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Efficient Detection of Direction Indicators on Road Surfaces in Car Black-Box for Supporting Safe Driving

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Abstract

This paper proposes an efficient method to detect direction indicators on road surfaces to support drivers in driving safely using the Simulink model. In the proposed method, the ROIs are detected using the detection method of maximally stable extremal regions (MSER), and the road indicator regions are detected using the speeded up robust features (SURF) matching method for the corresponding point matching of the detected ROIs and the road indicator templates. Experiments on various road satiations show that the processing time of about 0.32 sec per frame was required, and a detection rate of 91% was achieved.

Keywords: *Advanced driver assistance systems, maximally stable extremal region, speeded up robust feature, road direction indicator*

1. Introduction

A recent analysis of traffic accidents shows an increasing trend of vehicle-to-vehicle and vehicle-to-person accidents among the elderly drivers [1-3, 12]. To prevent these traffic accidents, various advanced driver assistance system techniques are being developed, such as the inter-vehicle collision avoidance technology, road traffic sign recognition and the lane departure warning technology [4-7, 9, 13]. Further, the technology for supporting the safe driving of a vehicle is continuously being developed, and driver awareness is being improved considerably. In accordance with these advances, vehicle drivers are installing black boxes in order to store the real-time status information around their vehicles. The fundamental reason for installing a car black box on a means of transportation is to utilize it to determine the precise cause of traffic accidents. However, in reality, the car black box has not been very helpful in supporting safe driving because thus far, it has only been used to judge the after-accident situation. In other words, the reality is that drivers are not recognizing the black box as supportive equipment due to a lack of features for safe driving. Among the five senses that a human has, the sense used most often for driving vehicles is vision. In other words, a vehicle is operated on the basis of the recognition and determination of driving situation in accordance with the driver’s visual information. However, for elderly drivers, presbyopia

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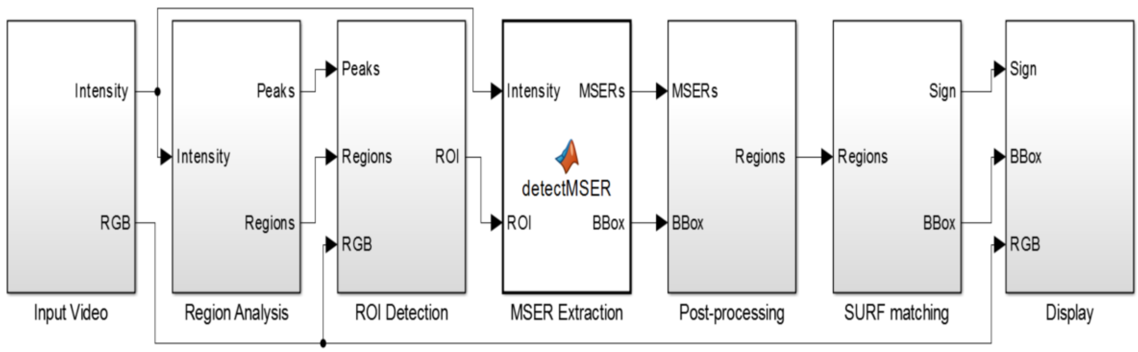


Figure 1. Simulink model of the proposed method.

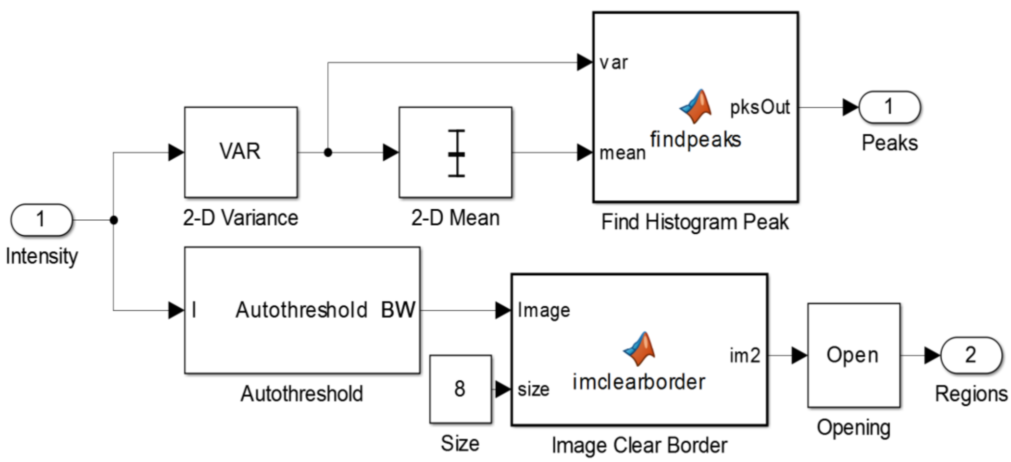


Figure 2. Simulink model for region analysis.

and reduced ability to react instantly due to side effects of physical aging are some of the causes of traffic accidents [2]. A car black box with technologies to compensate for these would play a huge role in supporting safe driving as an alternative way of obtaining visual information [7, 8]. After all, it is possible to provide drivers with pre-processing information by loading an image processing technology on the existing black boxes.

This paper proposes an efficient method to detect direction indicators on road surfaces by receiving images from a car black box using the Simulink model. In order to load such a technology on the black box, it is necessary to design a relatively simple and efficient method since the lowest possible amount of memory and power consumption and real-time processing are required. First, as a result of analyzing the characteristics of the direction indicators on the road surface, we have found that the pertinent indicators are composed of white color tone and located on dark road surfaces. Thus, we need to detect the connected pixels that are formed by a single color from the image. For this, the proposed method detects the maximally stable extremal regions (MSER) [10] and then, detects the road surface indicators by using the speeded up robust features (SURF) [11] matching method.

The Simulink model of the proposed method is shown in Fig. 1. Whether it contains a road indicator or not is determined by analyzing the changes in the intensity of the road surface areas on each frame. Then, a binary region of interest (ROI) video is outputted through the detection process of the MSER after the pre-processing of a particular frame, such as noise reduction, and emphasizing the intensity pixels.

Thereafter, the removal of regions adjacent to the boundaries of the ROIs is performed through the post-processing, and the removal of a small region is performed using the connected components analysis. After matching the final binary ROIs with the SURF characteristic features of the road surface templates, the most similar road surface indicator regions are detected.

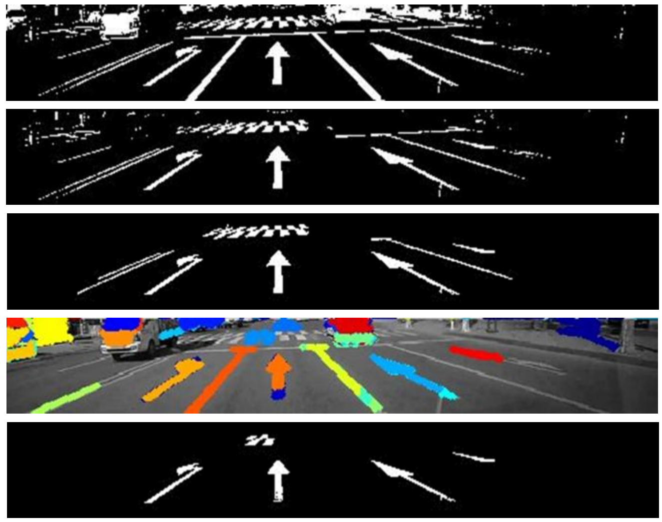
2. Proposed method

In order to reduce the processing time of the images measuring 270×480 pixels by 0.25 times as compared to that of the colored images of 1920×1080 pixels, the Simulink model of region analysis step in Fig. 2 includes determining whether the pertinent indicators are contained in the particular frame or not by using the degree of changes in the intensity, the number of peaks in the intensity histogram, and the number of connected regions that have more than an adaptive threshold value for the regions excluding the upper and the lower areas, i.e., excluding the sky and the road part in front of the bumper. The determination criteria of whether or not the indicators are contained in the input frame (I) are as shown in Eq. (1). After applying Eq. (1)'s average variation, the number of histogram peaks of variation, and adaptive thresholding, we detected the candidate frames with a road direction indicator from the video. Then, the pre-processed binary image and the ROIs are outputted. From the output, regions of less than 40 pixels are removed using a connected components analysis of the binary regions adjacent to the boundary of the detected ROIs along with the road lanes.

$$
\begin{aligned}
& X = \mathrm{var}(I),\ Y = mean(X) \\
& peaks = findpeaks(X, "MINPEAKHEIGHT", Y, "MINPEAKDISTANCE", 20) \\
& whitepixs = size(find(I > 130), 1) \\
& Frame = \begin{cases} if\ \{(X \geq 100) \wedge (Y \geq 6) \wedge (peaks \geq 3)\}, & 1 \\ others, & 0 \end{cases}
\end{aligned} \tag{1}
$$

2.1 MSER Extraction

As for the direction indicators on road surface, they have distinguishable colors and shapes from the background, and thus, MSER has a superior performance with respect to the detection of the significantly prominent regions. The MSER detection process involves sorting out pixels in the order of their intensity, creating groups of the regions with the same level of intensity, and detecting grouped regions that satisfy certain conditions. At this time, the detection conditions are determined according to the minimum and the maximum sizes of the pixels for the grouped regions, and the degree of the changes in brightness. The proposed method sets the threshold level of the intensity of the collected region as 4, the minimum size of the region as 70 pixels, the maximum size of the region as 400 pixels, and the maximum degree of change in intensity as 0.6. Fig. 3 shows the results of the MSER detection and the post-processing.

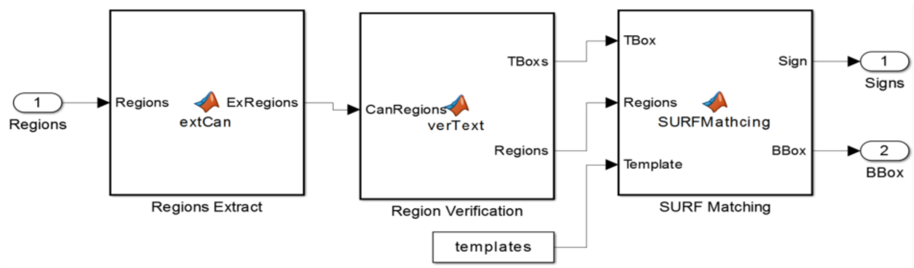


(a)
(b)
(c)
(d)
(e)

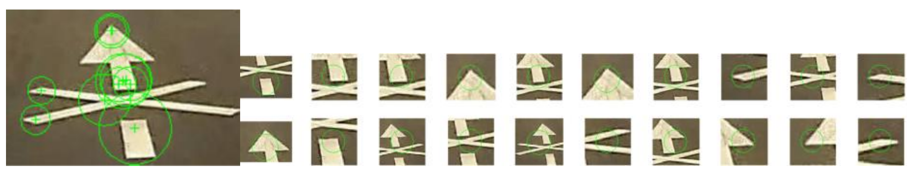
Figure 3. Results of MSER extraction step, (a) adaptive thresholding, (b) removal of boundary regions, (c) removal of regions with less than 40 Pixels, (d) MSERs detection, and (e) result of post-processing.

2.2 SURF Matching

To find the corresponding point is to find the points that have the same characteristics while being in the same physical location, from many images including the same object or scene. In order to find the corresponding point using the local features in various environments, we need to execute the two main steps of feature point extraction and descriptor generation. First, the feature point extraction step has to be executed to find the location of the feature that can be found robustly even when the environment changes in the image. The feature point should be located in the same physical point in the corresponding image and the probability of finding the particular feature point in the other images should also be high. The second step has to be executed to generate descriptors that can explain the feature points found in the previous step. The descriptors should have the characteristics that do not change with environmental changes, and we should be able to distinguish from other feature points. Lastly, the descriptors should be generated using the minimum amount of data to improve the speed of finding the corresponding points by comparing the descriptors of the found feature points. The representative method that satisfies the conditions described above, finds the feature points, and generates the descriptors is SURF algorithm [6] of fast and robust feature point extraction. This algorithm finds a feature point that is unchanging for the changes in scale and rotation from the image, and generates a descriptor at a high speed by using minimal data. Therefore, since the road surface indicators exist in standardized shapes, these indicators are detected in the proposed method by finding the feature point that a road surface indicator has, extracting the SURF-specified information that generates the descriptors by using the minimum amount of data and detecting regions that have the pertinent feature point and the descriptors from the candidate road surface indicator regions. Fig. 4(b) shows the top 10 SURF characteristic information on the road surface indicator template, and Fig. 4(c) displays the regions containing the top 20 SURF regions. In the final indication detection of the proposed method, the template having the minimum Euclidean distance is detected by SURF matching for each indicator template (Fig. 4(d)).



(a) Simulink model for SURF matching



(a) 10 Top SURF **(b) Top 20 SURF Regions**

(d) Detection Result of Road Surface Indicators based on SURF Matching

Figure 4. Detection of Road Surface Indicators using SURF Matching

3. Experiment Results

The input images in the proposed research have a pixel size of 270×480, which is reduced by 0.25 times as compared to the full-HD colored images with a pixel size of 1920×1080, taken by the black box installed inside the vehicle at 10 frames per second. From these input images, the images showing the locations of the direction indicators on the road surfaces are outputted. The environment used for the experiments is Windows7 64-bit operating system (Quad Core 2.3GHz, 32GB) and a GPU device, and Matlab was used for the experiments. The road surface indicators were detected from the input images that were inputted at three frames per second. As a result of comparing the results from the manual detection of the road surface indicators and the results from the proposed method that applied detection in order to test the accuracy of the proposed method, 91% accuracy of detection was obtained for a total of experimental images and the average processing time per frame was about 0.32 sec (as shown Table I). Most of the processing time was consumed by the detection process of the MSER, and the time consumption was minimized as other image processing was carried out only with the connected pixel regions in the 270×480 binary images. As a result of the experiment, most detection errors occurred because of the misrecognition caused by the low light and road contamination. In addition, there were some cases of misrecognizing the letters written on the road surface as the direction indicators. Furthermore, SURF matching detected only one direction indicator when there were two or more same direction indicators by detecting the most suitable direction indicator region.

Table 1. The Detection Confusion Matrix of Direction Indicators on Road Surface

						천천히	30			Other
	98.1			1.38						0.52
		97.5		2.1						0.4
			95.9					2.7		1.4
	1.3			**97.4**				0.2		1.1
					92.3	4.2			0.7	2.8
천천히					7.9	**81.5**				10.6
30							**91.2**			8.8
			4.3					**93.1**		2.6
					3.1				**96.3**	0.6

4. Conclusions

In this paper, we introduced a method to detect direction indicators specified on road surfaces for the purpose of supporting safe driving. The proposed method efficiently detects the road surface indicators from an input image through the MSER detection method and SURF feature information extraction. Even though the proposed method provides relatively good performance in experiments carried out with images acquired during the daytime, a more precise implementation is required to apply it to various road environments such as nighttime and rain. For the purpose of achieving small memory, low power consumption, and minimal heat output as in the case of a vehicle-type black box, a study on a detection and recognition method that is robust to environmental changes will be performed using a learning machine along with a study on the most effective processing technique.

Acknowledgments

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