Extraction and Recognition of Speed Limit Signs in Night-scene Videos

Yoichi Kageyama*,† Member, Kazuto Suzuki† Non-member
Chikako Ishizawa† Member, Takuya Suzuki† Non-member

(Received September 29, 2017, revised October 28, 2017)

Abstract: Road signs provide important information that guide and regulate the behavior of drivers and pedestrians to make their travel safer and more comfortable. However, failure to recognize road signs compromises their safety. The rate of accidental death due to speed limit violation is extremely high at night. To address this problem, automatic video extraction and recognition of road signs can be utilized to contribute to a reduction in traffic accidents. In this paper, we propose an extraction method focusing on the outlines of signs, and a recognition method focusing on the numerical symbols on signs in a night-scene video.

Keywords: speed limit sign, night scene video, image processing, template matching

1. Introduction
Road signs provide important information that guide and regulate the behavior of drivers and pedestrians to make their travel safer and more comfortable. However, failure to recognize road signs compromises their safety. Various traffic sign detection and recognition methods have been developed. Methods using support vector machines [1], random forests [2], scale-invariant feature transforms (SIFT) [3], and neural networks [4]-[6] were have been proposed.

In our previous studies [7]-[9], we proposed methods to detect and recognize circular road signs on the basis of the color and accurate information obtained from images. We demonstrated that one of the approaches that made effective use of light as well as hue and chroma involves able to detect circular road signs with high accuracy under conditions of backlight or shade [9]. These techniques focused mainly on data acquired in the daytime; however, the information provided on the road signs greatly varied between day and night depending on the lighting conditions.

The accidental death rate due to speed limit violation is high at night [10]. To address this problem, automatic video extraction and recognition of road signs can be utilized to contribute to a reduction in traffic accidents. We studied a method to recognize the speed limit signage at night [11]. As a result, it was suggested that focusing on numerical symbols on the sign was useful in recognizing the sign. However, in the paper, (i) there was an image that failed to recognize the marker, and (ii) several pixels above a certain value determined in advance was necessary for recognition.

Fortunately, by common experience, if we fail to recognize a sign in an image, we are still able to recognize the sign by paying attention to the preceding and succeeding frames on our journey. In this paper, we therefore propose a method to improve the extraction rate and the recognition rate of the speed limit signs by using night-scene video, instead of image.

2. Data Used
A high-sensitivity camera manufactured by ELMO (SVM2130) was installed at the passenger seat of a vehicle. Night-scene videos were captured from the vehicle, which was driven within the legal speed limit. The experiment was carried out under weather conditions of which there were rainy periods, and data was collected between 5:00 p.m. and 10:00 p.m. in Akita, Japan.

Approximately 5 h and 40 min of video (RGB color images; 720 × 480 pixels; 30 FPS) was captured. Speed limit signs that satisfied the following three conditions were used as targets: (i) the sign shows no significant discoloration or deformation, (ii) the sign could be visually recognized within 30 frames, and (iii) signs located at the side of a multiple-lane road were not included when the vehicle was not traveling in the left-most lane. The number of the speed limit signs that did not satisfy the above conditions was 75. Thus, a total of 341 instances of signs were used (i.e., 107 instances of 30 km/h speed limit signs; 125 instances of 40 km/h speed limit signs; and 109 instances of 50 km/h speed limit signs). A total of 120 of the 341 instances were used as reference data for analysis, which comprised of 40 instances of each speed limit. The remaining 221 instances were used as the experimental dataset A. Figure 1 shows examples of the speed limit signs. In the experimental dataset A, 97 in-

Figure 1: Examples of speed limit signs captured.
stances captured during the rain periods were adopted as the experimental dataset B.

3. Proposed Method

The proposed method consists mainly of two processes for extracting and recognizing speed limit signs. Specifically, we propose an extraction process focusing on the shape of the signs and a recognition process focusing on the numbers on the signs. Figure 2 shows a flow of the proposed method.

3.1 Extracting the speed limit signs

Focusing on the position where the signs appear in the video, we adopted a target range. Thereafter, by scaling down each $3 \times 3$ pixel area to 1 pixel, pixel smoothing and reduction in processing speed were attempted. Because color information is minimal in a visual scene recorded at night, the image contrast and the gamma values were adjusted. An 8-dimensional Laplacian operator focusing on the Red value of the RGB color system was applied because the outline of the speed limit signs in Japan is red. In addition, by performing binarization, the contour of a sign was extracted as an edge. Because the sign is circular, we estimated the circular region in the videos using the generalized Hough Transform [12]. Based on the preliminary experiment, the maximum diameter of the sign in the reference data was found to be 37 pixels and the diameter of the target sign was set to less than 40 pixels in the scaling down size. As a result, although it is possible to better extract the sign using 40 pixels, the 40 pixels setting was adopted because it allows for noise, such as illumination, and circular signboards at the same time. We focused on the apparent directional face of the signs relative to the motion of our vehicle. It was found, by calculation, that of the displacement of the signs within one frame of video in the experimental data found it to be less than 7 pixels. When a circular outline moved by 8 pixels or more in one frame, the object was assumed not to be a sign and was rejected.

3.2 Recognizing the speed limit signs

First, a labeling process is performed on the extracted circular region. Thereafter, a binarization process, using a discriminant analysis method, is performed to extract the interior white region of the signs. Further, noise is removed by extracting only the largest white area within the circular region. As a result, the region inside the sign is accurately extracted.

In this study, by dividing the area in half, the common part and the feature part were obtained. That is, the number 0, located in the right area of the speed limit sign, was defined as the common part of the speed limit signs. The numbers 3, 4, and 5, located in the left area of the sign, were defined as the feature part of the speed limit for 30 km/h, 40 km/h, and 50 km/h signs, respectively. The signs in Japan are regulated by the Ministry of Land, Infrastructure, Transport and Tourism, and the shape of signs is consistent [13]. In this study, the recognition of signs was performed using template matching. By using bilinear interpolation, the template image was converted to the same image size as the extracted common part and feature part. The template image used consisted of a total of four images ($33 \times 66$ pixels) of the numbers 0, 3, 4, and 5, as shown in Fig. 3. By comparing the extracted common part and feature part with the template image, it is possible to recognize the sign.
4. Results and Discussion

4.1 Extracting and recognizing results for the dataset

A. Figures 4, 5 and 6 show the extraction results and recognition results of the speed limit signs obtained using the proposed method. The proposed method can recognize a sign satisfactorily even if it is situated in a dark area either...
by using the low beam of the headlight (see Fig. 4) or the high beam of the headlight (see Fig. 5). The overhang type road sign is also recognized in Fig. 6.

Table 1 gives the experimental results of the extraction and recognition of speed limit signs by the proposed method. The proposed method obtained an extraction success rate of 95.0%. It also achieved a recognition success rate of 82.8%.

4.2 Comparison with experimental results obtained using a previous method. To verify the usefulness of the proposed method, we also compared it with a method previously used [11]. Because the previous method was intended for images, images were acquired from the video frames. Specifically, an intermediate frame image of “a frame at which visual inspection starts” and “a frame at which visual inspection ends” was used for the previous method. Table 2 gives the experimental results of the extraction and recognition of speed limit signs by the previous method. The previous method had an extraction success rate of 71.5% and a recognition success rate of 21.3%. That is, the proposed method improved the extraction success rate by 23.5% and the recognition success rate by 61.5% under the conditions set in this study.

The results thus confirm that the proposed method is more effective than the previous method for extracting and recognizing speed limit signs at night.

4.3 Processing speed of the proposed method. The average processing time per image (1 frame) of both the proposed method and the previous method was calculated. The experimental environment included a PC with Windows 10, an Intel ® Core™ i7-6700K 4 GHz CPU, and a 16 GB RAM. As a result, the proposed method required approximately 0.29 s of processing time, and the previous method required approximately 0.41 s. This result indicates that the proposed method is approximately 1.4 times faster than the previous method.

Although we did not record the real vehicle speed, the vehicle ran within a legal speed. This is useful for examining the relation between processing time and distance for a vehicle and a circular road sign. The road sign size was 24 pixels or more when the distance between them was closer than approximately 20 m. Data acquisition in this study was possible between 8 to 20 m. In the case of a vehicle traveling at a speed of 50 km/h (approximately 13.9 m/s), the vehicle can reach 4 m in 0.29 s. The result indicates that the proposed method can process multiple frames. In order to process many frames for improving accuracy, shortening the processing time will be considered in future studies.

4.4 Extracting and recognizing results for the dataset B. Table 3 lists the experimental results of the extraction and recognition of the speed limit signs by the proposed method. The proposed method obtained an extraction success rate of 94.8% and a recognition success rate of 78.4%. Compared to Table 1, the recognition rate during the rainy periods decreased.

Figure 7 shows an example of recognition failure. Although the speed limit sign is correctly detected, unfortunately, recognition could not be achieved because of a strong reflection of the headlights. For other reasons, it failed to extract the contour of the sign and internal information displayed on it because of insufficient light intensity. It is therefore necessary to develop algorithms to switch processes according to the data acquisition condition.

5. Conclusion
This paper proposed a method to improve the extraction rate and the recognition rate of speed limit signs at night by using video, instead of image, extraction and recognition. The
following conclusions were obtained:

(a) The experimental results revealed that the proposed method is highly robust to changes in color information and sign size in night.

(b) Sign recognition that was independent of the installation configuration and position of a sign at night was possible by the proposed method.

(c) In the proposed method, it was possible to recognize speed limit signs in 183 out of the 221 images from the experimental dataset A (82.8%). In addition, images captured during the rainy periods (the experimental dataset B) were recognized at a rate of 78.4%.

Shortening the processing time and developing algorithms to switch processes according to the weather conditions will be considered in future studies.

Acknowledgements

This work was supported by a research grant from the Cooperative Research Center, Akita University.

References


