Improved Traffic Signs Detection Based on Significant Color Extraction and Geometric Features

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Abstract—**Traffic signs detection is a key part of traffic signs recognition system. We propose an improved approach for traffic signs detection based on significant color extraction and geometric features. Firstly, we use a median filter to remove the noise. Secondly, we calculate the quadratic weighting difference of R, G and B in RGB color space to extract the significant color of the traffic sign. Thirdly, the morphological processing is applied to get connected regions. Finally, we filtrate the connected regions based on geometric features to locate the traffic sign accurately. The experiment on 200 traffic sign images shows the detection rate of 95.4%. Our algorithm can adapt to various environment, has a high accuracy and a good robustness.**

***Keywords*-traffic signs detection; significant color; quadratic weighting; geometric feature**

I. INTRODUCTION

The intelligent transportation system is the development direction of the future traffic system and is being focused on widely at home and at abroad. The traffic signs recognition system is an important part of the intelligent transportation system. The traffic signs recognition system is a system which uses the image processing equipment in the car to provide the traffic information included in the traffic signs to the driver in real time. It can ensure the safe driving and avoid traffic accidents. It is a branch of intelligent auxiliary driving system. It has become a hot research topic and also is one of the key unresolved problems. The traffic signs recognition system mainly includes a detection module and a classification module [1]. The traffic signs detection is the key module and will directly affect the success or failure of a traffic signs recognition system.

Detection of traffic signs is mainly based on color features and geometric features at present. There are three main implementation schemes. The first scheme is based on only color features [2]. It has the advantages of scale invariance, rotation invariance and visual invariance. It is also simple and quick to implement. But it is relatively sensitive to the light change, climate change and fading. The second scheme is based on only geometric features [3] [4]. It is not sensitive to the light change, climate change and fading. But it is greatly affected by the shooting angle, the shooting distance and the deformation of traffic signs. The third scheme combines the color features and the geometric features [5] [6] [7]. It can effectively make up for the defect existing in the two schemes mentioned above.

In recent years, many traffic signs detection methods are proposed by scholars at home and abroad. Reference [8] has proposed a method based on RGB color components normalization and threshold segmentation. Reference [9] has improved the traffic signs detection based on the HOG feature extraction by increasing a color conversion link. Reference [10] proposes an approach based on visual attention mechanism. Reference [11] has proposed an algorithm for significant object detections based on the color properties and the spatial information, and uses the algorithm to traffic signs detection; Reference [12] has proposed a traffic signs detection method based on color invariants and tower gradient direction histogram. Reference [13] proposes a method for construction of a cascaded traffic sign detector. These methods mentioned above can improve the performance of traffic signs detection, but when there are some distractors which have the same geometric features and background color with the traffic signs, the detection accuracy will decrease.

Our main contribution in this paper is that we present an improved approach for traffic signs detection based on significant color extraction combining with geometric features analysis. The proposed algorithm makes full use of the characteristics of significant color. This approach can remove the interference objects and can adapt to various environment. It has a good robustness for a rainy day and haze weather.

The organization of this paper is as follows. Section II introduces the method of image preprocessing. Section III introduces the method of significant color extraction. Section IV introduces the filtrating based on geometric features. Section V presents experimental results. We conclude the paper in Section VI.

II. THE METHOD OF IMAGE PREPROCESSING

The image collected by the on-board camera will be affected by a variety of external interferences, such as various weather conditions, insufficient light and strong light and so on. These interferences have a big impact on the follow-up work. However, they are inevitable. In order to eliminate the impact brought by the external interferences ,We use the preprocessing to improve the image SNR (Signal Noise Ratio) and suppress the background noise.

The method of image preprocessing is described below. Firstly, we extract the R, G and B color components of a color image in the RGB color space. Then we use the median filter to R, G and B components respectively to remove the noise. Finally, we combine R, G and B together. Figure 1 (a) ~ (b) are the original images. In order to manifest the superiority of our program, figure 1(a) is taken in a rainy day and figure 1(d) is taken in haze weather. Figure 2 (a) ~ (b) are the images after preprocessing.

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

Figure 1. Original images

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

Figure 2. Images after preprocessing

III. THE METHOD OF SIGNIFICANT COLOR EXTRACTION

Traffic signs can be mainly divided into three categories. They are indication signs, prohibition signs and caution signs. The indication signs have a circular or rectangular shape, blue background, a white border and a white pattern. The prohibition signs have a circular shape, white background, a red border and a black pattern. The caution signs have a triangular shape, yellow background, a black border and a black pattern. The three types of traffic signs all have different significant color. The significant color of indication signs is blue. The significant color of prohibition signs is red. The significant color of caution signs is yellow. The significant color can help human's eyes tell the location of traffic signs in an instant. The traffic signs recognition system can also locate the traffic signs using the significant color. The characteristics of the traffic signs are shown in table 1.

TABLE 1. THE CHARACTERISTICS OF TRAFFIC SIGNS

category	**shape**	**background**	**border**	**pattern**	**significant color**
indication sign	circular or rectangular	blue	white	white	blue
prohibition sign	circular	white	red	black	red
caution sign	triangular	yellow	black	black	yellow

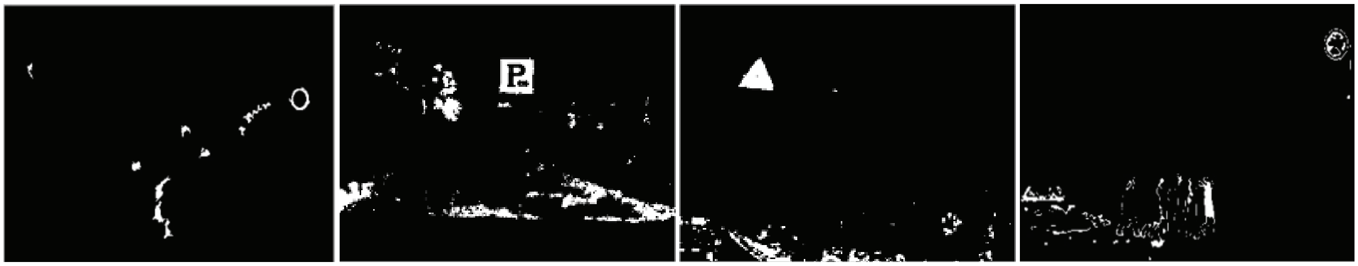
Reference [14] has proposed a method for traffic signs detection based on the three-component chromatic aberration of R, G and B in RGB color space combining with the Otsu's dynamic threshold segmentation. It firstly extracts the R, G and B three components of traffic images. Then it uses the following formula (1) for processing. It uses the red prohibition sign as an example.

$$CA = \begin{cases} 0 & \lambda R - G - B < 0 \\ 255 & \lambda R - G - B > 255 \\ \lambda R - G - B & \text{others} \end{cases} \tag{1}$$

CA is the gray-scaled image of chromatic aberration, and λ is the weight. Then it uses the Otsu's dynamic threshold segmentation method to obtain the traffic signs. We present an improved approach for traffic signs detection on the basis of reference [14]. We use the quadratic weighting to calculate the difference of R, G and B to extract the traffic signs. Our method is more simple and more quickly than reference [14]. Because it needn't the dynamic threshold segmentation step. The following formula (2) is the calculation method. We use the red prohibition sign as an example.

$$
OC=\begin{cases} 0 & \lambda_1(\lambda_2 R-G-B)<T_1 \\ \lambda_1 R-G-B & \lambda_1(\lambda_2 R-G-B)>T_2 \\ 255 & \text{others} \end{cases} \tag{2}
$$

OC (Outstanding Color) is the extracted color image. λ_1 and λ_2 are two weights, T_1 and T_2 are two thresholds. Through experiment comparison, we choose $\lambda_1 = 10$, $\lambda_2 = 1.6$, $T_1 = 1$ and $T_2 = 255$. Figure 3 (a) ~ (b) are the significant color images after extraction.



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

Figure 3. Significant color images

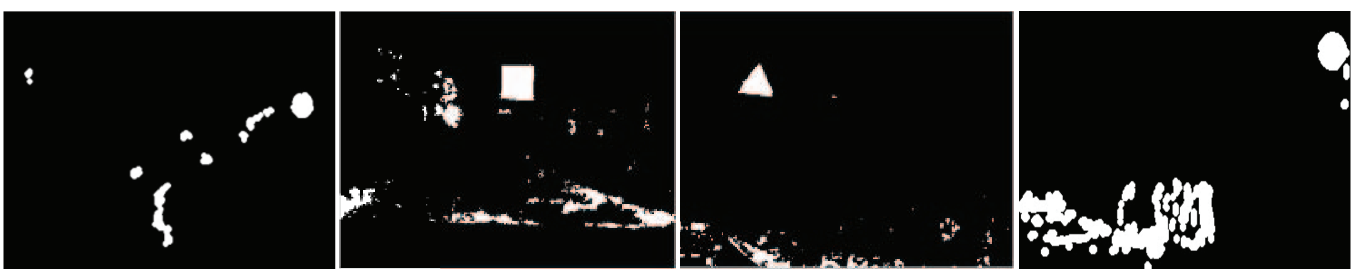
IV. THE FILTRATING BASED ON GEOMETRIC FEATURES

A. Preliminary Filtrating Based on Area Feature

We fill the significant color images to make the extraction regions closed. The closed regions are called suspected regions of traffic signs, which referred to as ROI (Region of Interest). Then we take preliminary filtrating based on area feature. As the area of the traffic sign is in a range, we set two thresholds. If the area of ROI is between the two thresholds, then we keep the ROI, else remove the ROI. The area of a ROI can be calculated by counting the number of pixel in the ROI. We use a function $f(m, n)$ to represent a pixel in the image. If the pixel is in the ROI region, then we can get $f(m, n) = 1$, else we can get $f(m, n) = 0$.We use A to represent the area of ROI, then we can get the following formula (3).

$$
A = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f(m, n) . \tag{3}
$$

After calculating A, we choose two thresholds: the maximum area $A_{\max}$ and the minimum area $A_{\min}$. If the value of A is between $A_{\max}$ and $A_{\min}$, then we keep the ROI, otherwise remove the ROI. Through experiment comparison, we choose $A_{\max}$=4500 and $A_{\min}$=350. Figure 4 (a) ~ (b) are the images of ROI after filling. Figure 5 (a) ~ (b) are the images of ROI after preliminary filtrating based on area feature.



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

Figure 4. Images of ROI after filling

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

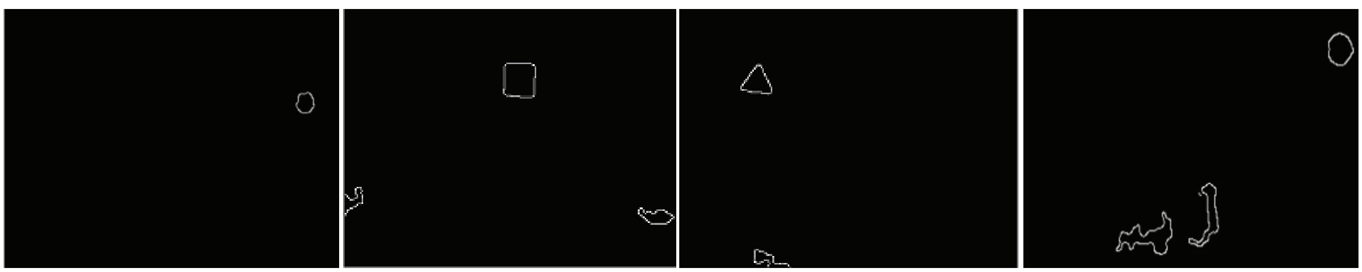
Figure 5. Images of ROI after preliminary filtrating

B. Further Filtrating Based on Shape Feature

Traffic signs all have fixed geometry. The indication signs have a circular or rectangular shape. The prohibition signs have a circular shape. The caution signs have a triangular shape. So we can use shape analysis to further filtrate the ROIs. We use $\mathrm{d_{min}}$ to represent the minimum distance from a centroid to the edge. We use $\mathrm{d_{max}}$ to represent the maximum distance from a centroid to the edge. According to the knowledge of the geometry, the ratio of the maximum distance from a centroid to the edge and the minimum distance from a centroid to the edge is in a range. The ratio is 1 for a circle. The ratio is 2 for an equilateral triangle .The ratio is $\sqrt{2}$ for a square. The ratio is $\sqrt{5}$ for a rectangle. The following formula (4) can be obtained. We can further filtrating the ROIs based on the formula.

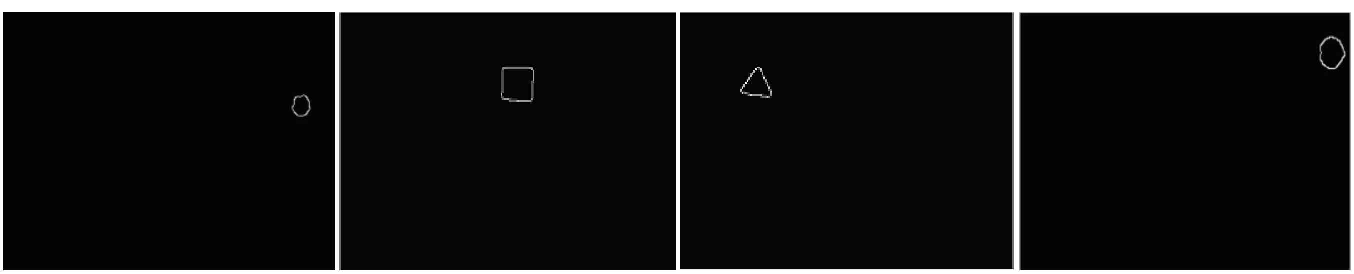
$$\frac{d_{\max}}{d_{\min}}\begin{cases} 1 & \textit{for a circle} \\ 2 & \textit{for an equilateral triangle} \\ \sqrt{2} & \textit{for a square} \\ \sqrt{5} & \textit{for a rectangle(the ratio of the length and the width is } 2\,) \end{cases} \tag{4}$$

The method for further filtrating based on shape analysis is described as below. Firstly, we extract the edge of the ROI using canny operator. Secondly, we calculate the centroid of ROI, and then calculate the minimum distance $d_{\min}$ and maximum distance $d_{\max}$ between the centroid and the edge. Finally, we choose two thresholds th_1 and th_2 . If $th_1 \leq \frac{d_{max}}{d_{min}} \leq th_2$, we keep the ROI. Otherwise, we remove the ROI. Through experiment comparison, we choose $th_1 = 0.8$ and $th_2 = 2.5$. The finally remaining ROI region is the region of traffic signs. Figure 6 (a) ~ (b) are the edges of ROI after canny operator. Figure 7 (a) ~ (b) are traffic signs regions after shape filtrating.



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

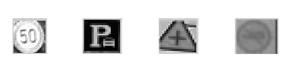
Figure 6. Edges of ROI



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

Figure 7. Region of traffic sign.

We use the method of horizontal projection and vertical projection to segment the traffic signs. Through the horizontal projection we can get the height of the traffic signs region. Through the vertical projection we can get the width of the traffic signs region. The traffic signs can be segmented according to the height and the width. The results are shown in figure 8 (a) ~ (b).



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

Figure 8. The extracted traffic signs

V. THE EXPERIMENT RESULTS AND ANALYSIS

In order to verify the feasibility of our algorithm and the good robustness for a rainy day and haze weather, an experiment was performed on 200 images that were taken in various environments. Some images are taken in a rainy day and some images are taken in haze weather. The computer we used is a Thinkpad computer with 4GB of memory and 2.5GHZ of master frequency. We use the Matlab to run the program of our algorithm and compare the result of our algorithm with references [10] and [14]. The result of our experiment is shown in table 2. We use the correct detection rate, the leak detection rate, the false detection rate and the average elapsed time of the program as evaluation indices. The correct detection rate is the ratio of the correct detection number and the total number of traffic signs. The leak rate is the ratio of the leak number and the total number of traffic signs. The false detection rate is the ratio of the false detection number and total number of detected signs, and the total number of detected signs is the sum of the correct detection signs and the error detection signs.

TABLE 2. THE EXPERIMENT RESULTS

Algorithm	corrected rate	leaked rate	false rate	average time
Our	95.4%	4.6%	1.25%	1.55s
Reference[10]	92.8%	7.2%	2.7%	1.90s
Reference[14]	94.1%	5.9%	0.84%	2.45s

The experiment verified that the correction detection rate of our algorithm is 95.4%, the leaked detection rate of our algorithm is 4.6% and the false detection rate of our algorithm is 1.25%. The average elapsed time of our algorithm is 1.55 seconds.

Compared with references [10] and [14], the correction detection of our algorithm is higher, the leaked detection rate of our algorithm is lower, the average elapsed time is less. The false detection rate is lower than references [10], but it is higher than reference [14]. Our algorithm is the quickest of the three algorithms. In addition, our algorithm has a good robustness for a rainy day and haze weather. Through the comparison, we can find that our algorithm is better than the algorithm of reference [10] and the algorithm of reference [14]. In the later work, how to reduce the false detection rate will be focused on.

VI. CONCLUSION

We present an improved approach for traffic sign detection based on significant color extraction combining with geometric features analysis. The algorithm seizes the characteristics of significant color and the fixed geometric features of the traffic signs. It can effectively detect the traffic signs. It is simple and quick. Firstly, we extract the significant color of the traffic signs by calculated the quadratic weighting of R, G and B in RGB color space and fill the extracted significant color regions to get connected regions. Secondly, we preliminary filtrating the suspected traffic signs based on area characteristic. Thirdly, we further filtrate the suspected traffic signs based on geometric shape analysis. Finally, we locate the location of the traffic signs and segment them. Matlab is used to simulation. Compared with the algorithm proposed by reference [10] and reference [14], our algorithm has a better detection effect and has a better robustness. In addition, our algorithm is the quickest of the three algorithms.

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