Stereo Vision based On-road Vehicle Detection under Illumination Changing Conditions using Self Quotient Image

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Abstract: Today the many of automotive research groups study how to reduce vehicle accidents. For this reason, they have been developing the advanced driver assistance system (ADAS). In ADAS, the various sensors are used for recognizing the driving situations. For example, there are supersonic wave sensors and radar sensors and so on. In particular, in computer vision research groups, the vision sensors (ex. CCD, IR) are used for this. But it has some difficult problems because the vehicles are mainly driven in outdoors. The images captured by outdoors have various illumination conditions due to weather. It makes difficulty to detecting vehicles in images. In this paper, we introduce the vehicle detection method when the input images of system have illumination changes. We use the self quotient image (SQI) algorithm for illumination equalization. But SQI algorithm produces many false positive results. So we eliminate the false-positive results using stereo vision technique. In main section, we explain this method in detail. And we prove the proposed method has superior performance than existing systems using experiments.

1 INTRODUCTION

Every minute on average, at least one person dies in vehicle accidents. In addition, specific information hasn't been known, vehicle accidents make many casualties or property damages. According to this, the research groups associated with automotive industries are researching and developing various methods for reducing vehicle accidents. One of these is the advanced driver assistance system (ADAS). The ADAS notifies on-road situations to the drivers and helps their safety driving. For this, ADAS should be able to detect the obstacles and information of road. So, in various fields, the researchers are developing the objects detection system for ADAS. For example, there are the smart parking assist system (SPAS) using ultrasonic wave sensor, advanced smart cruise control(ASCC) using radar sensor, night vision using infra-red(IR) sensor and so on. In recent years, especially, the object detecting methods using vision sensors (e.g. CCD, CMOS) are being studied by the computer vision researchers. But the object detecting technique in image has some difficulties. The images from vision sensor have many of the environmental variables according to locations where images are taken. Especially, vehicles are mainly driven on outdoors and the environment of outdoor has various illumination changes. Figure 1 shows the illumination changing effects on vehicle's appearance. The images are taken continuously when the vehicle passes under the bridge. The vehicle appears differently by shadows and reflections.

Figure 1: Illumination change effect.

In this paper, we introduce a vehicle detection method when there are any changes of illumination in image. We use captured images from driving vehicle and the images hold the forward looking of vehicle. Stereo camera equipped with CCD sensors

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was used in the experiment and the output image size of camera is VGA (640×480). First of all, the self quotient image (SQI) algorithm is applied to the output image of camera. SQI algorithm has been mainly used in the field of face recognition and effects on illumination normalization. But SQI decreases the contrast sensitivity of images and decreases classification ability of the classifier also. It makes that the classifier outputs many false-positive results. To solve this drawback, we propose the stereo vision technique. We set the region of interests (ROI) using depth map from stereo camera output. The detection window of classifier is search on the ROI only and the false-positive results of other region (out of ROI) are limited.

The paper is organized as follows: Section 2 analyzes the related approaches, we will explain the SQI algorithm and stereo vision based vehicle detection method in this section. Section 3 shows our proposed method. The experiment results and performance comparison are presented in Section 4. Finally, the conclusion is described in Section 5.

2 RELATED APPROACHES

2.1 Self Quotient Image

In this subsection, we explain the Self Quotient Image (SQI) briefly. As mentioned in the previous section, SQI has been used in face recognition field mainly and effects on illumination normalization. For illumination normalization, above all, the light analysis is needed. The light analysis is widely used in the Retinex algorithm. The Retinex algorithm is compensation method for images degraded by light changing. It is based on the reflectance illumination model like equation (1).

$$I = RL \tag{1}$$

Where I is the image, R is the reflectance of the scene and L is lighting. The light is considered as the low frequency component of image because it mainly affects plane region of objects. So L is represented as the following equation.

$$L \approx F * I \tag{2}$$

We consider the F is a Gaussian filter and * is convolution operation. According to the equation above, R of (1) can be expressed again like equation (3).

$$R = \frac{I}{L} = \frac{I}{F * I} \tag{3}$$

Using the reflectance component R, the SQI is defined as follows:

$$Q = \frac{I}{\hat{I}} = \frac{I}{F * I} \tag{4}$$

Where Q is self quotient image (SQI), $\hat{I}$ is smoothing result of input image I, F is smoothing filter. Figure 2 is SQI algorithm results from Figure 1.

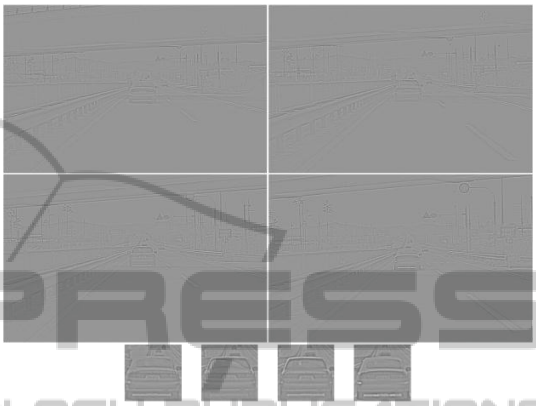

Figure 2: SQI results.

Like Figure 2, the results of SQI algorithm similar to high-pass filter results. Those are same as if they were edge-highlighted images. And we can see the illumination changes of plane region are removed. Especially, SQI is very effective to remove the shadow region.

2.2 Vehicle Detection in Image

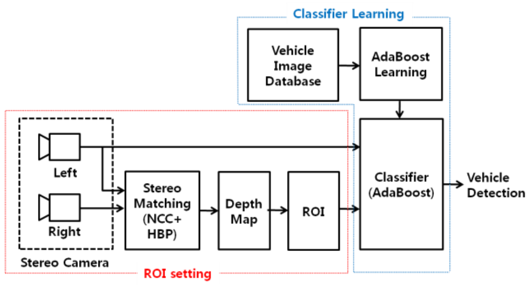

Figure 3: Stereo vision based vehicle detection.

Figure 3 shows the system flow chart that explains the stereo vision based vehicle detection method. This system is divided into two main parts. First part is ROI setting. Second part is classifier learning. In this paper, we introduce this method briefly because this method was fully introduced in our previous papers.

2.2.1 ROI Setting using Stereo Vision

Like Figure 3, the stereo matching part gets two images from stereo camera and computes the depth information. We calculate the matching cost using normalized cross correlation (NCC) and optimize the matched costs using hierarchical belief propagation (HBP). From this depth map, we estimate the road region using U-V disparity calculating method. From this information, we can eliminate the road region and set the remaining blob to ROI. Needless to say, because of depth estimation, we can know the distance from blobs.

2.2.2 Classifier Learning

We use the AdaBoost classifier and Haar-like feature for vehicle detection. The AdaBoost classifier is learned by our vehicle image database. This database is made-up by positive images and negative images. The positive images have vehicle's appearances and the negative images have backgrounds of on-road. To get better performance, we made the image database with our hand but do not use opened one. We set the cascade of AdaBoost classifier to 14 levels and use the Haar-like features that specialized in vehicles.

3 PROPOSED METHOD

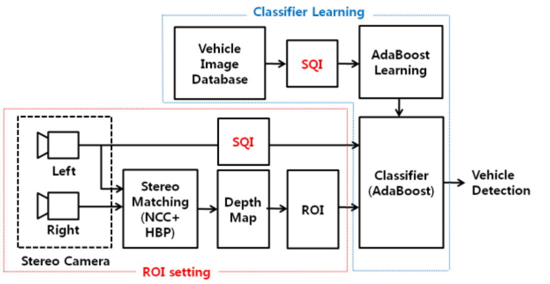

Figure 4: Proposed method.

Figure 4 shows our proposed method. In this method, the AdaBoost classifier is learned by image database that processed SQI algorithm. And the detection window of classifier searches on SQI applied input images. As we explained, the SQI has drawbacks of making many false-positives. To overcome this, we set the ROI using stereo vision technique like subsection 2.2.1. In next section, experiments, we evaluate our proposed method.

4 EXPERIMENTS

Figure 5: Our experimental vehicle and system.

Figure 5 shows our experimental environments. We got the database and test images from stereo camera mounted on experimental vehicle. For real-time processing, the stereo matching part is implemented in hardware (FPGA) and other part is implemented in PC. The used PC has Intel® core™ i7 CPU 2.67 GHz, RAM 4.0GB and Microsoft Visual Studio 2010. For evaluation tests, we use the images below.

Figure 6: Test scenes.

Like Figure 6, the test image sets have illumination changing condition. The scene #1 has 40 frames, the scene #2 has 150 frames, the scene #3 has 100 frames and the scene #4 has 100 frames. Total 390 frames are used for our test.

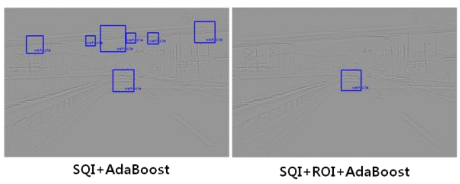

Figure 7: Example of ROI effects.

In Figure 7, the left result have many false-positives. Like the right result, however, our method removes the false-positives using ROI.

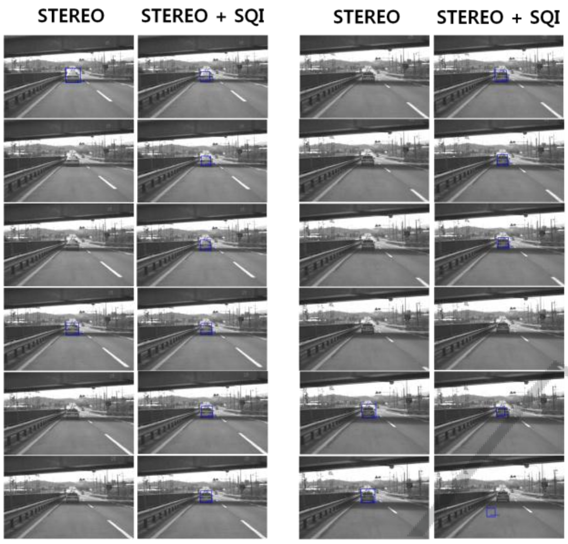

Figure 8: Example of SQI effects.

In Figure 8, the performance of proposed method is better than the conventional one. This experimental result can be seen in YouTube web site (http://www.youtube.com/watch?v=sUwWvBMLPhs).

Table 1: Evaluation results of proposed method.

Scene		#1	#2	#3	#4
F-measure	Stereo	0.786	0.712	0.669	0.754
	Stereo +SQI	0.893	0.801	0.692	0.796

$$\mathrm{F-measure} = \frac{2 \times \mathrm{Recall} \times \mathrm{Precision}}{\mathrm{Recall} + \mathrm{Precision}} \tag{5}$$

Table 1 represents comparison of performance. In all scenes, our method has better performance than the conventional method. In general shadow region, the performance of our method is superior. In completely dark place like scene #3, however, the both classifiers cannot detect the vehicles well.

5 CONCLUSIONS

We have proposed a vehicle detection method under illumination changing conditions. In various illumination conditions, we could see our method has better performance than existing one. In outdoor image, the vehicle detection must consider the illumination effects. Our proposed method contributes to improving performance of vehicle detection. If this method has further improving, the intelligent vehicle technology will be more perfect. In this paper, we could not make accurate performance evaluation because of lack of test scenes. Though more tests, we will get the more accurate results and continue to improve this method.

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REFERENCES

Sun Z., Gebis G., Miller R., 2006. On-Road Vehicle Detection : A Review. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 28, No. 5.

Wang H., Li S. Z., 2004. Face recognition under varying lighting conditions using self quotient image. *Proc. 6th IEEE Int. Conf. On Automatic Face and Gesture Recognition* (FGR'04).

Kim J., Lee C., Lim Y., Kwon S., Park C., 2011. Stereo Vision-Based Improving Cascade Classifier Learning for Vehicle Detection. *Lecture Notes in Computer Science, Advances in Visual Computing*, Vol. 6939, pp. 387-397.

Kim J., Lee C., Lim Y., Kwon S., 2011. Optical Sensor-based Object Detection for Autonomous Robots. *Proc. 8th IEEE Int. Conf. On Ubiquitous Robots and Ambient Intelligence* (URAI 2011). ,

Kim J., Lee C., Lim Y., Kwon S., Park C., 2012. Multithreaded Programming for Real-time Vehicle Detection. *Proc. Int. Conf. On Electronics, Information and Communication* (ICEIC 2012), pp. 194-195.

Kwon S., Lee C., Lim Y., Lee J., 2010. A Sliced synchronous iteration architecture for real-time global stereo matching. *Proc. of SPIE-IS&T Electronic Imaging*, Vol. 7543, No. 754312-1.

Lee C., Lim Y., Kwon S., Lee J., 2011. Stereo Vision-based Vehicle detection using a road feature and disparity histogram. *Optical Engineering* Vol. 50, No. 2.

Viola P., Jones M., 2011. Rapid object detection using a boosted cascade of simple features. *Computer Vision and Pattern Recognition*, pp. 511-518 (CVPR '01).

Van Rijsbergen C. J., 1979. Information Retrieval. *Butterworth-Heinemann*, London.