Speed Limit Traffic Sign Classification Using Multiple Features Matching

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Abstract. This paper presents the method to classify the speed limit traffic sign using multiple features, namely histogram of oriented gradient (HOG) and maximally stable extremal regions (MSER) features. The classification process is divided into the outer circular ring matching and the inner part matching. The HOG feature is employed to match the outer circular ring of the sign, while MSER feature is employed to extract the digit number in the inner part of the sign. Both features are extracted from the grayscale image. The algorithm detects the rotation angle of the sign by analyzing the blobs which is extracted using MSER. In the matching process, tested images are matched with the standard reference images by calculating the Euclidean distance. The experimental results show that the proposed method for matching the outer circular ring works properly to recognize the circular sign. Further, the digit number matching achieves the high classification rate of 93.67% for classifying the normal and rotated speed limit signs. The total execution time for classifying six types of speed limit sign is 10.75 ms.

Keywords: Speed limit traffic sign · HOG · MSER · Template matching

1 Introduction

Traffic sign recognition based-on a machine vision is one of the extensive researches in the intelligent transportation system. The system detects and classifies the traffic sign for assisting the driver or employed as an integral part in the autonomous vehicle. The speed limit traffic sign is one of the traffic signs that should be obeyed by the driver to avoid an accident. An automatic system to recognize the speed limit traffic sign is an interesting topic such as addressed by [1–6].

Traffic sign recognition is usually divided into detection stage, where the location of sign is detected from an image, and the classification stage where the detected sign is classified to the reference. In the classification stage, template matching techniques [7–9] and machine learning techniques [1, 3–6, 10, 11] are commonly employed.

In [7], the traffic sign templates consist of the pictograms (black and white images) of traffic signs in the normal position and the rotated one. Instead of the black and white images, the color images were used as the templates [8]. In [7, 8], the correlation technique was employed in the matching process. In [9], the ring partitioned matching was employed to classify the red circular traffic sign. The matching was performed on

K.J. Kim et al. (eds.), *IT Convergence and Security 2017*,
Lecture Notes in Electrical Engineering 449,
DOI 10.1007/978-981-10-6451-7_26

each ring with the different weights. To cope with the rotated images, the method employed the image histogram (fuzzy histogram) in the matching process.

The methods commonly used in the machine learning techniques are k-Nearest Neighbors algorithm (kNN), Support Vector Machine (SVM), and Artificial Neural Networks (ANN). In [1], the kNN was employed to classify the rectangle speed limit sign according to the size. Further the optical character recognition (OCR) technique was employed to read the speed number of the sign. The SVM classifier was employed in [3, 10] for classifying the traffic sign. In [3], the property curves of segmented digit number of speed limit sign was used to train the SVM classifier. The histogram of oriented gradient (HOG) was employed as the descriptor of the traffic sign image in the classification process which is performed using the SVM [10, 11]. They concluded that the HOG is an effective descriptor for classifying the traffic sign. In [5], the ANN was employed to recognize the number in the speed limit sign. The method first extracted the digit number of detected speed limit sign to generate the number in the binary image. Then the binary image was used by the ANN in the recognition process. Instead of using the binary image, the grayscale image was used as the input of the ANN [6].

The benefit of template matching technique compared to the machine learning technique is that no training process is required. However, to cope with all possible conditions of traffic signs, more traffic sign references are required as proposed by [7]. Our previous work in [9] overcome the rotation problems by employing the histogram of image which is calculated in each ring area. Since the method is used to classify the circular red sign where there are two colors in the image (red color on the outer part and blue or black color in the inner part), two color thresholding techniques are employed in the preprocessing stage.

In this paper we propose a novel technique to classify the speed limit sign using the multiple features, namely HOG and maximally stable extremal regions (MSER) features extracted from a grayscale image. The method first extracts the HOG feature in the outer border of image to match the circular ring. Then the MSERs are extracted in the inner part of image to obtain the binary image of the digit number of speed limit sign. The template matching is employed to match the number into the predefined one. To cope with the varying rotation problem, an affine transformation is applied in the binary image before the matching process. The main contributions of our work are: (a) it employs the grayscale image, thus there is no complex color conversion; (b) it employs the simple matching technique; (c) the method is rotation invariant.

The rest of paper is organized as follows. Section 2 presents our proposed system. Section 3 presents the experimental results. The conclusion is covered in Sect. 4.

2 Proposed System

2.1 System Overview

Flowchart of proposed system is illustrated in Fig. 1. It starts with the grayscale color conversion to convert RGB image into grayscale image. It is noted that the input image is the detected traffic sign bounded with the rectangle box. Then the HOG feature is extracted in the outer part of the image. Since the outer part of speed limit sign is a

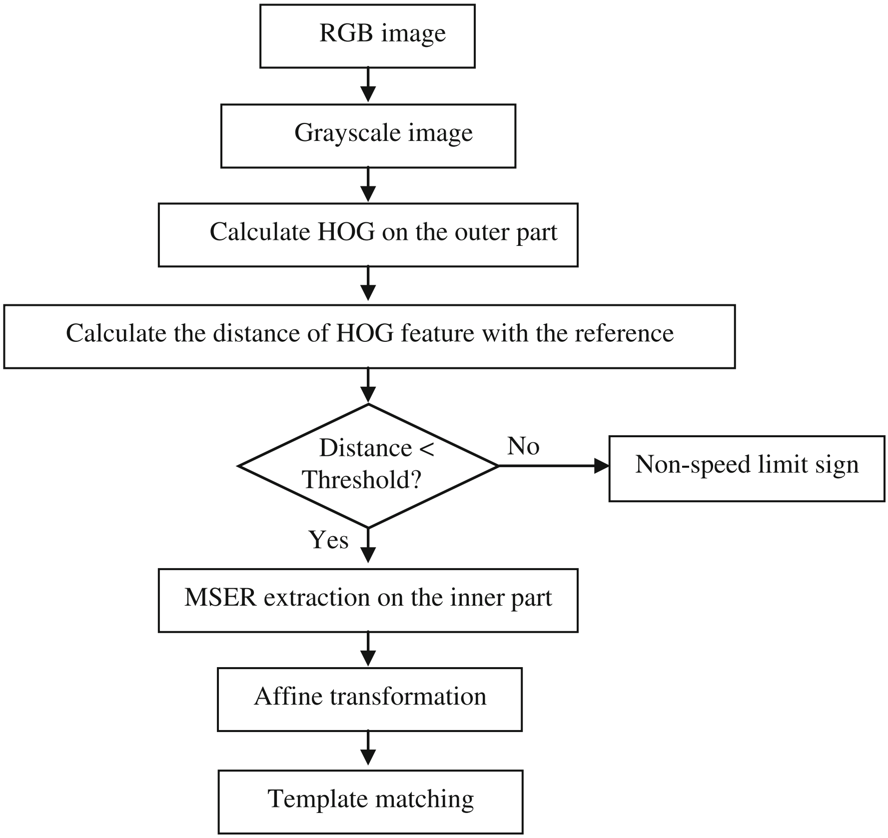


Fig. 1. Flowchart of proposed system

circular ring, the HOG feature is rotation invariant. Thus, the HOG feature could be matched with only one reference circular ring. When it is matched, the next step is to match the digit number, otherwise the sign is classified as the non-speed limit sign.

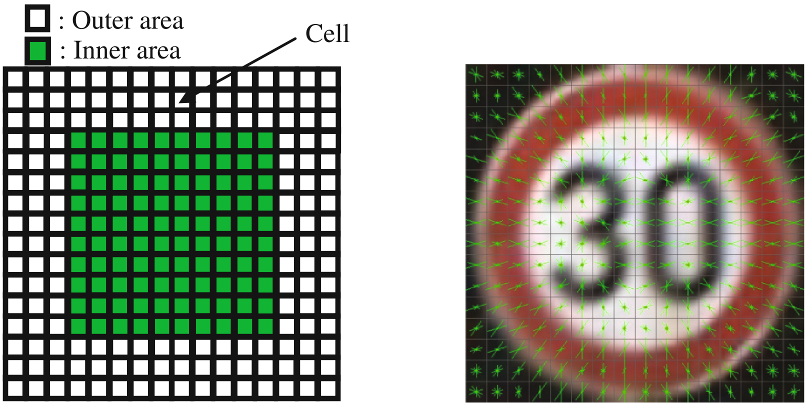
To match the digit number, it performs the MSER extraction in the inner part of the grayscale image. It yields the connected component of each digit in binary image. Then the contour of each component is found. The ellipse fitting technique is adopted to find the orientation of the component. It is assumed that when the traffic sign rotates, all digits will rotate with the same orientation. Thus we could get the rotation angle from the orientation of the ellipse.

From the detected rotation angle of the sign, an affine transformation is adopted to rotate the number to the normal position (orientation of zero degree). Finally the template matching technique is employed to match the digit number to the predefined reference.

2.2 HOG Feature

The HOG represents the histogram of orientation of gradient in an image which is proposed by [12]. The descriptor is robust to illumination changes. However, it is rotation variant. In this work we adopt it to match the outer part of the speed limit sign (see Fig. 2(a)), where the circular ring exists. Thus, when the speed limit sign is rotated, the HOG feature of the outer part does not change.

To calculate HOG, the image is divided into cells as shown in Fig. 2(a). In this work, the image is resized into 128 × 128 pixels. The cell's size is 8 × 8 pixels, thus an image is divided into 16 × 16 cells. The HOG is calculated on the overlapped blocks, where a block consists of 16 × 16 pixels. An example of the HOG of the speed limit sign is illustrated in Fig. 2(b), where the orientation of gradient is drawn in the image. To match the HOG feature of the tested image with the reference one, the Euclidean distance method is adopted. Since only the outer part of the image is considered, any types of speed limit signs could be used as the reference. The tested image is classified as the circular sign when the distance is lower than a threshold.



(a) (b)

Fig. 2. (a) Outer and inner parts of image; (b) HOG visualization

2.3 MSER Extraction

The MSER is a method proposed by [13] to find the regions which remain the same when the threshold is changed at several values. In the traffic sign recognition system, it is usually employed in the detection stage to find the region of candidate signs as proposed in [11]. They extract the MSER from a grayscale image to detect the traffic sign with the white background. Our method works in the similar approach but in the different way. In the sense that in our method the MSER is used to extract the digit number in the inner part of the speed limit sign for classifying the sign, not detecting the sign. The benefits of our proposed method are twofold. First it extracts the digit number effectively, due to the fact that the MSER is robust against the illumination changes [11]. Second, since the area of image to be extracted is in a small area inside the traffic sign, the computation cost for extracting the MSER could be reduced.

2.4 Rotation Detection and Affine Transformation

To cope with the rotated sign, we propose to detect the rotation angle of the sign by analyzing the blobs (binary image) representing the digit number obtained by the MSER extraction. The examples of blobs are illustrated in Fig. 3, where the image in first column represents the speed limit sign in the normal position, while the images in second and third columns represent the speed limit sign in the rotated position.

To find the rotation angle of the sign, first we find the contour of blobs which represents the boundary of blob. Then the ellipse fitting technique is applied to the contour. The rotation angle of the sign is obtained from the angle of detected ellipse. As illustrated in Fig. 3, the detected ellipse is drawn with the blue color. In the case of speed limit 30 km/h, the ellipses extracted from the number "3" and "0" have the same orientation. The orientation of both ellipses represents the rotation angle of the sign. However, for the speed limit 70 km/h, the ellipses extracted from the number "7" does not represent the rotation angle of the sign. Fortunately, the speed limit signs used in this work have the number "0" in the last digit. Thus we may use the last digit or the rightmost blob to find the rotation angle.

Fig. 3. The blobs and rotation angle

Once the rotation angle is calculated, the next step is to find the affine transformation to transform the image into the normal position (no rotation). The affine transformation for rotation is expressed by

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & cx \times (1-\cos\theta) - cy \times \sin\theta \\ -\sin\theta & \cos\theta & cx \times \sin\theta + cy \times (1-\cos\theta) \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{1}$$

where x, y are the pixel coordinates in source image, x', y' are the pixel coordinates after transformation, cx, cy are the center coordinates of rotation, and θ is the rotation angle.

2.5 Template Matching

From the previous stages, the blobs of digit numbers are already in the normal position. Thus in the matching process, we only provide the standard templates of the numbers of the speed limit sign. The template size is the same as the size of inner area shown in

Fig. 4. Templates of digit numbers in the speed limit sign

Fig. 2(a), i.e. 80 × 80 pixels. The templates used in this work are illustrated in Fig. 4. To match the blob with the template, the Euclidean distance is adopted.

3 Experimental Results

The proposed system is tested on a PC, Intel Core i7 3.4 Ghz. The algorithm is implemented using the C++ languange and the OpenCV library [14] for handling the image processing tasks. The speed limit signs used in the experiments are the speed limit of 30, 50, 60, 70, 80, 100 km/h. The tested images are obtained from GTRSB dataset [15]. The tested images consist of six types of speed limit signs as mentioned before, where each type contains 20 images. To examine the rotation problems, we create the rotated versions of the tested images by rotating them by 10°, 15° in both clockwise and counter-clockwise directions. In addition, to verify the algorithm for matching the outer circular ring, we introduce 100 images contain the non circular signs. Therefore there are total 700 tested images used in the experiments.

The results of the circular ring matching using HOG distance are given in Table 1. From the table, the maximum distance of the speed limit sign is 0.1097, while the minimum distance of the non-speed limit sign is 0.1212. The result suggests us to classify the outer circular of the sign properly by setting the threshold value to 0.12. If the distance is below than this value, then it is classified as the speed limit sign. From the experiments, the execution time of the outer circular matching is 2.95 ms.

Table 1. Results of the outer circular matching

Speed limit sign	Minimum matching distance	Maximum matching distance
30 km/h	0.0514	0.1030
50 km/h	0.0589	0.1008
60 km/h	0.0551	0.1062
70 km/h	0.0557	0.1056
80 km/h	0.0570	0.1097
100 km/h	0.0562	0.1084
Non-speed limit sign	0.1212	0.1946

The results of the digit number matching are given in Table 2. The results show that the average classification rate of the sign in normal position (no rotation) is highest. When the signs are rotated by 15° or −15°, the classification rate decreases about 9%. It is worthy to note that even though the classification rate decreases, the proposed algorithm provides a promising method to cope with the rotation problem. The method only requires six templates (and no learning process is required) to classify 600 speed limit signs with the higher classification rate of 93.67%. The performance of the method could be improved in the blob extraction and the template matching techniques, such as by employing the skeleton of digit number in the matching process. It will be addressed as the future work.

We also examine the execution time required during the digit number matching. It requires 46.78 ms to match an image with six reference images, or the matching time is about 7.8 ms for one reference image. Therefore combining with the outer circular matching, the computation time of our proposed classification method is 10.75 ms (2.95 + 7.8).

Table 2. Results of the digit number matching

Speed limit sign	Classification rate				
	Rotation angle of speed limit sign				
	0°	10°	15°	−10°	−15°
30 km/h	100%	100%	90%	100%	85%
50 km/h	100%	100%	95%	90%	100%
60 km/h	100%	90%	90%	90%	90%
70 km/h	95%	100%	95%	80%	80%
80 km/h	100%	90%	80%	95%	85%
100 km/h	100%	95%	95%	100%	100%
Average	99.17%	95.83%	90.83%	92.5%	90.00%
Total average = 93.67%					

4 Conclusion

The multiple features are extracted in the outer and inner parts of the speed limit sign for classifying the sign using the template matching technique. The proposed system first matches the outer part with a circular ring reference. Once it is matched, the digit number in the inner part are extracted and matched with the standard reference signs. The method offers an efficient way in the classification, in the sense that no training process is required. Further the number of sample images is very few. For classifying six types of the speed limit signs, only six reference images are required. The results show that the method achieves the high classification rate and the fast computation time. In future, some improvements of the method will be addressed to increase the performance. Further the method will be extended to cope with the other types of traffic signs.

Acknowledgements. This work is supported by the Research Grant 2017, Competence-based research scheme from Directorate General of Higher Education, Ministry of Research and Technology and Higher Education, Republic of Indonesia, No.: SP DIPA-042.06.1.401516/2017.

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