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Color and Shape Feature-based Detection of Speed Sign in Real-time

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***Abstract*— This paper presents a method for detecting speed sign based on color and shape features in real-time under real-life environment. In our method, Region Of Interest(ROI) is extracted and verified based on shape feature. In the first step, ROI is roughly extracted by segmentation of a red rim and the segments are optimized by the boundary using guided image filtering. Next step, the shape-based detection verifies the extracted red rim. We compare three different shape-based detection methods, RSD, BCT, and STVUE, and the RSD shows the best speed sign detection rate of 93% on the experimental data of 62 images containing 85 speed sign.**

Keywords-TSR; speed traffic sign; guided image filtering; RSD; BCT; STVUE

I. Introduction

Advanced Driver Assistance Systems (ADAS) are very important issues for intelligent vehicles. The Traffic Sign Recognition (TSR) is one of ADAS and re-quires a high accuracy since it is directly related to the driver's safety. Various methods have been proposed for TSR [2, 3, 4]. In the competition of German traffic sign recognition benchmark (GTSRB) [5], the commit-tee of CNN/MLP method of Ciresan [6] achieved a highest recognition rate of 99.15%. However, GTSRB is only a multi-category classification competition and it does not include traffic sign detection. Even though the traffic sign classification is excellent, but the traffic sign detection is not enough to be used in many real applications.

This paper focuses on the speed sign detection among the various traffic signs. Some of the real examples are shown in Figure 1. Speed signs in Korea are round with white backgrounds, a red rim and black pictograms. The speed sign has the red rim in order to attract driver attentions. So we first segment the red rim and verify whether the shape of the rim is a circle. Shape-based speed sign detection is studied in [7, 8, 9] and achieves high performance. But the performance largely depends on the preprocessing stages.

In this paper, we present color segmentation and a shape–based verification methods. Figure 2 shows the overall approach in this paper. Section 2 presents a method of rim segmentation based on color features. Section3 compares three different shape-based detection methods. Section 4 shows the experimental results and final conclusion is given in Section 5.

II. Red Rim Segmentation using Color

The detection methods using color features are studied in [10, 11, 12], but these methods are not suitable to the illumination changes. In our approach, the red rim color feature is used for the segmentation of ROI and the shape-based detection is applied to the verification of ROI to increase the detection accuracy. There are two steps in the red rim segmentation: the red rim is first separated from the whole image by applying color thresholding. After that, the guided image filtering is executed to correct boundary shape of extracted traffic sign candidates.

A. Red Rim Segmentation

Color segmentation method should be simple for a real time processing and be robust to the illumination changes. Thresholds in YUV and HSV color spaces for the color segmentation are used in many methods. Kiran [11] proposes an enhanced hue and saturation method using lookup tables, and this method shows excellent results in clear images. But, the results are not suitable for the poor or the complicated images. Therefore, the segmented regions from [11] could have lots of disturbed and miss estimated boundary, which make hard to detect speed sign. To prevent this situation, the shape of segmented regions must be restored to deal with these cases while maintaining real-time performance. The matting is one of the possible solutions to correct boundary, however, it cannot be used in real-time system due to the computational complexity. As alternative to this, we adopt *Guided image filtering* proposed by He et al [13].

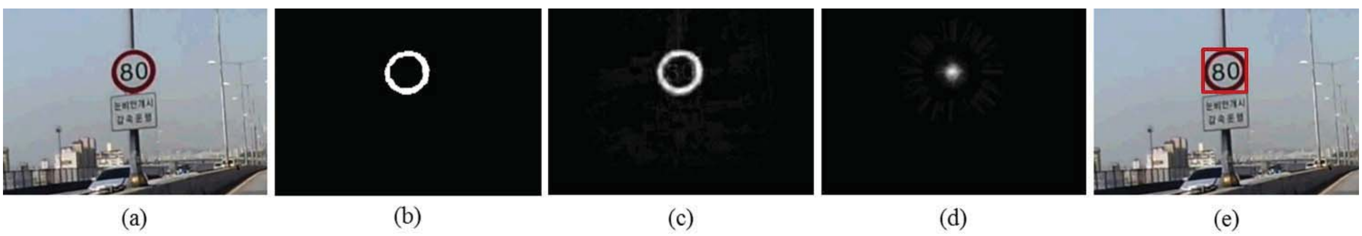

Figure 1. The overall approach: (a) Input image, (b) Red rim segmentation, (c) Red rim optimization (d) Shape-based verification, (e) Detection result

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Figure 2 Examples of speed signs in Korea

The Guided image filtering is kind of edge-preserving smoothing operator like the popular bilateral filter. Because the guided image filtering uses *guidance image* to calculate appropriate weight for neighbor pixel of center smoothing pixel, it can be roughly used as simple matting which called *guided feathering*. For the thresholding image I^t and guidance image I which is input color image, the output image I' can be acquired as

$$I'(p) = \sum_q W_{p,q}(I) I^t(q) \tag{1}$$

where $I'(p)$ is value of pixel p in I', $I^t(q)$ is value of pixel q in I^t, and the $W_{p,q}$ is filter weights depend on guidance image I. For the guidance image, the filter weight $W_{p,q}$ is deinfed as

$$W_{i,j} = \frac{1}{|\mathcal{w}_k|^2} \sum_{k:(i,j)\in \mathcal{w}_k} \left(1 + \frac{(I(i) - \mu_k)(I(j) - \mu_k)}{\sigma_k^2 + \epsilon}\right) \tag{2}$$

where $|\mathcal{w}_k|$ is the number of pixels in filtering window $\mathcal{w}_k$, μ_k and σ_k are the mean and variance of I in $\mathcal{w}_k$. In the guided image filtering, output image I' can be computed using some linear operations as

$$a_k = \frac{\frac{1}{|\mathcal{w}|}\sum_{i\in \mathcal{w}_k} I(i) I^t(i) - \mu_k \overline{I_k^t}}{\sigma_k^2 + \epsilon} \tag{3}$$

$$b_k = I_k^t - a_k \mu_k \tag{4}$$

$$I'(i) = \bar{a}_i I(i) - \bar{b}_i \tag{5}$$

where $\overline{I_k^t} = \frac{1}{|\mathcal{w}|}\sum_{i\in \mathcal{w}_k} I^t(i)$, $\bar{a}_i = \frac{1}{|\mathcal{w}|}\sum_{k\in \mathcal{w}_k} a_k$, and $\bar{b}_i = \frac{1}{|\mathcal{w}|}\sum_{k\in \mathcal{w}_k} b_k$. As shown in figure 3, the shape of possible traffic sign is improved after applying guided image filtering.

III. Shape-Based Detection and Verification

In this section we compare three different shape-based detection methods for the verification of the extracted red rim. All the methods regard each pixel of the red rim as an element of the circle, and each pixel of the red rim estimates the center of the circle considering its gradient orientation. These methods can be divided into two types, single pixel voting and pair-wise pixel voting. In the single pixel voting type, each pixel votes for the center of the circle. In the pair-wise pixels voting type, the pair-wise pixels are regard as the elements of a circle and votes for the center of the circle.

A. Radial Symmetry Detector

Radial Symmetry Detector (RSD) [7] is a single pixel voting scheme to detect a circle. It estimates center of the circle which has distance r from each pixel in gradient orientation. Each pixel votes for estimated center of a circle. This step is run repeatedly in all the possible radii. Figure 4 shows voting scheme of RSD.

B. Bilateral Chinese Transform

Belaroussi [8] proposes a Bilateral Chinese Transform (BCT) for the road sign detection that includes speed sign. BCT is a pair-wise pixel voting scheme, and it can detect circle, square, rectangle and octagon. Figure 5 shows the voting scheme of BCT. If a pair-wise pixel has parallel or converse orientation and distance in a specific range, a pair-wise pixel votes for their middle point.

C. Single Target Vote for Upright Ellipses

Single Target Vote for Upright Ellipses (STVUE) [9] is a pair-wise pixel voting method and it is similar to the BCT. Figure 6 shows the voting scheme of STVUE. The main idea is that a pair-wise pixel votes for the intersection point of two straight lines passing each other. Considered pair is same x-coordinate for more performance.

Maxima voting take local maxima in vote image. And then, by comparing a center of the red rim and the maxima voting in the vote image, it can be verified whether the red rim is a speed sign or not.

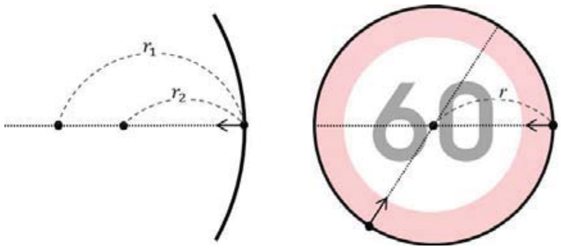

Figure 4 Radial Symmetry Detector

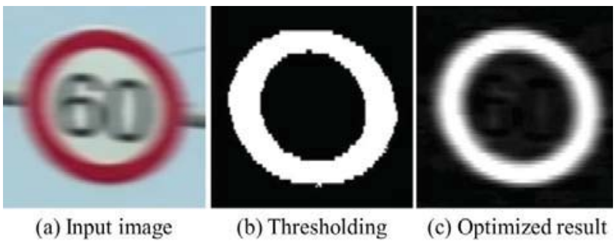

Figure 3 Example image from real driving environment (a) camera shake caused blurness (b) result of thresholding (c) optimized result from guided image filtering

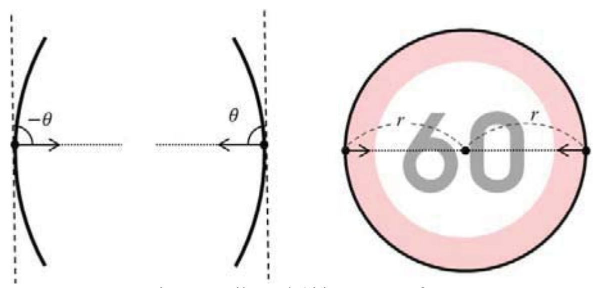

Figure 5 Bilateral Chinese Transform

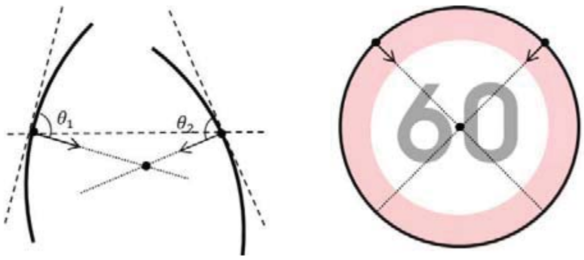

Figure 6 Single Target Vote for Upright Ellipses

IV. Experimental Result

In our experiment, we use the test image data which are obtained by the vehicle's black box camera and the mobile phone camera. Dark and noisy images also included to test image data which are shown in Figure 7. We use 62 test images having 85 speed signs.

The detection rate of proposed method is compared with 3 different detecting method explained in Section 3. The first experiment is executed by measuring the number of maxima voting for the detailed performance comparisons, which measure method is adopted by Houben [9]. A high rate with a small number of considered maxima voting means that a false positive is low and a true positive is high. Thus a stable method has a high detection rate with a small number of considered maxima voting. In Table 1, the RSD has the highest detection rate with a small number of maxima voting. We confirm that the detection rate is not affected even if the number of maxima voting exceeds 15.

Next, we compare the detection rates according to the color space representations by measuring the color distance from the true red values. In this experiment, the maxima voting were set to 15.

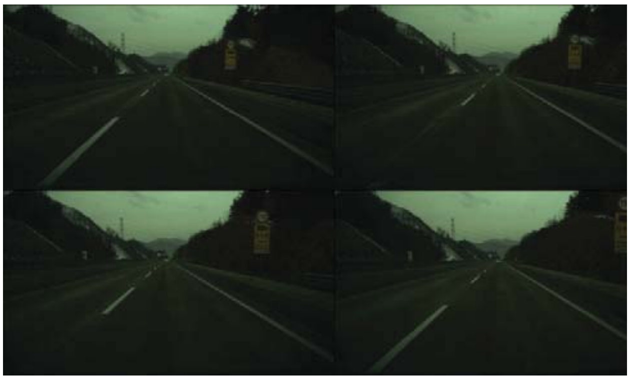

Figure 7 Examples of the experimental data

Table 2 The detection rates according to the number of maxima voting

# of maxima voting	RSD(%)	BCT(%)	STVUE(%)
5	90.6	85.9	88.2
10	91.8	88.2	88.2
15	94.1	91.8	91.8
20	94.1	91.8	91.8

Table 1 The detection rates according to each method of color distance from the true red value

Method	Enhanced H & S (%)	V in YUV (%)	Our method (%)
RSD	87.1	88.2	94.1
BCT	84.7	85.9	91.8
STVUE	87.1	85.9	91.8

Table 2 shows that our method has the highest detection rate. Even though the detection rate of BCT is the lowest in every case, BCT is also improved by using our segmentation method. Figure 8 shows images of the correct detection.

Our method has advantages in both improved detection rate and reduced processing time. With desktop environments (Intel core2 quad 3.0Ghz, 2GB RAM), each processing time is 300ms on the average. Especially, the pair-wise pixel voting methods such as BCT and STVUE are greatly improved. However it has still difficulties in poor images like Figure 9.

V. Conclusion

In this paper, we propose the simple real-time speed sign detection algorithm using color and shape features. The proposed method improves not only the detection rate, but also the processing speed.

Future work would be to improve the detection rate under restrict case which input images captured at night or bad weathers. We will also extend our work to detect the various traffic signs to construct a robust TSR system.

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Figure 8 Images of the correct detection

Figure 9 Images of the failed detection

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