Detection and Recognition of Traffic Signs Based on HSV Vision Model and Shape features

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***Abstract*—A detection and recognition method of traffic signs is implemented based on traffic signs' color and shape features. This method consists of image segmentation based on HSV color space, detection and affine transformation correction based on geometry features, extraction of eigenvector by using Gabor filter, Classification and recognition by Support Vector Machine (SVM). The above algorithms are implemented by using MATLAB language.**

***Index Terms*—Traffic signs detection, HSV color space, Affine transformation, Gabor filter, Support Vector Machine (SVM)**

I. Introduction

In recent years, the development and application of intelligent transportation system has gained widely attetion of the government and academic circles, and the automatic recognition system of traffic signs as the one of the intelligent transportation system subject has become a research focus. Traffic sign recognition system shoots environment image along the way through the installation of high-speed camera and the images have taken to the image processing module and recognition module of the system, finally the recognition result will be sent to the driver. However, the amount of image information recognized by the system are large, and the real pictures taken under natural conditions are usually affected by unpredictable illumination, camera angles and so on to cause considerable interference on processing and identification, so how to reduce the complexity of the algorithm and effectively eliminate the interference so as to improve the system accuracy become the main difficulties of this topic at present.

In China, traffic signs have 3 kinds. They are yellow warning signs, red prohibiting signs and blue indicating signs. They are triangle, round and square, as shown in Figure 1.

TABLE I.
THE H, S, V COMPONENT THRESHOLD RANGE OF THE MAIN COLOR OF TRAFFIC SIGN

Color	H	S	V
Red	$H \geq 240$ or $H \leq 10$	$S \geq 40$	$V \geq 30$
Yellow	$18 \leq H \leq 45$	$S \geq 148$	$V \geq 66$
Blue	$120 < H \leq 175$	$S \geq 127.5$	$V \geq 20$

Figure 1. Typical example of traffic signs.

This makes segmenting and extracting the traffic signs based on the color and shape features possible. But, because natural scenes under complex background illumination and such factors exist, the recognition accuracy is hard to guarantee. The main influence factors mainly in the following aspects: changing of the light conditions, vehicle motion blur, contaminating, damaging, occlusion or fading of the traffic signs, rainy weather, uncontrol of the camera angle and the high complexity of the background. The overall train of thought of traffic sign recognition scheme are as follows: firstly, based on the HSV color space of the three component threshold to extract target color of the real map, then detect the shape feature of resulting region and correct the affine

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transform, Gabor filter the target area ing to obtain the feature vector and transfer then to support vector machine (SVM) for training, classification and prediction. [1].

II. Detection and Extraction of Traffic Sign

Detection and extraction of traffic sign is divided into three steps: region segmentation of traffic signs, detection of region shape and image correction based on shape.

A. Region Segmentation of Traffic Sign based on HSV Space

Because of the traffic signs with specific colors (such as red, yellow, blue, and so on) separation extraction based on the color of traffic signs is the main method for traffic sign image segmentation. Different color system, or "color space", corresponds to different segmentation threshold. Color space of images is RGB space, HIS space, HSV space and YUV space. The general camera are used in RGB color space, and image segmentation algorithm based on RGB space is no conversion, so it is simple. But the correlation among R, G, B components makes the effect of image segmentation easily influenced by light. The YUV color space is mainly used in Europe and the United States color television signal, and it is less applied in image processing. HISand HSV space is more suitable for image segmentation, because H and S components in general are not affected by light intensity. So HSV space is choosed in this article.

TABLE II.
Different shapes corresponding to the value range of the shape attribute

Shape	Circular degree C	Rectangular degreeR	Elongation degree E
Circle	C≥0.75	R>0.70	E>0.85
Triangle	0.35<C<0.70	0.4<R<0.65	E>0.80
Rectangle	0.60<C<0.75	R>0.80	E>0.30

HSV color space (or HSB color space) is composed of Hue H, Saturation S and Value V. It is a nonlinear transform of RGB space. HSV color space model corresponds to a conical subset in cylindrical coordinate system. The formula for conversion of RGB color space into HSV space is shown in Figure 2, in which, max = max(R,G,B), min = min(R,G,B).

$$h = \begin{cases} 0^\circ & \text{if } max = min \\ 60^\circ \times \frac{g-b}{max-min} + 0^\circ, & \text{if } max = r \text{ and } g \geq b \\ 60^\circ \times \frac{g-b}{max-min} + 360^\circ, & \text{if } max = r \text{ and } g < b \\ 60^\circ \times \frac{b-r}{max-min} + 120^\circ, & \text{if } max = g \\ 60^\circ \times \frac{r-g}{max-min} + 240^\circ, & \text{if } max = b \end{cases}$$

$$s = \begin{cases} 0, & \text{if } max = 0 \\ \frac{max-min}{max} = 1 - \frac{min}{max}, & \text{otherwise} \end{cases}$$

$$v = max$$

Figure 2. The formula for conversion of RGB color space into HSV space

Three main color in H, S, V component threshold range is shown in Table 1: (H, S, V values were normalized to [0, 255])

B. Traffic Sign Detection and Judgment based on the Shape Feature

There are mainly three kinds of traffic signs shapes: circle, triangle and rectangle. Traffic signs with different shapes have different attributes, such as circularity, rectangularity, elongation and distance from centroid to edge. Because in the natural scene there are some complex backgrounds similar to the traffic signs color, basing solely on color inspection is not reliable [2]. However, detection methods based on the shape can further eliminate the background which have similar colors , because the complex backgrounds often do not have the special shape of traffic signs [3].

In the actual scene, the shooting angle is uncertain, uptook traffic signs will distort, such as a triangle is generally triangular, so a circle will be oval [4]. Therefore the attribute value range of the rectangle degree, elongation degree and circular degree are used to determine the shape of the target area, experimental, the data in table 2 can solve the problem effectively.

In fact, because of many complicated background exists in natural scenes, judgment region shape based on C, R, E attribute still has big error. A method correcting region based on shape and calulating the number of vertexes corresponding the shape is raised. When correcting region of triangle or rectangle, the number of vertex of the region will be calulated. As all know there are three vertexes in a triangle and four vertexes in a rectangle, so if the marked regional shape does not correspond to the number of the vertexes, the region will be rejected.

C. The Affine Transform Correction and Normalization of Traffic Signs

In natural scenes, if the camera lens is not parallel to the plane of the traffic sign, projection distortion occurs. Considering the actual situation of imaging conditions of on-board camera, it is not possible that camera is parallel with the plane of the road traffic sign, therefore before classification and identification, image correction of suspicious regions is indispensable. Actually, different distances or different angle will cause that the size of real traffic signs is not controllable, so standardization and classification of the images are necessary [5]. All traffic signs are standardized to 32 x 32 pixels. Circular traffic signs directly use simple horizontal and vertical scaling manner and the rectangular and triangular traffic signs use affine transformation method for the correction and normalization [6].

As shown in Figure 3, A1B1C1 is the standard corrected triangle of ABC. According to the correspondence of the six vertex, a set of values of six affine transformation parameters a, b, c, d, e, f can be obtained , the affine transformation formula can be

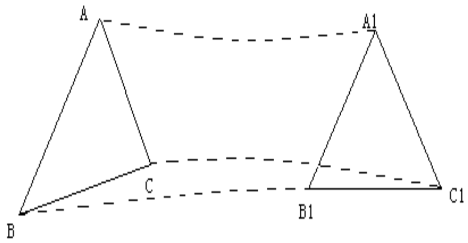

Figure 3. Note how the caption is centered in the column.

obtained for correction and normalization.

$$AX + BY + C = X'$$

$$DX + EY + F = Y'$$

In the formula: (X, Y) for original triangle point, (X′ , Y′) for corrected equilateral triangle point.

three vertex coordinates of corrected triangle can be calulated by the method of centroid edge distance map.The specific steps are as follows:

Calculating the centroid of target region in the binary image, finding all the boundary points of the region, sorting in the counterclockwise direction, drawing the centroid edge map, the extreme points of the image are obtained. Under normal circumstances, the coordinates of the extreme points are the wanted coordinates of the vertexes.

Correction of rectangular traffic signs can also adopt a similar approach. Four vertexes can get four group corresponding points coordinates, to calculate the parameters of affine transformation to transform correction.

Because of its simple shape circular traffic signs can be simply scaling for correction, as shown in Figure 4.

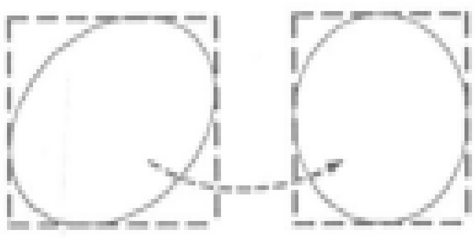

Figure 4. Circular traffic sign correction diagram

By finding the rectangle box around the elliptic, it will be standardized to 32 x 32 pixels, then the elliptic corrected to a circle.

As shown in Figure 5, in the edge of region, maximum of centroid edge map will be affected by the selection of the edge starting point(here " maxima " understood as a certain range of maximum), and if the

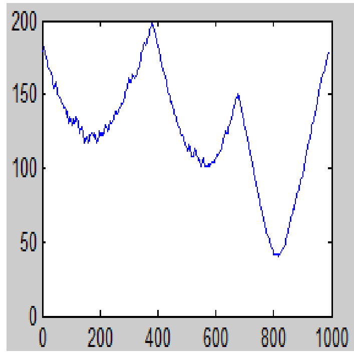

Figure 5. Triangle sign edge centroid distance map correction results

regional edge points positions are saved as a one-dimensional array, this array should be also end to end. So when calculating the vertex position corresponding the maximum of the image, both right and left ends of the image should be linked. About the determination of the maximum, here is the method: considering the number of edges of triangle and rectangle, assume that the total number of the edge points is M, to some extent, M is equivalent to the perimeter of the region. If the distance from some edge point to the centroid is larger than the distance from the M/8(rounding) points in front of and behind it to the centroid, that means this edge point corresponds a maxima. It is identified as a vertex of the region.

III. Classification and Identification of Traffic Signs

There are Gabor filter feature vector extraction and SVM (support vector machine) classification in the classification and identification of traffic Signs.

A. Gabor Filter Feature Vector Extraction

There are many applications of Gabor filtering in feature extraction of image processing, texture analysis and stereo disparity estimation. It belongs Windowed Fourier transform, and it is special case of STFT that the window function is taken as a Gaussian function, in which Gabor function in the frequency domain at different scales, different direction can extract relevant features. This conversion can be achieved purpose of time-frequency localization, and it can provide all the information of the signal overall, while providing the information of the intensity of the signal changes in any local time, while providing the localized information of the time and the frequency domain.

Gabor extract per short signal on the signals to be analyzed, making periodically extension to extension at both ends of this subparagraph, analyzing the signal by traditional Fourier method, getting the frequency characteristic of the frequency domain of this subparagraph, translating the subparagraph position in the original analyzed signal, obtaining the frequency component of the whole analyzed signal in each small range.

Gabor filter first identified kernel function templates, then make a Convolution with the image. The impulse response that it corresponds is the result of oscillating function of the complex exponential multiplied by Gaussian envelope function. The kernel function of Gabor filtering method to extract feature vectors is showm as follows:

$$g_{uv}(x,y)=\frac{k^2}{\sigma^2}\exp\left(-\frac{k^2(x^2+y^2)}{2\sigma^2}\right)\bullet$$

$$[\exp(ik\bullet\begin{pmatrix}x\\y\end{pmatrix})-\exp(-\frac{\sigma^2}{2})]$$

$$k=\begin{pmatrix}k_x\\k_y\end{pmatrix}=\begin{pmatrix}k_v\cos\varphi_u\\k_v\sin\varphi_u\end{pmatrix}$$

$$k_v=2^{-\frac{v+2}{2}}\pi$$

$$\varphi_u=u\frac{\pi}{K}$$

Figure 6. Kernel function.

The value of v determines the wavelength of the Gabor filter, and the value of u represents the direction of the Gabor kernel function, K represents the total number of directions. Parameter σ/k determines the size of the Gaussian window, here take σ = π. procedure takes five frequencies (v = 0, 1, ..., 4), eight directions (i.e., K = 8, u = 0, 1, ..., 7), a total of 40 Gabor kernel function. Calculating the convolution of gradation matrix and the kernel function of the target image one by one, using the mean and variance of the results as the extracted feature, after each convolution the pulling results into a one-dimensional vector, and then stringing the every result of the convolution together, the one-dimensional feature vector of the target image will be obtained.

B. The Classification and Recognition based on SVM

Many machine learning takes the empirical risk minimization as a target to work towards, but gradually we found generalization ability of many classification function in the real classification is poor. Considering the number of samples, vc-dimensional size and other factors, in order to achieve empirical risk with confidence risk minimum, the SVM (support vector machine) technology is used to classify and predict. Support vector machine is a structural risk minimization algorithm based on statistical learning theory [7]. It maps lower dimensional linearly nonseparable data into the high dimension so that superior plane can be divided.

The basic principle for the SVM: a given set of training data is {(x1, y1) (x2, y2) ... (xi, yi)}. If the general form of the linear discriminant function in n dimensions is g (x) =(w x) + b, and all data can be correct divised by classified surface (w x) + b = 0, then this classified surface is the optimal hyperplane, while the heterogeneous vector which stay the closest to the plane is the support vector, a group of supportvector can only determine one hyperplane.

Pre-prepared nonlinear mapping maps the input vector x into a high dimensional feature space, and construct the optimal separating hyperplane in this space, on both sides of the separate data on the hyperplane there are two parallel hyperplanes. Establishing the appropriate directioned separated hyperplane make the distance between two parallel hyperplanes maximum. Vectors only do dot product operation, so kernel function is used to avoid to carry out complex calculations in high dimensional feature space.

SVM method, its parameters, kernel functions and parameters selection has not yet formed a unified model in the international community, so the optimal SVM algorithm is only by virtue of experience, trial and comparison optimization. SVM software package LIBSVM here is used and slack variable parameters in the experiments are default.

After many experiments, RBF(radial basis function) as the kernel function for training and classification will make prediction accuracy highest.The form is of the kernel function is as follows：

exp（-gamma*|u-v|^2）

in which

gamma=（2σ^2）^(-1)

SVM itself is the two classifier, and it can combine with the basic idear of the binary decision tree. Considering that many traffic signs logo is to similar to distinguish. One to many way is taken. Each time SVM is used to separate one class structure sample training model whoch is farthest from others, until all samples type are separated.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

By analyzing the principle and algorithm of traffic sign detection, MATLAB tool is used to design and implement traffic sign detection, traffic sign correction, feature extraction and classification of SVM identify.

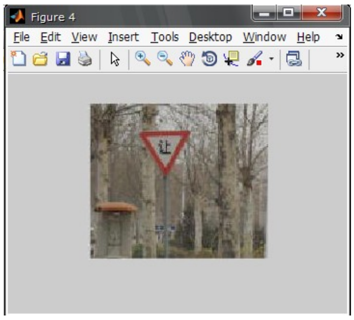

Figure 7. Sign of slowdown and yield

In order to verify the efficiency of the algorithm, some scene pictures(image format for the JPG, 180*160 resolution) for detection and recognition are as shown in Figure 7.Extracting specific color area by three component threshold method, calculating regional shape attribute to exclude the interference of the background, binary image based on the edge is obtained, as shown in Figure 8.

The result of distance between centroid and centroid edge is calculated, and then the correction results of 32*32 gray image is shown in Figure 9, and the

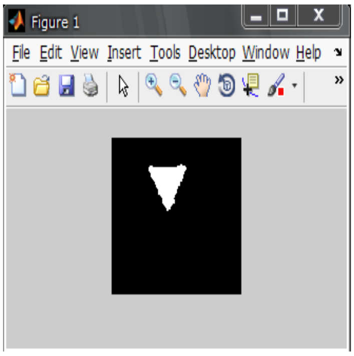

Figure 8. Detection based on color and shape

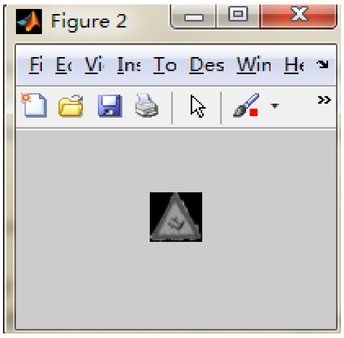

Figure 9. Affine transform correction

prediction of the recognition results after correction, Gabor filtering and classification in SVM is shown in Figure 10.

Figure 10 shows that algorithm successfully identify the real picture containing a "slowdown and yield" traffic signs. The experimental computer has Pentium core duo CPU, 2.00GB memory and Microsoft Windows XP operating system. Running total time is 0.5320 seconds to 0.5630 seconds. When the resolution of picture decrease, the program speed will go up.

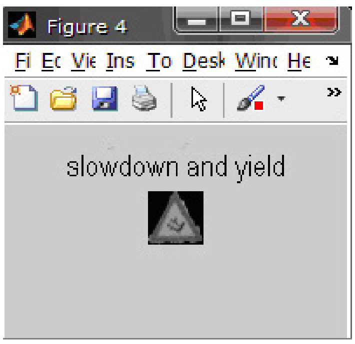

Figure 10. Result of classification & identification

V. CONCLUSION

In this paper, we maily aims at color and shape feature of the traffic signs and realizes a kind of traffic sign detection and recognition method. Firstly, RGB images will be converted to HSV color space, and traffic sign area based on the HSV three component threshold is separated. Then according to the shape of the region attribute make a judgment of area shape and remove complex background interference. And then the circular area makes a simple scaling correction, the triangular and rectangular region with affine transform correction of weakened projection distortion, and the images to be recognized all standardized to a specific size. Finally using Gabor filter extract the identifying image characteristic vector into the support vector machine for classification. The experiment shows that this method can accurately detect, classify and identify traffic signs from natural scenes.

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