Obstacle Detection by Monocular Camera

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Abstract

Recently, the installation rate of in-vehicle camera has been increased as driver assistance device. Above all, the movement which makes installation of rear camera compulsory is active. Moreover the role of rear camera is not only visual assistance but also giving driver's feeling of security for driving, so that it is developing into assistance function.

However secure function by rear camera is mainly provided as a line option, then it isn't mostly possible to be installed in existing cars in the market. We have developed obstacle detection technology which can accurately estimate moving amount of host vehicle only by the image of rear camera without use of vehicle sensor signal, as a secure system which is easily installed in existing cars. We would like to introduce this technology. Also, this technology is introduced to parking assist "Expansion Box for camera function (BSG17)" which was released in December, 2016 by FUJITSU TEN.

1 Introduction

Recently, the installation rate of in-vehicle camera has been increased as driver assistance device. Especially as the movement for compulsory installation of rear camera is active, the fitting rate in 2020 is estimated to be two times of that in 2014. Moreover, traffic accident by reversing vehicles accounts for about 20% of the whole traffic accident, then the role of rear camera is not only visual assistance but also giving a feeling of security to drivers while driving, so that it is developing into one with assistance function.

2 Aim of Development

In the situation like the above, security function by using rear camera such as parking assistance system is mainly provided as a line option, then it isn't mostly possible to be installed in existing cars. We have developed obstacle detection technology by images of rear camera in the aim of providing a security system which is easily installed in existing cars.

Obstacle detection by the images needs calculation of moving amount of host vehicle, but when we take the data of vehicle speed pulse signal or steering wheel angle signal from vehicle, installation capability becomes worse. Therefore, we have developed original image processing technology which can accurately estimate moving amount of host vehicle only by the image of rear camera without use of vehicle sensor signal and could provide obstacle detection function which is superior in terms of installation.

3 Outline of Processing Method (Basic Principle)

Motion stereo method is popular as one of obstacle detection method with use of monocular camera. This is a method for calculating distance to an object based on difference on screen (parallax) at different viewpoint which is measured by moving host vehicle. The object with small parallax (small moving on screen) is far from viewpoint of camera, and the object with large parallax (large moving on screen) is close to it. **Fig. 1** shows the use case of this basic principle for rear camera. **Fig. 1** shows the change of difference of moving amount on screen in proportion to difference between camera viewpoint and distance to the object, focusing on high position and low position (road surface) of the object while a vehicle reversing. In this case, when the object is located high, the distance between camera viewpoint and the object are close, and moves greatly on the screen of camera. As the object which we want to detect is higher than road surface, by calculating the moving amount of road surface on screen, namely magnitude of moving amount of host vehicle, we can judge the object which moves larger than it as the object which is higher than road surface.

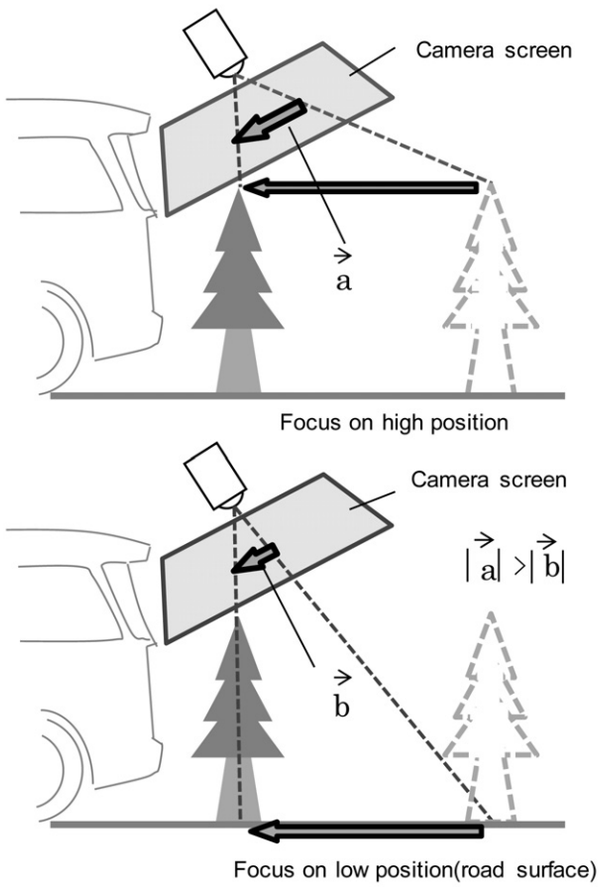

Fig. 1 Basic Principle of Obstacle Detection

4 Flow of Entire Process

Fig. 2 shows a block diagram of entire process flow.

After extracting singularity (namely feature points) such as the corner of an object etc. on a camera image, the direction and magnitude (vector) of feature points are calculated from its movement between two camera images with different time stamp each by image analysis method called "optical flow". The calculated vector is converted to a vector in actual space from the information of mounting height and direction of the camera, then moving amount of host vehicle is estimated from the vector which represents actual host vehicle movement. From the result, the road surface vector is specified and the object which moves larger than it is judged as an obstacle.

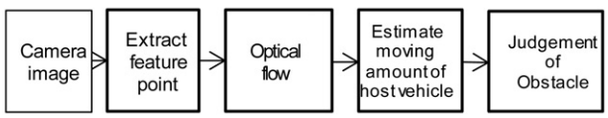

Fig. 2 Block Diagram of Entire Process

5 Moving Amount Estimation Method of Host Vehicle

This time we have developed the method with "road surface projection vector" to estimate moving amount of host vehicle, and realized high speed performance. By this method we have realized real time obstacle detection.

Conventionally, camera images are converted to top-down view of road surface, and those before moving and after moving are shifted to find the matching position by a moving amount estimation method with camera images as shown in **Fig. 3**. (shifting amount equals to moving amount)

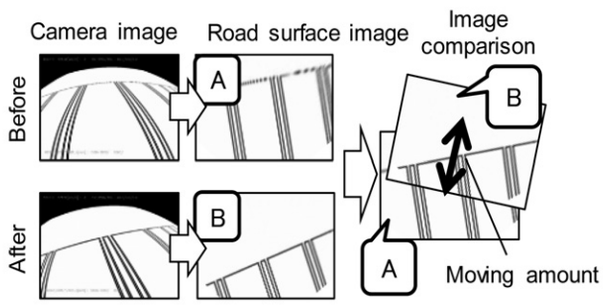

Fig. 3 Moving Amount Estimation by Conventional Method

It is difficult in this conventional technology to process in real time because it needs to search matching position during large image data processing. Then we have developed the method to project the vector on camera image (road surface projected vector) calculated from optical flow onto road surface, and to observe it as a vector on actual space as shown in **Fig. 4**. By use of this method, we can reduce the image data amount to be processed to a minimum and identify moving amount uniquely. Then this method performs processing several ten times faster than conventional processing.

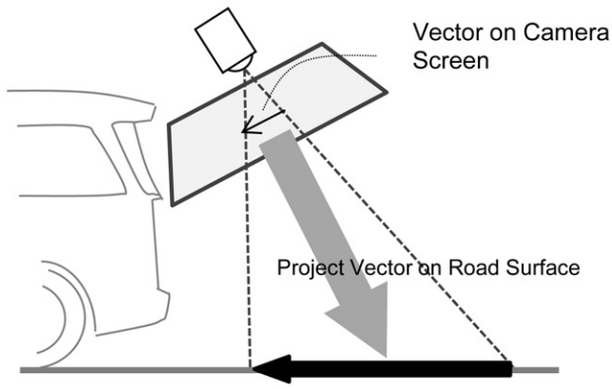

Fig. 4 Road Surface Projection of Vector on Screen and Moving Amount Estimation

6 Judgment of Obstacle

We have simultaneously used "feature point method",

which is effective for short distance detection and "background-subtraction method", which is effective for long distance detection for judgment of obstacle, then we have achieved obstacle detection from distant place to close place of

vehicle stably.

6.1 Feature Point Method

When an obstacle is near vehicle, it is useful that accurate distance to the obstacle is understood and the information is provided to the driver. For example, our product specification recommends that the warning method is changed in stages in accordance with the decreasing distance between the obstacle and the host vehicle to raise attention level to the driver. In case of short distance, we calculate the distance by realizing the obstacle in three-dimensional space with principle of triangulation. As shown in **Fig. 5**, in particular, we measure the distance between the camera and the obstacle with the geometric relationship used by triangulation based on magnitude of a vector of host vehicle (namely inter-view distance) and magnitude of a vector of feature point projected onto road surface. However, the longer the distance from the camera to the obstacle is, the more difficult obstacle detection is because of large calculation error. Also it has another problem that the shape of obstacle is difficult to be recognized.

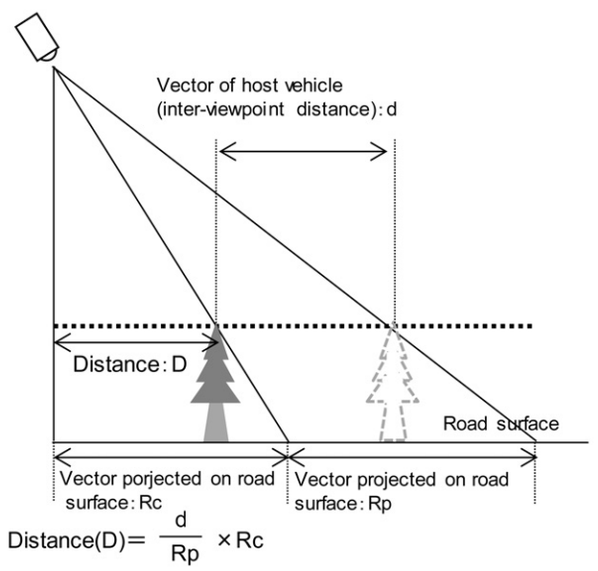

Fig. 5 Distance Measurement Method to Obstacal

6.2 Background-subtraction Method

We simultaneously use the background-subtraction method this time for obstacle detection in order to compensate the problem of feature point method.

The background-subtraction method distinguishes obstacle with height from road as the feature point method by the difference of movement on camera image which is generated by the movement of host vehicle.

Big difference between the background-subtraction method and the feature point method is that the former handles the movement on image as not "point" but "pixel set" with a certain size. **(Fig. 6)** In case of the feature point method, an obstacle is accurately judged by the calculation of moving vector for specified "point" on image. But in case of the background-subtraction method, the obstacle is judged by extracting "pixel set" whose value is larger than a certain threshold on differential image. In this way, the background-subtraction method detects existence or non-existence of the obstacle simply by with / without difference, therefore the obstacle even at a long distance can be detected when the system extracts larger difference than threshold. This method can respond to detect the obstacle at a long distance which is issue of the feature point method, and can recognize shape of the obstacle. But this method doesn't calculate moving amount (equivalent to magnitude of vector) of the extracted obstacle unlike the feature point method.

Therefore this method cannot calculate distance and height in three-dimensional space.

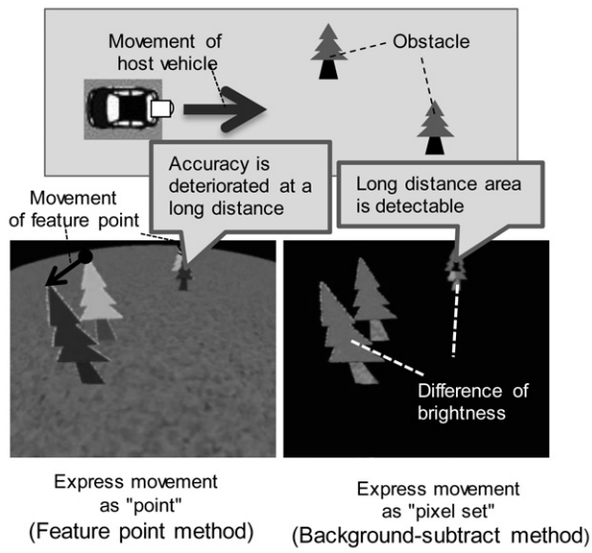

Fig. 6 Difference of Expression of Host Vehicle Movement by Each Method

7 Conclusion

Now we are ready to easily provide security function to a driver only with a rear camera by newly-developed "obstacle detection by monocular camera" technology. This technology is introduced to parking assist "Expansion Box for camera function (BSG17)" which was released in December, 2016 by FUJITSU TEN.

By expansion of this technology obstacles which locate in not only rear area but also front and side area can be detected, then opportunity giving additional feeling of security to driver increases.

We believe further high-precision processing is needed to apply this technology to sensing technology of advanced driver assistance systems. As the means, we will improve the performance to support higher resolution of camera and higher frame rate etc., and continuously contribute the development of the driver assistance systems which make drivers secure to the future.

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