# Real-time Korean Traffic Sign Detection and Recognition

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# ABSTRACT

In this paper, we propose a real-time Korean traffic sign detection and recognition method based on color properties and shape geometries of images. The proposed method supports detecting and recognizing various shapes of traffic signs in realtime. Our method consists of four stages: 1) color based image segmentation; 2) region of interest (ROI) detection; 3) shape classification; and 4) numeral recognition. The proposed method can classify even the signs that are partially occluded. In addition, we improve efficiency of shape classification by using simple shape geometry measurements. Our experiment shows that our approach can provide high classification accuracies for octagonal shape signs (92%) and speed-limit signs (94.5%).

## **Categories and Subject Descriptors**

I.4.9 [Image Processing and Computer Vision]: Application; I.5.1 [Pattern Recognition] Models – Neural nets; I.5.4 [Pattern **Recognition**]: Application – Computer Vision;

## **General Terms**

Algorithms, Measurement, Verification

## Keywords

Traffic Sign, Road Sign, Color Segmentation, Shape Classification, Sign Symbol Recognition, Sign Character Recognition

## **1. INTRODUCTION**

Recently, Advanced Driver Assistance System (ADAS) became one of the key techniques studied in the field of intelligent vehicles. Within ADAS, Traffic Sign Recognition (TSR) system is an important component for the driver's safety, and the system needs to achieve high accuracy and real-time performance. There

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have been various methods[1-6] proposed to assure high accuracy. TSR methods include mostly three steps, color segmentation, sign detection and sign recognition:

- Color segmentation: This stage generates a color map by using characteristic color properties of traffic signs in a given image. The characteristic colors are red, yellow and white since they are the most dominant colors in the traffic signs. Typical color segmentation methods make use of static thresholding or dynamic thresholding. However, fiding a proper threshold value is not easy due to various illumination changes (backlight, night, etc.) in the images acquired from the vehicle. Recently, diverse preprocessing techniques are proposed to deal with such illumination problems. The segmentation result is a binary image such as Color map[1] or Saliency map[2].

- Sign detection : This stage extracts pixel blobs in the color map and performs shape classification. Typically, the pixel blobs are generated by connecting adjacent pixels based on 8-neighbor system from the color map. Each blob can be rejected or accepted by connected component analysis or geometry characteristics.

- Sign recognition : This stage recognizes the sign contents. In this stage, all the possible traffic signs in a given database are used. For each sign, based on the shape of the sign, the content of the sign, i.e. pictogram, is recognized with sign classifiers that are trained for the shape. Since the shape of the sign is already determined in the detection stage, the appropriate classifiers are applied to recognize the content.

On the other hand, Jialin Jiao et al[3] suggested a robust multiclass traffic sign detection and classification system using asymmetric Haar-like features for traffic sign detection and classification. C. Nahlmann et al [4] was ranked highest in German traffic sign recognition test and D. Ciresan et al [5] achieved 99.15% of recognition rate using neural network approaches. However, they only perform recognition of traffic sign contents within the pre-defined ROI, and detection of signs in the image was ignored. Even though the accuracy of recognizing the sign contents was quite high, their system is not appropriate for real-time applications in intelligent vehicles.

Also, while classifying the shape of the segmented blobs, shapes can be distorted by camera angle or by partial occlusion of trees

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and streetlights. Jafar Abukhait *et al* used vertices and distance between two vertices to recognize shapes of occluded signs [1,7].

In this paper, we propose a system for detecting Korean traffic signs and recognizing speed-limit signs. Some examples of the signs are shown in Fig 1. Since Korea is a member of UN Vienna Convention and follows the Convention, our approach can also be applied to signs from those countries.



Figure 1. Examples of Korean Traffic Signs

This paper is organized as follows: Section 2 introduces the proposed algorithm including color segmentation, ROI detection, shape classification, and numeral recognition. Experimental results and evaluations are presented in Section 3.



Figure 2. Flow chart of the proposed method

## 2. METHODOLOGY

In this section, we present a traffic sign detection, its shape classification, and sign content recognition methods. Fig 2 shows individual steps using a flowchart:

- Color segmentation: It extracts candidates of traffic sign objects from a given image using RGB color thresholding.
- ROI detection: Pixel blobs are extracted from the color map, and ROI is selected based on the size, aspect ratio and color composition of each blob.
- Shape classification: Sign shapes are classified based on the geometric characteristics in ROI.
- 4) Numeral recognition: Characters inside the circle-shaped signs are extracted and recognized.

## 2.1 Color Segmentation

Each road image frame is segmented by red and yellow colors, thus generating two binary color maps. Each binary color map highlights the sign shape as shown in Fig.3.

RGB thresholding is applied to the input image to segment the specific colors used in the traffic signs. However, the colors of the real road images are often affected by the illumination changes. Thus, HSI color space is also used instead of RGB color space, since HSI is more robust to the illumination variations. In HSI, hue represents dominant color values, and saturation represents purity of each color[7]. By using hue in HSI, the segmentation can be more robust against the illumination changes. In our system, in order to support real-time processing, we use a normalized RGB color[8], which lowers illumination variations and avoids computations required for the color transformation.

With the normalized RGB colors, the red and yellow maps are generated by the following equations:

$$Map_{red}(i,j) = \begin{cases} true, \ red(i,j) \ge th_r \ and \ green(i,j) \le th_g \\ false, \ otherwise \end{cases}$$
(1)

$$Map_{yellow}(i,j) = \begin{cases} true, & red(i,j) + g(i,j) \ge th_y \\ false, & otherwise \end{cases}$$
(2)  
$$Where, & th_r = 0.4, & th_r = 0.3, & th_r = 0.85 \end{cases}$$

The binary color maps show whether each pixel value is within a predefined range.



Figure 3. (a)-(c) Input images, (d)-(f) binary color maps

Our system performs a pre-processing before the color segmentation. Appropriate pre-processing improves the quality of the binary color maps as shown in Fig. 4, since the color adjustments can generate the different results. Fig. 4 shows the extracted red map from the image that includes severe backlight. The result with a PDE Retinex method is the best, but it consumes too much computation time. In our experiments, we used only every three frames to reduce processing time.



Figure 4. (a) Original image, (b) simplest color balance result, (c) PDE Retinex result, (d)-(f) binary red color maps

#### 2.2 ROI Detection

In this section, blob-based ROI is generated from each color map and non-traffic signs are discarded from the candidate ROIs. The blobs are constructed from the connected pixels according to 8neighbor system. Each type of traffic sign has its unique shape and color compositions as shown in Fig 1. Thus each blob is verified though those properties.



Figure 5. (a) Red + yellow sign type, (b) only red or red + white sign type

For validating each blob, three properties are checked in a sequence: size, aspect ratio and color compositions.

- (1) Size: Blobs are discarded when they are too big or too small. Because too small blob's pictogram can't be recognized. In our experiments, we use the following constraints: minimum size = 35 × 35; (pixels) maximum width = ROI<sub>width</sub> × 0.25; (pixels) maximum height = ROI<sub>height</sub> × 0.25; (pixels)
- (2) Aspect ratio: The traffic sign usually has 1:1 aspect ratio. However, distortions can happen due to camera distortions and vibrations on the vehicles. Since the distortion is mostly within 10~15%, the blobs outside of this range are discarded.
- (3) Color composition: Each blob can also be discarded according to its color compositions. Red colors are distributed around the rim of signs or the entire signs, and the triangle signs are composed of red rim and yellow or white inside. As shown in Table 1, the specific color composition rules can be found in traffic signs. Thus, the blobs that are not in this bound are discarded.

Table 1	Color	composition	rate in	the sign R	OT.
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Туре	Red(%)	Yellow(%)
Circle	25.0	0.0
Octagon	51.5	0.0
Upper Triangle	21.8	15.0

## 2.3 Shape Classification

The sign ROI is classified according to its shape. Triangles and octagons have several corner points and circles do not have the corner points. Relationship between the corner points can be used for the classification. Our approach can also deal with partially occluded signs.

Since the vehicles in Korea are running on the right side of the road, occlusions occur more frequently on the right side of the traffic signs. Considering this tendency and the geometric symmetry of the sign, non-occluded parts of the sign can be used. The proposed method can classify such occluded shapes.

#### A. Non-circle classification

Non-circle signs have always corner points, and thus the relationships between the corner points are used for determining the sign shape. However, there still exists a chance that the multiple corner points can be found due to the color contamination of the edge regions. Thus, we applied the 8 types of vertex to represent sign shape [9]: Top-Left:  $T_l$ ; Top-Right:  $T_r$ ; Right-Top:  $R_t$ ; Right-Bottom:  $R_b$ ; Bottom-Right:  $B_r$ ; Bottom-Left:  $B_l$ ; Left-Bottom:  $L_b$ ; Left-Top:  $L_t$ . The vertices can be extracted by finding the most outer points from the detected corner points in the shape.

The classifications between triangle and octagon shaped signs are as follow.

#### A.1 Triangular sign classification

Triangular shape consists of Upper(normal) triangle and Lower(inversed) triangle. The triangular shape can be expressed by 8 vertices described above. The 8-vertice expression can handle the partial occlusion of the right side as shown in Fig 6.



#### Figure 6. Partially occluded triangular sign shapes

Even with such occlusions, Upper and Lower triangles are classified as below:

- Partially occluded (or not) Upper triangular shape:

Upper triangle satisfies the following constraint:

$$(L_t \approx L_b \& R_t \approx R_b) \text{ or } (L_t \approx L_b \& T_l \approx T_r) \quad (3)$$

- Partially occluded (or not) Lower triangular shape:

Lower triangle satisfies the following constraint:

$$(L_t \approx L_b \& B_l \approx B_r) \tag{4}$$

#### A.2 Octagonal sign classification

Octagonal sign shape also can be expressed as 8-vertices. Fig. 7 shows the possible cases of occlusion.



Figure 7. Partially occluded octagonal sign shapes

Octagonal sign shape satisfies the following condition:

$$(B_l \neq B_r \& L_t \neq L_b) \& (R_t \neq R_b \mid T_l \neq T_r)$$
(5)

#### B. Circle classification

Unlike non-circle shapes, circles have no corner points. Typically, Hough transform is used to detect circles, but it takes a huge amount of computation time. Thus, we suggest a new method.

The circle signs in the images obtained from the running vehicles are easily distorted as an oval or as circles with partial occlusions. The distance between the center and the edge point of a circle is fixed, but it is not fixed in the oval case as shown in Fig 8[10].



Figure 8. Cases of a normal circle and an oval



Figure 9. Examples of five points in the circular shape

Our prior pilot tests showed that the radius of arcs on nonoccluded region is uniform. Fig 8 shows the proposed five data points on the partially occluded circles or ovals. The proposed method can distinguish between the circle and the oval signs regardless of partial occlusions as described below.

#### - Partially occluded (or not) circle shape:

Partially occluded circles satisfied the following constraint:

$$l_{i} = \frac{1}{N} \sum_{p \in S} ||p - c||^{2}$$
(6)

Where,S is set of edge pixels from  $P_i$  to  $P_{i+1}$ c is the center pointN is # of edge pixels from  $P_i$  to  $P_{i+1}$ 

$$(l_1 \approx l_2 \& l_2 \approx l_3 \& l_3 \approx l_4) \tag{7}$$

#### - Partially occluded (or not) oval shape:

Partially occluded ovals satisfied the following constraint:

$$(l_1 \approx l_2 \& l_3 \approx l_4) \& (l_2 \neq l_3)$$
 (8)

## 2.4 Numeral Recognition

Speed-limit sign consists of red rim, white background and black numerical characters as shown in Fig 1. Thus, we extracted the characters inside and recognized them by using an artificial neural network.

We use the geometric layout of the signs. For example, for speed-limit sign the characters are located at center within 35% vertically and 15% horizontally of the ROI. With this method we can extract the character region accurately as shown in Fig 10.



#### Figure 10. (a) Original image, (b) Gray-scale image, (c) Horizontal and vertical guidance by the ratio, (d) Cropped image, (e) Histogram equalized result, (f) Final binary image

There can be more than one character in the extracted region. We first process the character region with histogram equalization and then apply the binarization. Finally, red rim is removed from the binarized image and each character blobs are extracted using the connected component analysis.

The extracted character blobs are a form of binary patterns that can be simply serialized and used as an input to the neural network. We constructed a 3-layer neural network. Neurons in the result layer consist of 0-9 classes. The neural network is trained by 500 images per each class, and 5,000 images are obtained from the video frames of the road vehicles.

## **3. EXPERIMENTAL RESULTS**

In our experiment, we use the test image data that are obtained by the vehicle's black box camera and smart phone camera. This data consist of various road scenes including highways and downtown streets, and some examples are shown in Fig 11. The road driving scene dataset starts from the moment of sign appearance to the disappearing moment of the traffic sign. This video has 1,827 frames in total. The detection rate of the proposed method is summarized in Table 2. The detection result is true when both ROI detection and shape classification are true.

Table 1. Summary of circular sign detection results

	Speed-Limit Sign	Other Circular Signs
Number of signs	807	620
Number of detected signs	763	498

Detection Rate	94.5%	80.3%
Speed Character	98.2%	N/A
Recognition Rate	2012/0	1011

Table 2. Summary other sign detection results

	Upper Triangular shape	Lower Triangular shape	Octagonal shape
Number of signs	205	95	50
Number of detected signs	176	79	46
Detection Rate	85.8%	83.1%	92%



Figure 11. Result of correct detection

The detection rates in the other circular signs are low when the sign does not follow the rules of the Vienna Convention or it has severe illumination changes. Such non-standard signs have thin red rims than the normal speed-limit signs, and the colors are not well segmented. Such phenomena frequently occur in the shapes as shown in Table 3. The detection result of the proposed method is relatively sensitive to various illumination changes such as backlight, night, *etc.* 

## 4. CONCLUSION

In this paper, we propose a real-time Korean traffic sign detection and recognition method based on color properties and shape geometries of the signs. The proposed method supports detecting and recognizing various shapes of traffic sign in real-time, and it can classify even the sign is partially occluded. Also, our shape classification method has lower computation time, since it used a simple measurement of the shape geometry. Our experiment shows the high classification accuracies for octagonal shape with a 92%, speed-limit sign with a 94.5%.

The future work includes an image quality improvement to handle various illumination changes and recognition of the noncircular shapes that are currently detected but not recognized.

## 5. ACKNOWLEDGEMENTS

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