A New Approach for Recognition and Position of Traffic Lights

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Abstract—**A kind of traffic lights automatic recognition and position approach which combines color filtering and flood-fill algorithm is discussed in this paper. This approach firstly conducts color analysis in the subspace of hue and brightness of HSV color space model. Then, it processes to filter traffic lights through setting threshold parameters. Finally, it uses flood-fill algorithm to evaluate the connected regions of filtered images and choose necessary target areas. Experiments with different kinds of images, like images of indoor single background, and complex background images in the day and at night have proved the effectiveness of this approach.**

Keywords-HSV color space, flood-fill algorithm, recognition and position

I. INTRODUCTION

Along with the booming development of the intelligent monitoring system, the Intelligent Transportation System (ITS) draws people's attention increasingly. The road traffic security monitoring, target tracking, image measuring and some other areas always demand of recognition and location of the specific target with the red, green or the other colors. And what's more, today's traffic lights recognition plays an important role in autonomous car driving and intelligent robot control. This paper proposes an efficient algorithm in recognition of traffic lights.

Scholars from domestic and overseas have already done some research on this color recognition project. Gong et al.[1], Lu et al.[2], Q et al.[3], Zhang et al.[4] and others proposed an image processing based method which is used to choose an appropriate color space [5] and recognize the color through the component set threshold [6]in the color space. But this method ignored the connection between the values of adjacent pixels in the space and tend to leave some small and isolating areas, while the actual value has a strong correlation between adjacent pixels. Jin et al. [7] and Ren et al.[8] Su et al.[9] and others proposed a method using K-means, but this method cannot recognize color efficiently in complex environment. Zhang et al.[10], Charette et al.[11] used the method based on machine learning, which is with high precision, but demands large amount of calculation and time while the real-time performance is very poor.

From all the above, we can see traditional color recognition methods have shortcomings in different levels. So this paper proposes an improved color recognition method which combined the HSV color space model with the advantages of flood-fill algorithm to segment the image and recognize the traffic lights areas and then locate them. This method only needs small amount of calculation, it is simple but efficient and easy to implement which enables the color recognition problem to be solved effectively.

II. COLOR SPACE MODEL AND IMAGE PROCESSING

As previously mentioned, there are many limitations in traditional methods, such as inaccurately identifying and locating images in different environment and real-time online identification without high accuracy, etc. In order to solve those problems, this paper proposes an efficient method which combines the HSV color space model with flood-fill algorithm to process the scenario twice. In the first time, it converts the RGB color space to HSV color space and set threshold value of the variable H and V to separate some colors, while in the second time, it strikes all the connected regions in the processed image and filter the useful parts by using flood - fill algorithm.

A. *RGB and HSV Color Space Model*

It is necessary to choose the right color expression model in order to express the color information correctly and effectively. Color model is set up in the color space, so the color space and color model are closely related. Because one color can be described by three basic variables during the establishment of the color model, so that the model can be seen as a three-dimensional coordinate system and every point on the spatial point represents a particular color. During the real-time image processing, people usually use the RGB model instead of others like CMY, UV, IQ and HIS model etc.

RGB color space is shown in Fig. 1 (a).It is one of the most basic color space and it is a kind of mix-type color space built on the basis theory of red, green, blue these three primary colors. According to the theory of the three primary colors, any color can be synthetized by certain proportion of red, green and blue. Building an unit cube based on the RGB axis in the Cartesian coordinate system, the origin (0, 0) represents black and diagonal vertices (1,1,1) represents white, the three vertices on the unit cube represents red, green and blue. With these three primary colors, all colors of light can be described on a point or a vector in the unit cube.

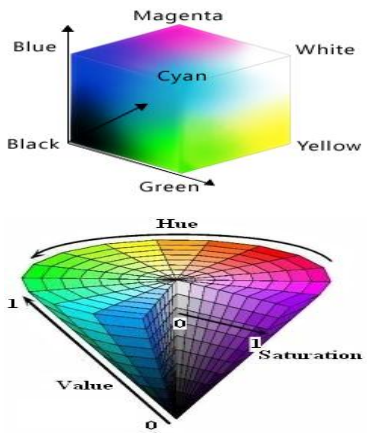

FIGURE I. (A) RGB COLOR PACE, (B) HSV COLOR SPAC.

To quantitatively describe the affection of color did to people's eyes, we establish a space model described and calculated by hue, luminance and saturation which called HSV color space model. The HSV color space model in polar coordinates definition is shown on the right in Fig. 1 (b).

Hue is decided by the dominate wavelength of visible light reflected by object. This parameter described by angle and becomes a circle that rotates 360 degrees around the center in the polar coordinate system. Saturation reflects the color's shade ranging from 0 to 1, represents the color's bright degree. The higher the degree of saturation, the deeper the color is, and when the saturation equal to 0 there only left grayscale. Brightness value refers to the effects of light waves acting on the sensor, The range is from 0 to 1, and the size is determined by the color of the object coefficient. The greater the coefficient of the color, the much brightness of the object has.

The brightness of the red, green, blue, these three primary components always have different degrees contribution to the image brightness. They bring troubles to the work which needs hue concentration information like traffic lights recognition. However the HSV model concentrates the color information on the H component, with S value showing the picture color saturation, and V component described grayscale which represents the brightness of the original figure. Therefore, HSV model can separate the brightness information in the environment, and minimize the brightness differences causing by the lights. So we use the HSV color space model in the traffic light recognition algorithm,

The general transformation from RGB to HSV model algorithm is shown as follows:

$$
\begin{aligned}
& v = \max(r,g,b) \\
& s = 1 - \min(r,g,b)/v \\
& h = \begin{cases} \theta & b \le g \\ 360-\theta & b > g \end{cases} \\
& \theta = \cos^{-1}\left(\frac{[(r-g)+(r-b)]}{2\sqrt{(r-g)^2+(r-b)(g-b)}} \right)
\end{aligned} \tag{1}
$$

where $r,g,b,s,v \in [0,1], h \in [0,359]$.

III. IMAGE SEGMENTATION BASED ON THE FLOOD-FILL ALGORITHM

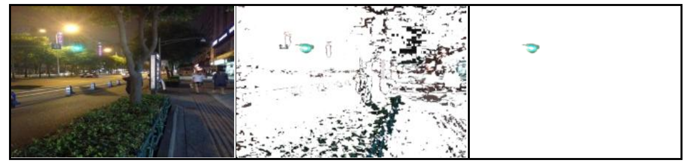

FIGURE II. (A) THE ORIGINAL SCENE IMAGE, (B) IMAGE CONVERTED TO HSV COLOR SPACE MODEL AFTER THRESHOLD PROCESSING, (C) IMAGE CONVERTED TO HSV COLOR SPACE MODEL WITH FLOOD-FILL ALGORITHM PROCESSED.

Before processing the images with flood-fill algorithm, we make the color information of the picture converts from RGB color space to HSV color space, and use the HSV color space model to simulate the image threshold. The original scene images we selected is shown in Fig. 2 (a), the histogram of H and V in the HSV model is shown in Fig. 3 (a) and (b). At the same time, by setting the threshold parameters, for H variable is (H>120 and H<200) or (H<10 and H >0) or (H>340 and H<360) and for V variable is (V>0 and V<0.7), we can see the effects in original image after HSV color space conversion and threshold processing in Fig. 2 (b), the histogram of H and V in the image of Fig. 2 (b) shown in Fig. 3 (c) and (d) as well.

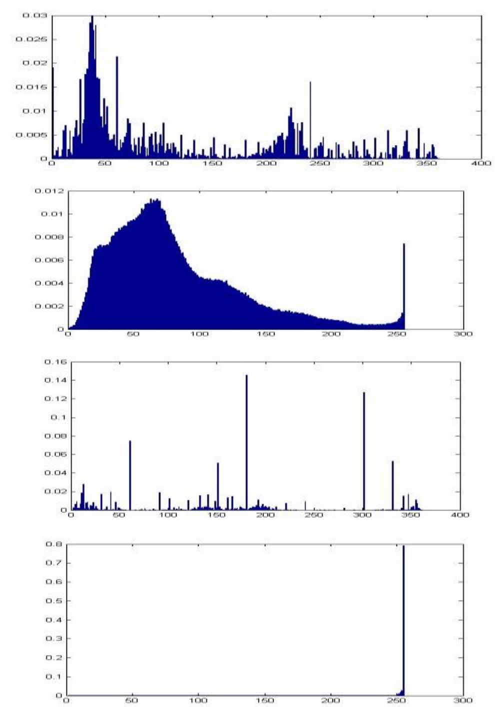

FIGURE III. (A) THE HISTOGRAM OF H COMPONENT IN ORIGINAL IMAGE, (B) THE HISTOGRAM OF V COMPONENT IN ORIGINAL IMAGE, (C) THE HISTOGRAM OF H COMPONENT IN THE IMAGE AFTER THRESHOLD PROCESSING, AND (D) THE HISTOGRAM OF V COMPONENT IN THE IMAGE AFTER THRESHOLD PROCESSING.

Referring to Fig. 2 (b), besides the area of color we need, we can also find a lot of effects from other factors which make sparse points and some small connected regions in the same property that we need. So that we use the flood-fill algorithm to calculate all the sparse points and small connected regions and choose these we need to recognize and locate the traffic light color area.

The flood-fill algorithm is a kind of area filling algorithm. Its essence is the seed filling algorithm. This method is applicable to fill internally defined area. The internally defined area refers to the field that all pixels in the region has the same color or brightness values, and those outside have the different ones. The application of the algorithm in recognizing traffic lights is: we use HSV color space to threshold processing, preliminary segment the image and divided it into two parts. One part is useful while the other part is not. And then we search the useful part with the flood-fill algorithm which in order to find the connected region in the whole scope. Finally we filter the regions we need for traffic lights recognition processing.

In order to strive for the connected region based on flood-fill algorithm, the connected region threshold size and direction in four or eight direction search option needs to be adjusted. We choose four directions to pursue more compaction connection of color regions in the process of traffic light recognition. We judge connected regions through adopting depth-first search method according to the different settings of the traffic environment to set up the parameters of the region size.

The flood-fill algorithm based on depth-first search code is shown as follows:

```
void Flood_Fill(int x,int y)
{
        if(vis[x][y]==1) return;
        vis[x][y]=1;
        if(x+1<m) Flood_Fill (x+1,y);
        if(x-1>=0) Flood_Fill (x-1,y);
        if(y+1<n ) Flood_Fill (x,y+1);
        if(y-1>=0) Flood_Fill (x,y-1);
}
```

In the flood-fill algorithm implementation process, if a certain pixel in the image is visited, then marked vis [x] [y] as 1 and the function returned directly; If it has not been visited, it will set vis [x] [y] to 1, and then visit this pixel's adjacency in four directions right, left, up and down in turn. After the HSV threshold processing we will use the flood-fill algorithm to select the effectively connected regions, and finally get the illustration shown in Fig. 2 (C).We can find that color image segmentation result based on the flood-fill algorithm is much better than the one based on HSV space.

IV. EXPERIMENTAL RESULTS OF TRAFFIC LIGHTS RECOGNITION AND LOCATION

In order to analyze the performance of the algorithm, we took a picture of paper-made traffic light in simple background under indoor environment and we also took the picture of the traffic lights near the highway under complex background in the day and night. We took two pictures of the same traffic lights, and each picture is the situation that red or green light lighted alone.

A. The Result under Indoor Simple Background

Fig. 4 (a) is the picture of paper-made traffic lights in simple background under indoor environment. It is 601 pixels wide and 430 pixels high. Fig. 4 (b) is the recognition of its results. Because of the simple background environment, the traffic light color region's boundary outside is in single color. After HSV color space conversion of the original image, with the threshold value up (H>70 and H<165) or (H<25 and H >0) or (H>340 and H <360) we can filter out the red and green region with clear boundary, which means the recognition is accurate. At the same time, the algorithm we proposed can also output the traffic light's coordinates of the center pixel (49,161), (27Z,134), (525,118).All the coordinates in this article is centered on the upper left corner, the x axis's positive directions to the right, and the y axis's positive direction is to the downward.

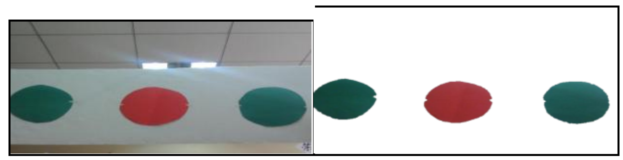

FIGURE IV. PAPER-MADE TRAFFIC LIGHT RECOGNITION IN SIMPLE BACKGROUND (A) ORIGINAL IMAGE (B)THE RESULT PROCESSED THROUGH OUR ALGORITHM.

B. The Result under the Complex Background in the Day

Fig. 5 is the image of traffic light near the highway and the recognized image under the complicated environment in the daytime. Compared with the previous experiments, this one is more complicated in the background in the variety of background hue brightness and grayscale. The traffic light's color region boundary is vague and the shape is irregular. Therefore, we have to do the HSV color space conversion first, and set a threshold filtering, and then obtain the connected region size to filter again, which is the final recognition results. Through the output of target images, we can see that under complicated background, recognition of traffic lights images we get near the road in the daytime is accurate. From the up to the down, the traffic center coordinates output by the system are (147,292), (168,361), (368,489), (453,469), (128,891), (340,488), (440,475) respectively.

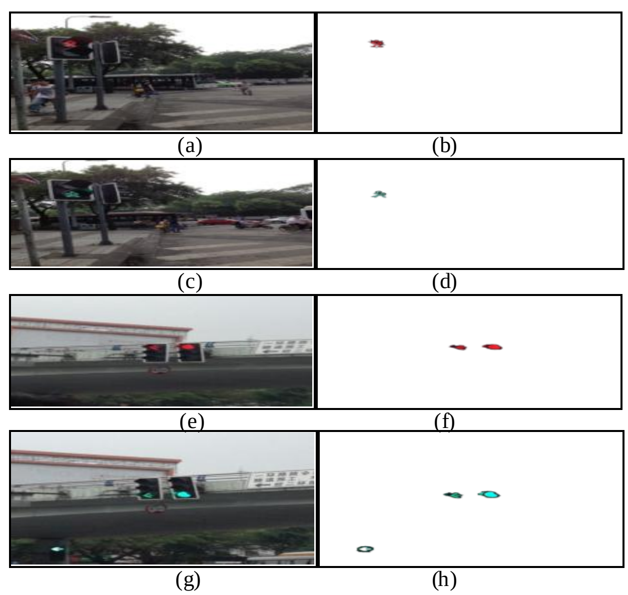

FIGURE V. THE TRAFFIC LIGHT IMAGES AND RECOGNITION RESULTS OF TWO DIFFERENT SCENES IN THE DAY.

C. The Result under the Complex Background at Night

Fig. 6 is the image of traffic light near the highway and the recognized image under the complicated environment in the nighttime. Compared with the previous experiments, this one is more complicated in the background in the variety of background hue brightness and grayscale. The traffic light's color region boundary is vague and the shape is irregular. The brightness of the traffic light color region is dramatically different from the environment background which increases the difficulty in color recognition. Therefore the method in recognizing these two pictures is the same as the last one. We have to do the HSV color space conversion first, and set a threshold filtering, and then obtained the connecting region size to filter again, getting the final recognition results. Through the output target image we can see that under the complicated background, traffic lights recognition rate we got near the road at night is not as good as the last one but still good enough. From the left to the right, the traffic center coordinates produced by the system, are (125,144), (146,112) respectively.

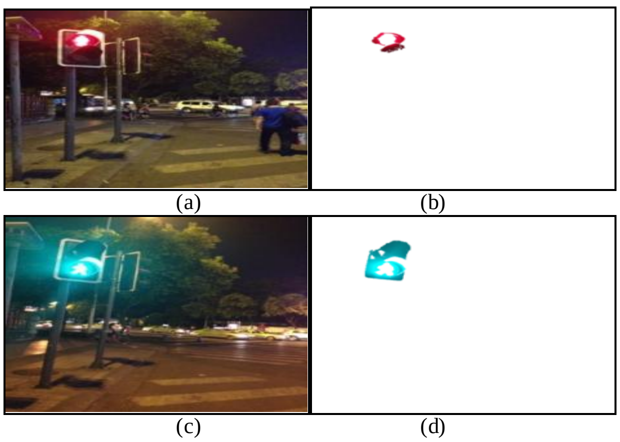

FIGURE VI. THE TRAFFIC LIGHT IMAGES AND RECOGNITION RESULTS NEAR THE HIGHWAY AT NIGHT.

V. SUMMARY

In this paper, we propose a new traffic light recognition algorithm based on HSV color space and the flood-fill algorithm. As the RGB color space do not have enough information in color distribution, we convert the image into HSV color space and use H and V components to threshold image. When it comes out with some connected regions not belonging to the target area, we use the flood-fill algorithm to filter the irrelevance regions so as to get the target regions and its coordinates. The model we used in this method is simple, and the calculation is convenient and easy to be realized. Experimental results show that our algorithm is valid.

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