and/or the noises, for the flow calculation of the feature-point tracking. However, this solution alone was not enough to eliminate all the unwanted detection. When the remained unwanted detection was compared with normal detection of approaching objects, it was found that the detection result of the unwanted detection disappears in a short time and its size is small. Therefore, by informing the detection result which is detected for longer than a certain period of time and detected larger than a certain size, additional solution to the unwanted detection in the dark has been achieved.

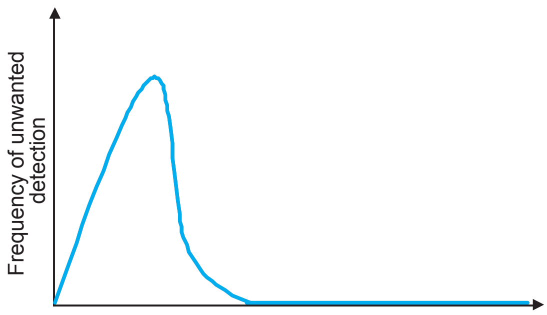


Fig.9 Degree of Unwanted Detection in the Dark

(2) Solution to annoyance with distant approaching object

The system is designed to detect approaching objects in the vicinity of a driver's vehicle. However, it detects distant approaching objects which appear moving inward on the image as shown in Fig. 10 because it can also detect distant approaching objects. Although in the scene in which the driver moves the vehicle out of a parking space, these distant moving objects have no risk of collision and are annoying to him/her. Therefore, we studied solutions to the excessive detection of distant moving objects. Both of the flows generated by nearby approaching objects and distant moving objects have the same inward-moving elements. Thus, it is difficult to separate the nearby approaching objects from the distant moving objects based on their flows. Therefore, as shown in Fig.11, by setting the vicinity area and the distant area on the image and removing the moving objects detected in the distant area from the detection targets, the solution to the excessive detection of the distant moving objects has been achieved.

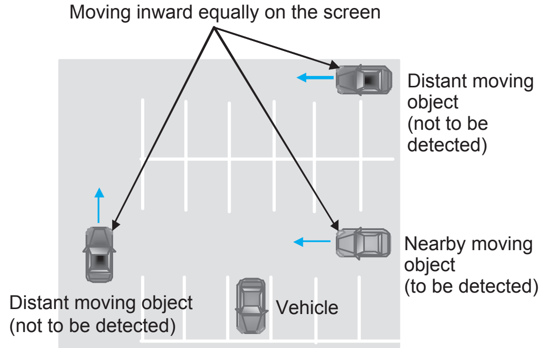


Fig.10 Moving Objects to be Detected and not to be Detected

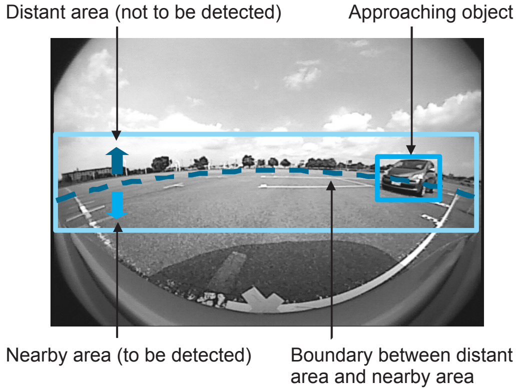


Fig.11 Separation Method of Objects Moving Nearby from ones in the Distance

(3) Solution to annoyance when turning

In the case of the driver moves the vehicle out of a parking space, a vehicle moves straight or turns slowly from the stopped state. When a vehicle moves straight, the background seen from the driver appears to move outward on the image. However, when a vehicle turns, the background in the turning direction appears to move inward on the image, as shown in Fig. 12, so that the structures in the background are detected. Since the structures in the background are stationary objects and not approaching objects, they are detected unnecessarily. Therefore, we studied solutions to the unwanted detection in turning.

When taking a look at the size of the flows, the flows of approaching objects and the background generated in turning are categorized as shown in Fig. 13. Since the flows of distant approaching objects overlaps with the flows of the background, they cannot be separated from the ones of the background. However, the flows of nearby approaching objects become larger than the flows of nearby background, so that they can be separated from the ones of nearby background and the nearby approaching objects can be detected.

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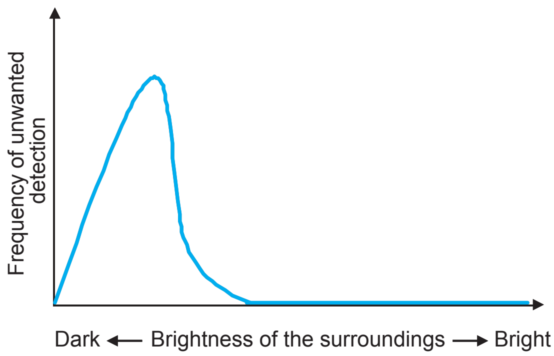

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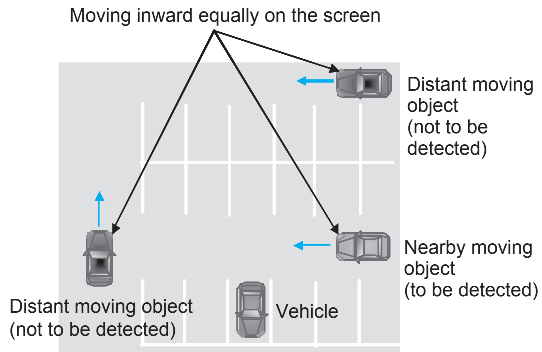

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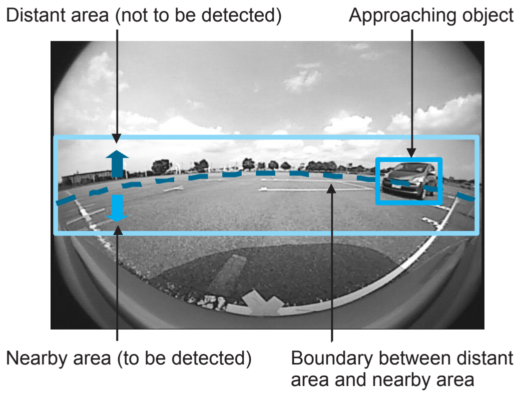

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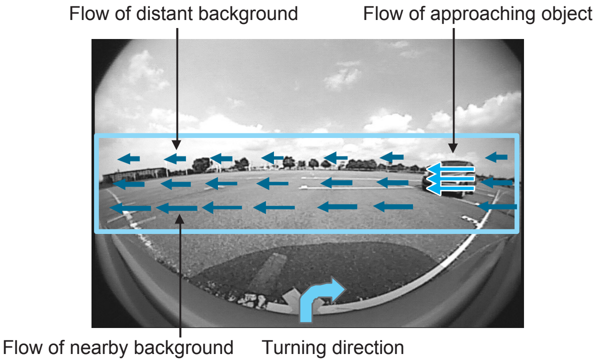

Fig.12 Optical Flows Generated at Turning

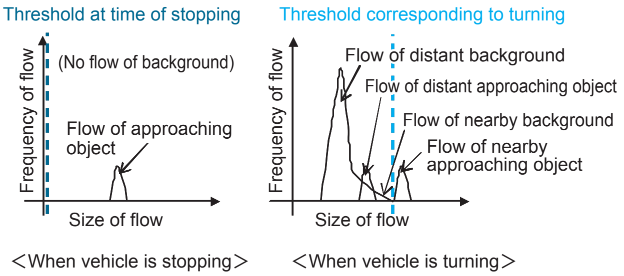

Fig.13 Separation Method of Optical Flows between Approaching Object and Background

By solving these challenges of mounting the system on vehicles, we achieved the system able to work in the assumed scene.

6 Conclusion

We have developed the "support system to inform driver of approaching object" which supports a driver's cognition by combining the existing vehicle-mounted camera system with the approaching-object detection technology. The system is expected to reduce close calls and/or accidents when the vehicle moves out of a parking space or others. Moreover, by incorporating the technology into the existing system, we could develop this system in a short time and at low cost. As the standard equipment, the developed system has been installed in new Harriers of the PREMIUM "Advanced Package" grade, released in December 2013 from TOYOTA MOTOR CORPORATION.

The system is assumed to be used when a driver is going to park the vehicle or is driving slowly. In the future, we think that the system is required to expand its operating conditions or improve its detection performance. Moreover, we think the system is also required to detect not only approaching objects but stationary objects for further reduction of accidents. We will work on these functional improvements of the system and will try to develop a system which can offer greater convenience. Furthermore, we aim to expand the use of the detection function by reducing cost through replacement of the hardware function of the approaching-object detection method with software and by incorporating it into the rear-view camera system in high demand in the market today.

7 Acknowledgment

Lastly, we would like to extend our cordial appreciation to FUJITSU LABORATORIES LTD's senior researchers Mr.Mizutani and Mr.Murashita, who provided cooperation and support for us by supplying the technology of approaching-object detection, and to others who also helped us for developing this system. Also, we greatly appreciate the cooperation of the people concerned, who made efforts to commercialize the system, in Vehicle control system development department No.4 of Vehicle control system development division TOYOTA MOTOR CORPORATION.

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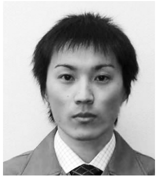
Profiles of Writers



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