Traffic Light Detection with Color and Edge Information

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***Abstract*—The concern of the intelligent transportation system rises and many driver support systems have been developed. In this paper, a fast method of detecting a traffic light in a scene image is proposed. By converting the color space from RGB to normalized RGB, some regions are selected as candidates of a traffic light. Then a method based on the Hough transform is applied to detect an exact region. Experimental results using images including a traffic light verifies the effectiveness of the proposed method.**

Keywords-image recognition; traffic light; intelligent transportation system; driver support system; Hough transform

I. INTRODUCTION

The concern of the intelligent transportation system rises and many driver support systems have been developed. Especially, systems that use images are paid attention recently. Some systems that recognize lanes or license plates have been put into practical use. Researches on recognition and understanding of road environments like surrounding cars and road signs are investigated. For example, Maldonado-Bascón et al. proposed a road-sign detection and recognition system [8]. In their system, a sign is segmented from a scene image by color information, and its shape is classified by the support vector machine. Fang et al. proposed a framework for detecting and recognizing road signs with a computational model based on the human cognitive processes [2]. Varun et al. proposed a traffic sign recognition system based on the template matching method [10].

Recognizing traffic lights are important for safety driving. If it is possible to detect and recognize a traffic light, it will give useful information to a driver to understand the road environment. However, it is not easy to detect a traffic light in a scene image since the traffic light is very small compared to other objects and there are many objects of which colors are similar to one of the traffic lights. Therefore, there are not so many researches on this topic. Lindner et al. proposed a detection and recognition system of traffic lights [6]. Their method uses GPS data and digital maps along with an image taken by a camera in order to enhance the performance of the system.

In this paper, we propose a method of detecting a traffic light from a single scene image taken by an in-vehicle camera. For detecting general object from a scene image, a lot of techniques have been proposed. The template matching is one of the most fundamental ones. Given a template and an input image, a region that is the most similar to the template is selected with a criterion such as the normalized cross correlation or the sum of squared differences [1]. However, the major drawback of the template matching is the high computational complexity. Using color histogram is another method for detecting an object [9]. Since Vinod and Murase developed a fast searching method using the color histogram, it is widely used for object detection [11]. However, a lot of objects in a scene image of which colors are similar to the one of the traffic lights. Detecting key points and matching with the features of the key points achieves a robust matching [7]. However, the shape of a traffic light is so simple that it does not have many distinctive key points.

Since the shape of a traffic light is a circle, we can find a traffic light from a scene image by detecting a filled circle of which color is the one of the traffic lights. The Hough transform is a traditional method for detecting a shape that can be expressed by a mathematical expression from an image [5]. Although it cannot be used for detecting complicated shapes, it can be used for detecting a circle. Since an expression of a circle has three parameters, in order to detect a circle with the Hough transform, voting into the three-dimensional parameter space is necessary, which is a time-consuming task. In order to reduce the computation time and enhance the stability of detection, we propose a method for modifying the voting process of the Hough transform.

In addition, we have to deal with various lighting conditions. If the lighting condition changes, the color of the traffic light will also change. In order to achieve a stable detection, we have to convert the color space from RGB to an appropriate one. We chose the normalized RGB color space since it has been reported that the normalized RGB is robust under illumination changes [3]. Experimental results using real scene images including a traffic light verifies the effectiveness of the proposed method.

II. PROPOSED METHOD

Fig. 1 shows an example of a scene image including traffic lights. In the proposed method, given a scene image, first the color space is converted from RGB to the normalized RGB. Then, some candidate regions for a traffic light are detected by remaining the pixels of which colors are the ones of traffic lights. Next, edges are detected from the

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Figure 1. Example of an input image.

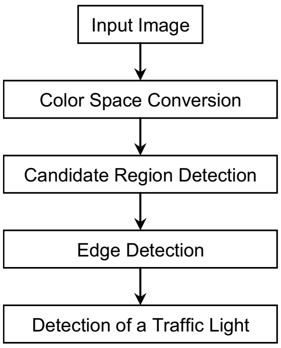


Figure 2. Flow of the proposed method.

remaining pixels. Finally, a circle which represents a traffic light is detected by the method based on the Hough transform. The flowchart of the proposed method is shown in Fig. 2.

A. Converting Color Space

The colors of traffic lights differ depending on the change in the lighting conditions caused by weather, time and other factors. In order to eliminate the slight change in the color, we convert the color space. It is known that the normalized RGB is robust under the change in the lighting conditions [3]. Therefore, we convert an RGB image into a normalized RGB one.

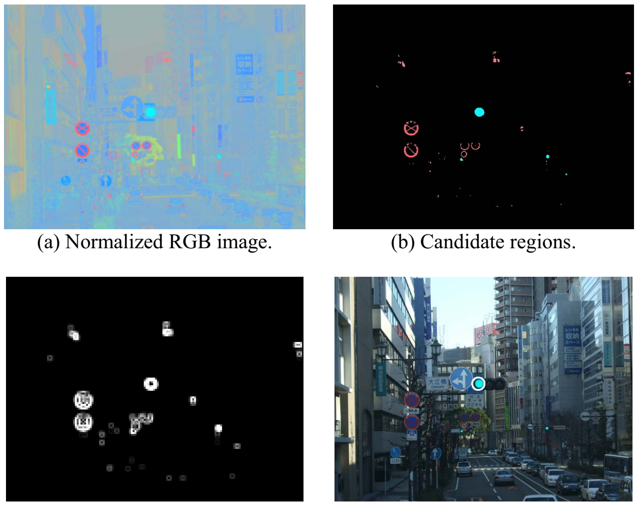
Suppose the red, green and blue values of a pixel be r, g and b, respectively. The values of the normalized RGB R, G and B are defined as:

$$\begin{cases} R = G = B = 0 & (\text{if } s = 0) \\ R = \dfrac{r}{s},\ G = \dfrac{g}{s},\ B = \dfrac{b}{s} & (\text{otherwise}) \end{cases}, \quad (1)$$

where

$$s = r + g + b.$$

Fig. 3(a) is the normalized RGB image converted from the input image.



(a) Normalized RGB image. (b) Candidate regions. (c) Edges. (d) Detected traffic light.

Figure 3. Intermediate images of the proposed method.

B. Extraction of Candidate Regions

From the normalized RGB image, some regions are extracted as candidates for a traffic light. The decision whether a pixel belongs to one of the candidate regions or not is done by the values of R, G and B. We observed the images of the traffic lights and determined the condition that a pixel belongs to a candidate region as follows:

$$(R > 200 \text{ and } G < 150 \text{ and } B < 150)$$
$$\text{or } (R > 200 \text{ and } G > 150 \text{ and } B < 150)$$
$$\text{or } (R < 150 \text{ and } G > 240 \text{ and } B > 220)$$

Connected regions obtained by the selected pixels are the candidate regions of a traffic light. Fig. 3(b) shows the regions that are the candidates of a traffic light.

C. Edge Detection

We extract only the candidate regions from the image and edges are detected from the image. We used the Sobel filter [4] to detect edges. Fig. 3(c) shows the edges detected from the image of Fig. 3(b).

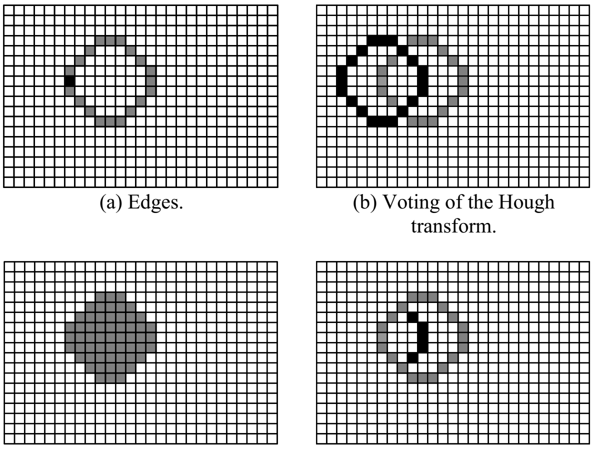
D. Detection of a Traffic Light

In order to detect a traffic light, a filled circle of which color is the one of the traffic lights is detected. In the framework of the Hough transform, edge image is used and circular edges are detected. A simple equation of a circle:

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

can be used to detect a circle from the edge image. For each pixel that is on a detected edge, voting into the three-dimensional parameter space (a, b and r) is done. The set of parameters that gets the most votes represents the position and the size of the traffic light.

However, in this framework, filled circles and open circles are both detected. In order to avoid this shortcoming and speed up the detection, we utilize the candidate regions displayed in Fig. 3(b). Fig. 4 shows an example. Suppose the



(a) Edges.

(b) Voting of the Hough transform.

(c) Candidate region.

(d) Voting of the proposed method.

Figure 4. Detection of a filled circle.

gray and black pixels in Fig. 4(a) are the ones of a traffic light. In the Hough transform, for each pixel (x, y), voting is done in the three-dimensional parameter space with (2). Black pixels in Fig. 4(b) show the results of voting for the black pixel in Fig. 4(a) into the ab-plane where the value of r is fixed. Suppose the candidate region corresponding to the edges of Fig. 4(a) is shown in Fig. 4(c). In the proposed framework, voting is done only if the pixel (a, b) and its four-neighbors belong to the candidate regions. The result of voting in the ab-plane by the proposed method is shown as the black pixels in Fig. 4(d).

Fig. 3(d) displays the result of detection. The white circle represents the detected region.

III. Experiment

In order to confirm the effect of the proposed method, an experiment of detecting a traffic light from a scene image was carried out.

A. Data

As far as the authors know, there is no database of traffic lights. Therefore, we took pictures including traffic lights by a digital camera (Fujifilm FinePix F31) through a windshield of a car. Thirty images were used for evaluation.

B. Results and Discussions

We compared the proposed method and the method in which the traditional Hough transform was used for detecting a circle. The detection accuracies (number of correctly detected traffic lights) and the averaged processing times are shown in Table I. The processing time for each image is displayed in Fig. 5. The results show that the proposed method can detect a traffic light in a reasonable time and the accuracy is better than the traditional method.

The proposed method not only improves the processing time but also the detection accuracy. This is because a lot of open circle objects exist in a scene image. Typical ones are traffic signs. An example is shown in Fig. 6. Fig 6(a) displays an image that the traditional method failed to detect

TABLE I. Accuracy and Averaged Processing Time

	Traditional method	**Proposed method**
Accuracy	20/30	26/30
Time [sec]	0.561	0.347

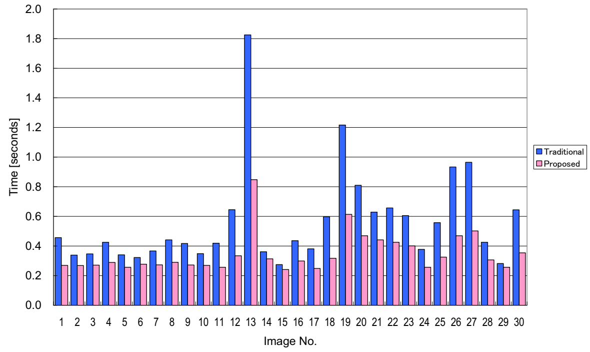


Figure 5. Processing time.

a traffic light, while the traffic light was correctly detected by the proposed method. The detected traffic sign has large white area in it. In the traditional method, only the circular edges are detected and it does not take into account whether there is a part of which color is not the one of the traffic light. Fig. 6(b) is the result by the proposed method. In the proposed method, since filled circles tend to be detected and the traffic light was correctly detected.

There was no image that the proposed method failed and the traditional method succeeded. Fig. 7 is an example of the image that both method failed to detect a traffic light. In this image, the traffic light is too small compared to other objects that have a similar shape or the same color. A traffic sign and a tail lamp were detected by the traditional method and the proposed method. Since we can predict the position of a traffic light in the image if the position of the camera is fixed, it will be effective for improving the accuracy to consider the position of the detected area.

IV. Conclusions

In this paper, a method for detecting a traffic light from a scene image was proposed. First a color space is converted from RGB to the normalized RGB in order to eliminate the effect of the change in the lighting condition. Then candidate regions of a traffic light are detected using color information, and edges are detected. Finally, a traffic light is detected by the method based on the Hough transform.

Experimental results show that the proposed method can detect a traffic light in a reasonable time and the accuracy is better than the traditional method. In order to improve the accuracy, taking into account the position of the detected area in an image is a future work. Moreover, a large-scale experiment with a lot of images is necessary to evaluate the proposed method. This is another future work.

(a) Traditional method. (b) Proposed method.

Figure 6. The image that the traditional method failed.

(a) Traditional method. (b) Proposed method.

Figure 7. The image that both methods failed.

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