Traffic Lights Detection and Recognition based on Color Segmentation and Circle Hough Transform

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Abstract—**Automatic detection and recognition of traffic light system is a useful real world application. In this paper, we describe our effort in building such a system. The image of scene obtained from on-vehicle camera is first segmented and converted into three binary images representing images with red, green and yellow color, respectively. Each binary image is then smoothed using Gaussian filter in order to remove noise. The traffic light is detected by finding circular object on the smoothed binary images. We employ Circle Hough transform for circular object detection. The recognition of traffic light is based on the color represented by the binary image with detected circular object. Evaluation of the above method with two real traffic videos demonstrates the effectiveness of the method.**

Keywords—traffic detection and recogintion; circular hough transform; color segmentation; gaussian bluring;

I. INTRODUCTION

Traffic accidents involve at least three factors: drivers, vehicle conditions and environment. The majority of traffic accidents are caused by human error. Regardless of its cause, drivers who disobey traffic rules contribute the most for traffic accidents, while accidents that are due to brake malfunction, broken engine, bad weather or due to bad road conditions are less likely.

Traffic lights play an important role in preventing traffic accidents, particularly around road junctions. A tool or device that can automatically detect and recognizes traffic light well ahead and then provide alert on the upcoming traffic light would enhance the driving safety. It could also help visually impaired pedestrian and driver deal with traffic lights.

Although it is an easy task for human, automatic detection and recognition of traffic lights is not a trivial problem. Its very small size in comparison with other objects in the scene image makes it difficult to spot. Many other objects with similarity in colors and/or shapes pose another noise problems. For example, the tail lamp of other vehicles might be confused as red traffic light. In addition, other objects such trees could partially or even completely block the appearance of traffic light. Moreover, varieties of illuminations due to bad weather or sunny day present another challenge. As an example, bright sunlight could change the color of traffic light to deviate from its normal range in the scene image.

In this paper, we report our work on real time traffic light detection and recognition. It is based on stream of scene images taken from on-vehicle camera. Circle Hough Transform and color segmentation are employed for traffic light detection and recognition, respectively. Gaussian-based filtering is applied to reduce noise in order to improve the detection of traffic lights.

The rest of the paper is organized as follows. Section II describes prior research related to our work. Section II provides the detail of our approach. The evaluation of our traffic light detection and recognition system is discussed in Section IV, followed by conclusions in Section V.

II. RELATED WORK

A lot of works has been done in traffic light detection and recognition. This problem has been tackled by three general approaches: template-based matching, circular extraction and color distribution-based recognition. The first approach applies standard template of red, green and yellow lights on the extracted regions [1, 2]. The second approach mainly employ a special case of Hough Transform for circle detection (i.e., the shape of traffic lights) [3]. The third approach commonly uses HIS, Lab and RGB color space for traffic light recognition [4, 5, 6]. Each of these approaches has its strength and weakness.

Jie *et* al. developed an electronic travel aid to help visually impaired persons to cross roads safely [7]. The traffic lights were detected using rectangular and circular extraction. The recognition of traffic lights were determined by combining the color distribution as well as its position within the rectangular shape.

Charette & Nashashibi has developed traffic light recognition system that is applied as an on-vehicle system [1]. It detects traffic light by finding bright area that is surrounded by a darker on grey-level image (spot light detection). The detected spot light is then examined using adaptive template matcher to select the one that represents the shape of traffic lights. In this work, the traffic light recognitions is based on the three states: go, caution and stop.

Traffic lights detection based on vehicle-mounted camera was also developed by Ghong et al. [6]. Morphological operator and color segmentation method was employed to extract candidate regions of traffic lights. The recognition of traffic light was performed using machine learning approach.

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In addition, they adopted continuously adaptive mean shift method for avoiding false negative and tracking loss.

Omachi detected and recognized traffic light using edge and color information [3]. They used normalized RGB color space to handle undesired effects of illumination changes. Similar to ours, it detects the circular of traffic light within the framework of Hough Transform.

Portable system for traffic lights detection and recognition was developed by Kim et al. to help driver who are color-blind [8]. To recognize traffic lights, the system uses RGB component adjustments, thresholding algorithms and median filter. Illumination change is handled by a simple adaptation method.

III. Our Approach

Our approach for traffic light detection and recognition is based on the observations that the traffic lights are of circle shape with red, green or yellow color. In addition, the detection and recognition process must be performed in real time in order to be useful. Figure 1 depicts the detection and recognition process of traffic lights.

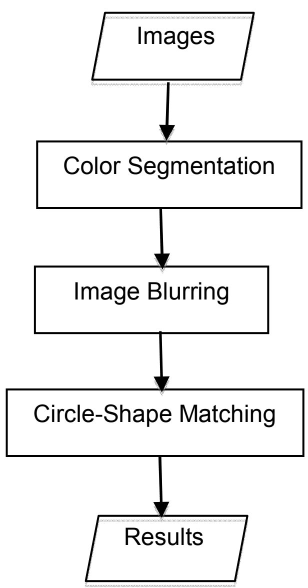

Figure 1. Traffic Light Detection and Recognition Process

The system accepts images captured from video or camera as input. It outputs bounding boxes covering any detected traffic lights and its color (red, green or yellow). The detection and recognition of traffic lights consists of three stages: color segmentation, blurring and circular matching. If any circle-shape object is found with red, yellow or green color, then it will be considered as a traffic light.

A. Color Segmentation.

Assuming that the input is a color image, the first stage is to convert the image into three binary images representing images with red, green and yellow color, respectively. This process separates an image based on its colors. On each binary image, pixels with red, green and yellow colors will be replaced with white, and the rest of the colors with black. Because the RGB values for the traffic light colors can vary depending on the intensity levels and other factors, we use samples from traffic lights with darker and brighter colors as the lower and upper bounds. Table 1 provides the ranges of RGB values for red, yellow and green colors identifications. Similar color segmentation approach was also developed by Gong et al. [9].

TABLE I. Definitions of Traffic Light Colors

		Range of RGB Color		
	Red	Red	Green	Blue
Traffic Light Color	Red	200-255	0-100	0-100
	Yellow	200-255	100-255	0-80
	Green	0-80	150-255	150-255

B. Bluring

The purpose of blurring in the second stage is to reduce noise by smoothing the binary images. This is an important step before circle-shape detection process. Gaussian blur is employed for image smoothing. Specifically, it uses Gaussian function (see Eq. 1) to blur the surrounding images.

$$f(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\left(-\frac{(x-a)^2+(y-b)^2}{2\sigma^2}\right)} \qquad (1)$$

In the Gaussian function above, (a, b) is the origin coordinate, σ is the standard deviation of the Gaussian distribution, and $f(x,y)$ is the weight for pixel in coordinate (x, y). Hence, the origin pixel has the highest weight and neighboring pixels have lower weights, smoothly reduced as it is farther from the origin.

C. Circle-Shape Detection

After color segmentation and image blurring, the last stage is detecting if the white part of the binary images has circle shapes. We employ Circle Hough Transform this process.

A circle with radius r and center (a,b) can be represented by equation:

$$(x-a)^2 + (y-b)^2 = r^2$$

The Circle Hough Transform seeks to obtain the values of a, b and r that fits the circle if exists. It starts by traversing edge pixels of an object. Assuming that the radius r is known, then circles will be drawn with edge points as the circle centers. A counter is maintained to count the number of circles that passes through a particular location. If the highest counter value exceeds a threshold, then the traced object is detected as a circle with the corresponding counter location as the center. Otherwise, the object is not a circle. The threshold is determined as the lower limit to define a circle. The higher is the value of threshold, the more accurate will it detect the circle. Very low threshold could result in non-circle object

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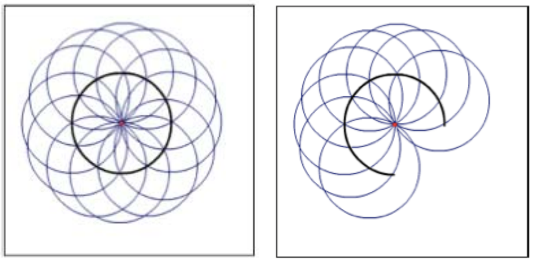

Figure 2. Full circle (left) and partial circle (right) detection based on Circle Hough Transform

mistakenly detected as circle. The right threshold value would allow circle detection that is partially occluded by other non-circular objects. Figure 2 illustrates how full and partial circles are detected using Circle Hough Transform.

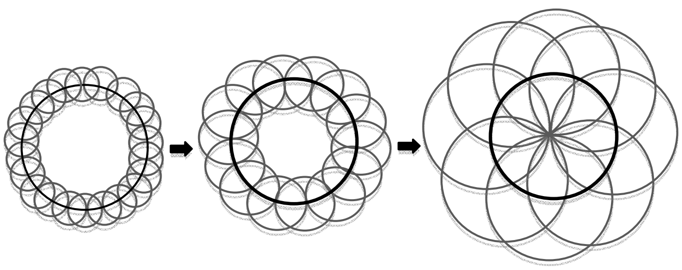

Figure 3. Searching circle object with unknown radius.

If the radius is not known, the process of circle detection is performed iteratively from the minimum to the maximum radius *r*. Figure 3 illustrates this process. The minimum and maximum values of radius as well as its increment become the parameters of the algorithm.

To speed up the circle detection process, we also take advantage of the fact that traffic lights that are within the detection ranges always appear in the upper part of images. Therefore, the circle detection can directly focused on this part, ignoring the image lower part.

IV. EVALUATION

We have implemented the system using a computer vision library in C#. The system takes images captured from camera or video as input. Running on Intel Core i3-312M @2.5GHz with 4 GB RAM, the detection time ranges from 12 to 14 milli-seconds, indicating that it can be done in real time.

To evaluate the detection accuracy, we perform experiments using two videos as inputs. The first video entitled "A guide to Singapore Traffic Lights" is obtained from Youtube.com. It has a clear traffic light and represent various kinds and situations of traffic lights in public. The second video, called "Veteran Video", contains video recorded directly in a car that was driven along Veteran street in the city of Bandung.

The detection accuracy is measured as the percentages of events that are correctly detected. An event is defined as the occurrence of the same traffic lights regardless of its duration. For example, thirty-seconds and one-minute green traffic light will be counted as a single event, although the system detects the presence of green light many times consecutively. The change of traffic lights (e.g., from green to red) will trigger a different event.

TABLE II. DATA FOR EXPERIMENTS

	Image Size	fps	#Event
Singapore Traffic Lights	640 x 360	25	13
Veteran	1920 x 1080	29	16

Preliminary experiments on the range of RGB colors revealed that the range of color that is narrower can provide better accuracy of traffic light detection and recognition. However, it is also more susceptible to the type of camera and the intensity level of background lights. On the contrary, the wider color range will result in less accurate of traffic light detection but it is more tolerant to the background lights intensity levels as well as to the different kinds of camera that is used.

Table III shows the experiment results. It turns out that the video resolutions (represented by the image sizes) greatly affect detection and recognition accuracy. The accuracy of "Veteran" video is much higher than the "Singapore Traffic Lights" video. This might be due to the fact that the resolution of "Veteran" video is about three times larger. With the image size that is 9 times larger on "Veteran" video, the detection processing time takes about 110 ms, which is 7.3 slower than that of "Singapore" video (about 15 ms). Nevertheless, the detection time of about 0.1 second is considered acceptable should this be applied for a real time system.

TABLE III. EXPERIMENTS RESULTS

	Accuracy	Detection Time
Singapore Traffic Lights	56%	15 ms
Veteran	93%	110 ms

On the Veteran video, 2 out of 14 events of traffic lights were missed to detect. In these events, the green traffic lights looks like white lights (see Figure 4), so it was filtered out during the color segmentation stage.

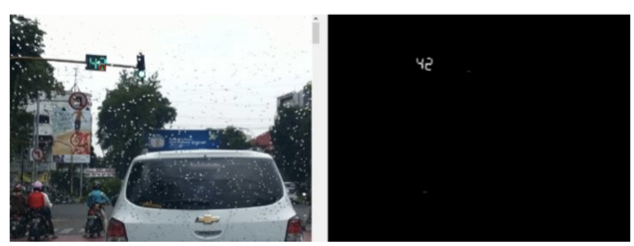

Figure 4. Green traffic light that looks like a white light.

The Singapore video provided more interesting cases for mis-detection. There was actually 15 events in this video but our system detect 16 events instead. The following describes the various cases of mis-detection.

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Figure 5. Mis-detection of pedestrian signal.

In the first case, signal for pedestrian is mis-detected as traffic light. Figure 5 illustrates this mis-detection. A signal for allowing pedestrian for crossing the street is still considered a green light for vehicle, which is very dangerous in real situation. This could be avoided by increasing the threshold level for circle detection.

Figure 6. Mis-detection of construction signal lights.

Another case is mis-detection of construction signal lights, which has amber color. Figure 6 shows this example. This construction signal light is detected as yellow/red traffic light because of the shape and color similarity between construction signal and traffic lights. The solution to this problem is similar to the mis-detection of pedestrian signal; that is, even further increasing the threshold level in detecting almost full circle.

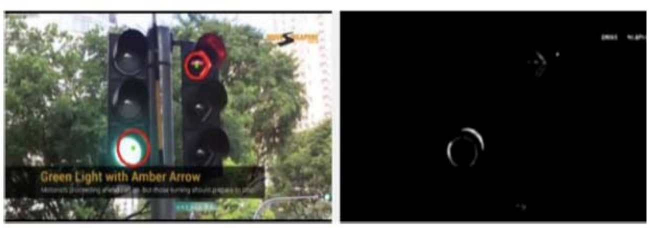

Figure 7. Mis-detection of turning signal lights.

The last case is that it cannot distinguish forward traffic lights from turning signals of traffic lights. The latter is mis-detected as the ordinary traffic lights. It occurs in an intersection that controls multi-direction traffic flows, for example, allowing vehicle to move forward but forbidding to turn right (see Figure 7). It indicated that circle detection is not enough for traffic light detection and recognition.

In addition, we also observed that the minimum radius of traffic lights that can still be accurately detected is about 9 pixels. Assuming using a 5MP camera with screen dimension of 1280 x 720 pixels, it corresponds to a maximum distance of 27 meters from traffic light signals in order for the system to be able to detect it. If a driver needs at least two seconds to react a given alert on oncoming traffic signals, the vehicle speed cannot be more than about 48 km/hour.

V. Conclusions

Driving safety can be enhanced by providing alert to the presence and status of traffic lights on the road junction ahead. In tis paper we have described our work on developing a system that detects and recognizes traffic lights based on Circle Hough Transform for the detection task and color segmentation for the recognition task. Experiments with two videos demonstrated that this method is quite effective at identifying traffic lights in the ideal situation and where the traffic light is partially occluded by other objects. However, the ability to recognize partially blocked circular also triggers another problem since it could mis-detect non traffic light objects. In addition, the traffic light is not only a circular, but the shape can also be an arrow for regulating turning movements, or can be a person icon for pedestrian crossing the street. Furthermore, traffic lights that are flashing also provide different interpretation, which has not been tackled in this work. These issues will be addressed in our future work.

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