Traffic Light Detection During Day and Night Conditions by a Camera

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***Abstract*—In order to reduce accident at traffic intersections during day and night, the algorithm of traffic lights detection which is applied in a vehicle driver assistance system is designed by using the image processing technology. The system of traffic light detection includes three parts: a CCD camera, an image acquisition card, and a PC. Based on RGB color space, the algorithm extracts red, green, and yellow objects in the image firstly; For the purpose of eliminating disturbance in the environment, the features of traffic lights are used to verify the object identity, and then the types of traffic signals are judged. The results of experiments show that the algorithm is stable and reliable.**

***Key words*—traffic intersection; traffic lights detection; vehicle driver assistance; image recognition**

I. INTRODUCTION

With the development of IVS (Intelligent Vehicle System), many achievements have been gained in the field of vehicle driver assistance system, such as the technology of car anti-collision, the technology of road curb detection and the technology of pedestrian detection [1~4], etc. Because many traffic accidents often take place at intersections, IVS at intersections has been studied in recent years [5~8]. For example, the system of traffic light recognition can be applied in the driver assistance system [9, 10], which can remind drivers to pay attention to their soundings when they reach an intersection and help him make a decision.

The information of traffic signal can be obtained through wireless communication technology, but it is high cost for installing wireless communication equipment and is difficult to construct the related hardware facilities. In order to simplify the hardware, the image processing technology can be used to recognize traffic lights. This method has several advantages, such as low price, high performance, and easy upgrade. Applying image processing method, Park [11] studied round traffic lights detection by judging the shape and size of an object, in which the arrow-shaped traffic light was not discussed. Chung [12] adopted HIS model to recognize traffic lights, in which the road scene was simple and some interference problems such as vehicle lamps, street lamps were not considered. So in this paper traffic lights including round and arrow-shaped signal light detection problems were discussed in a complex environment. The rest parts are organized as follows: The first is hardware structure, the next is traffic lights detection algorithm, and then is the experiment, the last is the conclusion.

II. HARDWARE SYSTEM DESIGE

Our traffic lights detection system includes a CCD camera, an image acquisition card, a PC (main frequency: 1.7GHz, DRAM: 256M). The CCD camera whose the frame frequency is 30FPS and the resolution is 680×480 is mounted on the vehicle front windshield. The color image sequences can be acquired by the image acquisition card. The PC is in charge of the tasks of traffic lights detection, road curbs detection and pedestrian detection, and the results are displayed on the PC LCD. The work process is as follows: As a vehicle travels at non-intersection (no traffic lights in the scene), the program of road curb detection operates, while it travels at intersection (traffic lights in the scene), the program of pedestrian detection operates, and if there is a hazardous event occurring, the assistance driver system give a warning signal to the driver.

III. TRAFFIC LIGHTS DETECTION ALGORITHM

3.1 Object extraction based on color

Based on experience, when the traffic light is on, its corresponding color component is much bigger than other color in RGB color space. According to this feature, red, green, and yellow color pixels of traffic lights can be extracted by subtraction between two color components. That is: when the red traffic light is on, R component is bigger than G & B component; when the green traffic light is on, G component is bigger than R & B component; when the yellow traffic light is on, R & G component is bigger than B component. The object extraction algorithm is shown as follows: if $x_R - x_G \geq T_R$ & $x_R - x_B \geq T_R$,then $x_R = 255$, $x_G = 0$, $x_B = 0$;if $x_G - x_R \geq T_G$ & $x_G - x_B \geq T_G$,then $x_R = 0$, $x_G = 255$, $x_B = 0$;if $x_G - x_B \geq T_{YG}$ and $x_R - x_B \geq T_{YR}$, then $x_R = 255$, $x_G = 255$, $x_B = 0$;(T_R,T_G, T_{YG} ,and T_{YR} are the thresholds, if the conditions are met, the correspond pixel is purified for color segmentation.); and other pixels are set to white color.

As shown in Figure 1, there is an intersection scene in figure 1(a); the extracted pixels are shown in figure 1(b). Because there are two types of the traffic lights, one is round and the other is arrow-shaped. In order to detect the two types

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of the traffic lights, the image is segmented by image region growing method firstly, and then the minimum out-connected rectangles are made to represent the segmentations. Because the traffic lights are often set at the top of an image, and in order to quicken the detection program, only the 1/3 region of the image is segmented in the algorithm. The results of the segmentation are also shown in Fig. 1(b).

Because of overtime exposure, the traffic light becomes white object when it is lighting, and the surrounding region of the traffic light has the same color type of the traffic signal. For example, when the traffic light is red, the traffic light in the image becomes white object and its surrounding region is red. So we should find the color region in an image firstly, and the pick up the white object as the candidate of traffic light.

Because there are often some color objects (such as red, green or yellow object) disturb the traffic lights detection in the complex environment, the verification method is needed to judge whether the traffic light exists or not.

(a) An intersection scene

(b) The results of extracted pixel and segmentation

Figure 1. Traffic lights extraction based on color

3.2 Rule-Based traffic light verification

There are many kinds of disturbance in the object extraction, such as vehicle lamps, vehicle bodies and road signs. In order to extract the true traffic lights, the disturbance must be eliminated.

1) Traffic light verification based on the shape of an object

Traffic lights have some shape features: the minimum out-connected rectangles are approximately square; and the rectangles have certain area when a vehicle is close to the intersection; in addition, a traffic light rectangle density of color pixel point is much more than a road sign rectangle. Those features can help to extract traffic lights from complex environment. The judgments are listed in details as follows: (given L(i), W(i), S(i) as a rectangle's Length, width and area)

(1) Judge if the minimum out-connected rectangle of an object is reasonable or not. If it is not reasonable, the object rectangle is eliminated as a disturbance. (Supposing $Th1$ is the threshold of length-width ratio, $Th2$, $Th3$ is the area threshold of traffic lights)

$$1/Th1 \le L(i)/W(i) \le Th1 \qquad (1)$$

$$Th3 \le S(i) \le Th2 \qquad (2)$$

(2) Judge whether the density of the color pixel points in the minimum out-connected rectangle is reasonable or not. If it is not reasonable, the object rectangle is regarded as a disturbance and should be eliminated, (Supposing Z stands for the total of the color pixels in the segmentation; $Th4$ is the density threshold)

$$Z(i)/S(i) \ge Th4 \qquad (3)$$

2) Traffic light verification based on position relationship

In a complex scene, there are often many vehicle lamps which may be judged as traffic lights because they can meet the condition of the traffic lights. According to the CCD camera installing angle, the lamps often appears below the 2/3 image and the traffic lights often appear at the top of an image. As shown in figure2, the traffic lights usually lie in a horizontal line. If there is a pedestrian traffic light in the scene, whose position is lower than the vehicle traffic lights, and by the position features of traffic lights, the segmentations of traffic lights can be verified precisely.

Figure 2. The positions of traffic lights

3.3 Signals of traffic lights extraction

According to the extraction rule of an image pixel points, the type of the traffic signals is decided by the color in the region of segmentation. There are three signal types, which include a red traffic light signal, a green traffic lights signal and a yellow traffic lights signal.

In order to distinguish an arrow-shaped traffic light from objects of rectangle segmentations, a central point of the segmentation rectangle and a gravity point of the pixels in the rectangle are calculated. The arrow-shaped traffic lights are shown in figure 3. If the distance of the two points is larger than the threshold Th6, the traffic light is judged as an arrow-shaped traffic light, otherwise, it is judged as a round traffic light. Once the arrow-shaped traffic light is judged, its direction can be easily identified by the relationship between the central point and gravity point. If the gravity point is on the left, its direction is left; if on the right, its direction is right; if on the top, its direction is forward.

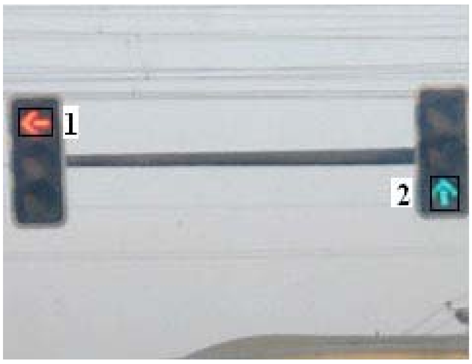

Figure 3. Arrow-shaped traffic lights

IV. EXPERIMENT

The experiments were carried out in the scene as shown in figure4. In fig.4 (a) there were one round and one forward arrow-shaped traffic light, which were in green signal; In fig.4 (b) there were one arrow-shaped traffic light, one round traffic light, and one pedestrian traffic light, which were in red signal; in fig.4(c) There were three round traffic lights at night, two were in green signal and one in red signal. The results of object extraction and segmentation about traffic lights are shown in figure 5, in which the thresholds of color point extraction were: T_R=100, T_G=100, T_{YR}=100, T_{YG}=100. The detection results were shown in figure 6.

In figure 5 (a), the right round roadside sign "1" was filtered by its area size and density of red pixel points. In fig. 5 (b), segment "3" was filtered for its low position (which was a pedestrian traffic light) than segment "1"& "2" , and "1"& "2" were basically in the horizontal direction. There were many non-target objects, such as vehicle lamps, road objects, etc. which are shown in figure 5 (c). Those non-target objects were well eliminated according to the features of the traffic lights' position and alignment. From the results of the detection, we can see that the traffic lights were extracted accurately, and the algorithm can give the correct types of traffic signal as well.

But during the night, the information of the signal direction can not be decided well because the light radiates. In order to solve this problem, the high resolution camera will be used in the system.

V. CONCLUSION

By using the object extraction in RGB color space and the rule verification, the traffic lights can be well extracted in the complex environment. The algorithm can obtain the round traffic lights as well as arrow-shaped traffic lights, and can give traffic signals accurately. Experiments show that the algorithm has the characteristics of stability and reliability. In order to strengthen the detection effect, the tracking algorithm will be taken into account in future study.

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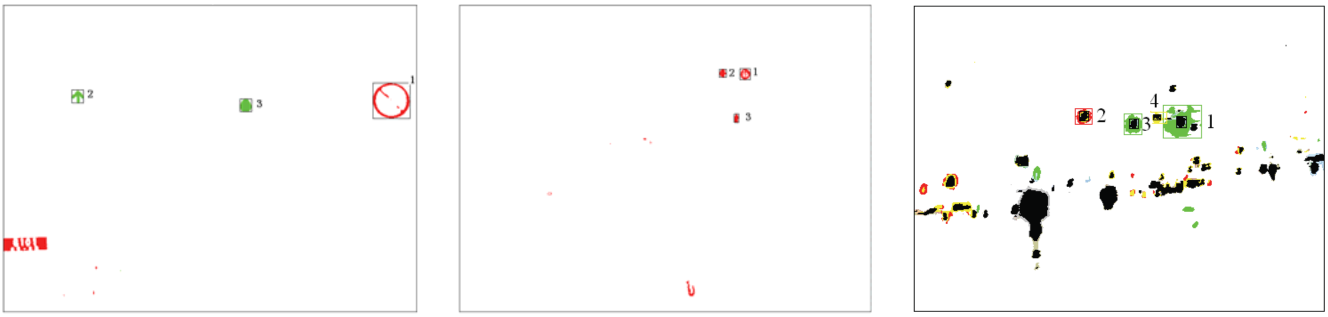
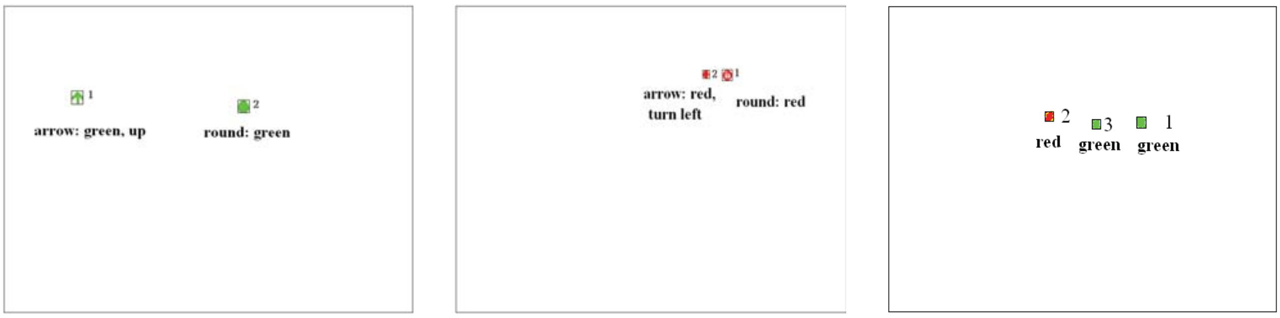
(a) (b) (c)

Figure 4. Traffic light in the intersection scene



(a) (b) (c)

Figure 5. Object extraction and segmentation



(a) (b) (c)

Figure 6. The results of traffic light detection