Traffic Lights Detection and Recognition Based on Color and Shape with SVM

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Abstract. Traffic signal lights recognition system is an essential part of Advanced Driver Assistance Systems (ADAS). Methods for traffic lights recognition based on single feature and fixed threshold filtering are usually ineffective in complex background and variable lighting environment. To solve this problem, an approach based on features combination of color and shape of traffic lights is proposed, and the method of machine learning is used for recognition of traffic lights. On the basis of extracting the characteristic parameters of the candidate region, the SVM classifier is constructed to classify the traffic signal lights. Experimental results show that this method can realize the accurate location and recognition of traffic lights in complex scenes.

Introduction

Autonomous ground vehicles have aroused increasing attention among researchers in recent years, which not only can be used in civilian areas to help people drive safely, but also widely used in military, aerospace and other fields. As being an essential part of driver assistance systems and unmanned ground vehicles, traffic lights detecting and recognition system has great research value and practical significance. This is mainly reflected in the following two aspects: (1) unmanned ground vehicles need traffic lights detecting and recognition system to provide the navigation information at traffic crossing. (2) it will give useful information for people with color blindness or weakness to understand the road environment and give timely warning to prevent running a red light for unintentional driver.

Many researchers have explored novel vision-based traffic lights detecting systems. Lindner et al. proposed a detection and recognition system of traffic lights which uses GPS data and digital maps along with an image taken by a camera in order to enhance the performance of the system [1]. J Tian et al. [2] proposed an approach using 2D-Gabor wavelets to extract the features of the candidate regions of traffic lights with PCA and ICA; template matching is used for classification. However, due to ICA and PCA algorithm is complex, amounts of data is large, this method is time consuming, real-time performance needs to be improved. Mahipa R. Yelal et al. [3] studied real-time tracking of signal light based on color tracking. But, limited for good sample image and background of signal lights is clean sky. Jin-Hyung Parket et al.[4] used frame check technique to distinguish between traffic lights and other similar lights like tail light of cars etc. This technique does not have good accuracy. Masako Omachi[5] proposed an approach for traffic light detection with color and edge information. N Bhattacharayaraya et al.[6] processed image for several levels of detection like color detection, circle detection, co-ordinate analysis and the vehicle density estimation. Xu Cheng proposed a traffic lights recognition algorithm based on Lab color space and template match [7]. SI J et al. proposed a comprehensive method for traffic lights detection in complex background [8].

Methods in literatures above are generally characterized by color or shape features from traffic lights, simple threshold is used for image segmentation and traffic lights extraction in the image, but
the natural environment under different light conditions with different average luminance lead to it's difficult to detect traffic lights by a specific threshold for a variety of natural environments. When using a fixed threshold to filter interference, high threshold will result omissions of traffic lights detection, low threshold will lead to more pseudo targets. And there are many objects of which single feature is similar to one of the traffic lights.

To solve these problems, in this paper, based on the characteristics combined color and shape, a plurality of characteristic parameters of candidate regions are extracted and machine classification method are used for traffic signal detection and identification signal states.

**Proposal Approach**

Real-time video of traffic crossing are taken by an in-car camera and then converted into images frame by frame, images are processed to detect whether there are traffic lights and then determine the type of signal if there are. The key of the work is to locate and extract traffic lights accurately. First, based on image pre-processing and color model conversion and segmentation, erosion and dilation processing operations are used to filter small target and then get a number of candidate regions, which may include traffic lights. Then parameters include average brightness, rectangularity aspect ratio of rectangular back box are extracted and calculated, and used for input arguments of machine learning classification to pick out possible traffic lights. After the extraction of traffic lights, another SVM models are constructed to determine the type of traffic lights. The flowchart of the proposed method is shown in Figure 1.

![Figure 1](image_url)

**Image Preprocessing**

The imaging device generally acquires image in a format of RGB, RGB color model is generally used in the computer, but the three color components of R, G, and B are relevant and difficult to separate. So HSV color model is exploited to extract the traffic lights from the image for it is less sensitive to light variations for color processing. RGB image should be converted to HSV image firstly. Traffic lights is active emitting light source, different from other target they have prominent feature of high
brightness and high saturation. From HSV image, some regions are extracted as candidates for a traffic light, the decision whether a pixel belongs to one of the candidate regions or background is done by the values of the saturation S and brightness V.

**Filtering of Regions**

After HSV image segmentation, morphological image processing includes erosion, dilation is done to eliminate the false connection between the regions and get rid of small targets which are generally disturbances.

Area of artificial structure and chunks of green plants are far more than the area of traffic lights in image, regional blocks whose area are more than a certain percentage of the whole image are eliminated. Figure 2 (b) shows the binary image after the morphology operation. Can be seen from the figure, the large blocks with little color change have been removed (FIG. 2 (b) in black areas), such as the sky, most of the green leaves and ground and so on.

![Original image and binary image after the morphology operation](image)

Figure 2. Original image and binary image after the morphology operation.

After the above series of operation, only a few regions are reserved, through morphological processing each domain block will be completely filled. In addition to the traffic lights, there are other interference regions, characteristic parameters of these areas such as circular, edge, color, etc. are different. Here it is assumed that there are N candidate area, referred to as $R_i, i=1, \ldots, N$. After traversing all regions of the binary image, typical characteristic parameters of each region are obtained.

**Features Extraction**

(1) **Brightness ratio.** The same object under different lighting conditions collected by the device may show a different color, to find a suitable brightness threshold for image segmentation under different light intensities is impossible. That image segmentation is dependent on lighting conditions, the same scene is split due to the different light intensities will get quite different results. To solve this problem, the ratio of mean brightness values of candidate regions and entire image of the mean is calculated as one parameter to eliminate or reduce the impact of lighting conditions.

(2) **Aspect ratio of back box.** Traffic lights backplane is an important factor to locate the position of the traffic lights, the backplane has two typical features, one is the color of the pixel is dark, the other is its geometry is rectangle. The minimum bounding rectangle of the region acquired and of which aspect ratio is calculated. Since extraction of back box is based on brightness component, the number and distribution of the target region acquired are different from extracted from $S$, so we use coordinates of the center of both regions to match each other.

(3) **Average hue of region.** Traffic light color will vary under different weather conditions. A stationary color threshold is unreliable. However, the hue of traffic lights varies within a certain range, so be chosen as one of the parameters.
(4) Degree of circularity. Traffic lights are usually round, standard circle circularity is 1 theoretically. But in actual scene, traffic lights showing an elliptical features due to occlusion, or different viewing direction, degree of circularity also fluctuate within a certain range, the closer the circle, the closer the value 1.

\[ e = \frac{4\pi \times s}{L^2} \]  

(1)

Wherein s represents the area of the region, L represents the regional perimeter.

A group parameters of each region are extracted to constitute a combination parameters \( X = \{x_1, x_2, x_3, x_4\} \), \( X \) is used to distinguish traffic lights and other targets. This is a problem of classification. We take Support vector machine (SVM) to classify in this paper.

**Classification and Recognition of Traffic Lights**

**Support Vector Machine Theory**

Support vector machine is a well-known pattern classification method, which has a very good generalization performance without domain knowledge of the problems. This is one of the reasons why SVM is selected as the classifier. SVM originally separates the binary classes \( (k = 2) \) with a maximized margin criterion [9]. Given training vectors \( x_i \in \mathbb{R}^d, i=1,..l \), in two classes \( y_i=+1 \) or \( y_i=-1, i=1,..l \), the SVM requires the solution of the following optimization problem:

\[
\min_{w,b,\xi} \frac{1}{2} \|w\|^2 + C \sum_{i=1}^{l} \xi_i \\
\text{s.t. } y_i(w\cdot\Phi(x_i)+b)-1+\xi_i \geq 0, \xi_i \geq 0, \forall i
\]  

(2)

where \( w \) is the weight vector, \( C \) is the regularization constant, \( \xi_i \) is a positive slack variable, \( b \) is a scalar threshold value, and \( \Phi \) is a nonlinear function that maps the input vector to a higher feature space.

Given a new test data \( x \) to be classified, its category can be predicted according to the following decision function:

\[
f(x) = \text{sgn}(\sum_{i=1}^{l} \alpha_i y_i K(x_i,x) + b) \tag{3}
\]

where \( K(x_i,x) = \langle \Phi(x_i) \cdot \Phi(x) \rangle \). In practice, \( K(x_i,x) \) is calculated through a kernel function instead.

**Support Vector Classification**

The support vector classification(SVC) is one of the key concept of SVM. The idea behind SVM is to map the original data points from the input space to a high-dimensional feature space such that the classification problem becomes simpler in the feature space[10]. The mapping is realized by a suitable kernel function.

In order to construct a proper classify model based on SVC, appropriate features should be extracted from the image. As can be seen from above section, four parameters constitute a set of vectors \( X \), which can be used to classify the region into two main categories, traffic lights or not.

**Model Construction**

The proposed method aims at an accurate recognition of traffic lights and to provide information whether it's passable or not for the vehicle at traffic intersection. The work carried out in two steps, first step is to determine whether segmented candidate regions are traffic lights, the second step is to determine the type of traffic light from region selected. The former need to create a classification model, the latter need to create multiple classification models.
In this paper, 100 groups of image collected by camera at the urban street are used as samples, among which 50 groups of image samples are selected randomly as the training samples while the remaining 50 groups as the testing samples. Corresponding objective functions of the candidate regions in training images are manually labeled. In the next stage, the model for traffic lights is constructed firstly, which is a binary classifier separating two categories of the candidate regions. The position of the circle in the black box is used as a new parameter when models for traffic lights reorganization are constructed. Gaussian RBF kernel is used as kernel function. Parameters optimization of SVM is by grid method.

**Experimental Results**

A traffic signal recognition system is designed to test the proposed method, which consists of image processing, traffic lights detecting, signal recognition and alarm reminder system. Some recognition examples are shown in Fig.3, recognition results are shown in the left-bottom of the picture, and a warning message is given by sound when there is a red traffic light in the same time. Different kinds of traffic lights include red, yellow and green were correctly detected. Images without traffic lights were judged correctly also.

![Traffic lights](image)

(a) Green traffic light (b) No traffic lights

(c) Red traffic light (d) Yellow traffic light

Figure 3. Some results of proposed method.

In general, the recognition accuracy is the most important criterion in evaluating the performance of the system; classification accuracy rate is defined as the ratio of the number of samples being correctly classified by classifier and the total number of samples. Statistical results are shown in Table 1.

<table>
<thead>
<tr>
<th>Models</th>
<th>Detection rate (%)</th>
<th>Recognition rate (%)</th>
<th>Total rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Lights</td>
<td>94</td>
<td>96</td>
<td>90</td>
</tr>
<tr>
<td>Non-Traffic Lights</td>
<td>96</td>
<td>100</td>
<td>96</td>
</tr>
</tbody>
</table>

Table 1. Accuracy of the proposed method.
Conclusion

In this paper, a new traffic light detection method that can be used to identify traffic lights in complex environment is proposed. Firstly, the images are converted to HSV color space, candidate regions are separated. Then pluralities of characteristic parameters include colors and shapes are calculated from all of regions. SVM classifier is created to distinguish between traffic lights or not traffic lights, and then determine the type of traffic light by the trained models if it is. Experiment results show that the proposed method can correctly identify the traffic lights with higher accuracy.

For future work, recognition of arrow-type traffic lights and countdown numbers of traffic lights are necessary to be completed, more experiment tests and actual road work at night are the future works.

Acknowledgments

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References


