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Traffic Signal Light Detection in Electronic Travel Aid System

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Abstract: Blind travel aid system is used to help blind people walk. Blind users can judge current environment with the prompt of ETA system. Traffic signal light detection is one of the important research. This study presents an algorithm base on color image segmentation and adaptive template match to detect traffic light information, then turned the information into sound and feedback to blind user. The adaptive template match algorithm, not only suitable for vertical and hanging traffic signal light, but also suitable for pedestrian traffic light. The experimental results show the algorithm is simple and easy to implement and is satisfactory in execution time and recognition rate.

Key words: Blind travel aid, traffic signal light detection, template match

INTRODUCTION

Electronic Travel Aid System (ETA) (Pissaloux, 2002) is mainly using sensing equipments to obtain environment information and converting the processed data into non visual signals which are easy to be understanding by blind people. The system is designed to help blind people to walk independently and safely.

For the blind users crossroads is the most dangerous region and the recognition algorithm of traffic signal lights at the crossroads is one of the main algorithms in blind travel aid system. Travel signal light detection mainly includes two aspects, one is to detect whether the image contains information of traffic lights, the second is to extract the color information of traffic lights. At present, most algorithms are based on visual image, using threshold segmentation (Kim *et al.*, 2007) or Sobel edge detection (Lindner *et al.*, 2004) which based on gray-scale images to extract signal information. However, this kind of algorithm has low applicability, because its low accuracy rate unless in the ideal background.

This study presents a simple, easy to realize, wide applicability of traffic lights recognition algorithm based on color and template match. Due to the large amount of calculation and low accuracy direct gray-scale image processing, therefore, at first, we make coarse detection to color image by color feature to find out the candidate region of traffic signal lights. And then, use adaptive template match algorithm to identify candidate region for traffic lights. The adaptive template is not only suitable for vertical and hanging traffic lights, but also suitable for pedestrian traffic lights. Considering the real-time

requirements in the algorithm, it should reduce the area to be identified by making some rules so as to reduce the amount of calculation.

SYSTEM CONCEPTUAL MODEL AND ITS ARCHITECTURE

The ETA system our designed called AudioGuide. It is a system model to assist the blind walk and the users can estimate the current environment by the information provided by the system. Main users are the blind, the weak sighted, the moon-eyed or the others who have visually impaired. For the convenience of carry and use, the system is mostly a PDA with GPS and camera. It acquires the environmental information by the way of GPS and image input and then feedback the information to the users by sonification with earphones. Its main function is immediate perception of the environment, including GPS navigation, road detecting and barrier avoidance. The picture of system conceptual model is as Fig. 1.

The AudioGuide system has four modules, including a main control module, an image processing module, an auditory display module and a GPS information processing module, where the main control module is in charge of the data communication among other three

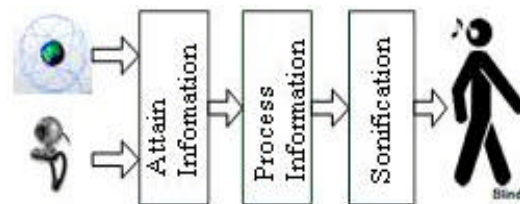


Fig. 1: System conceptual model

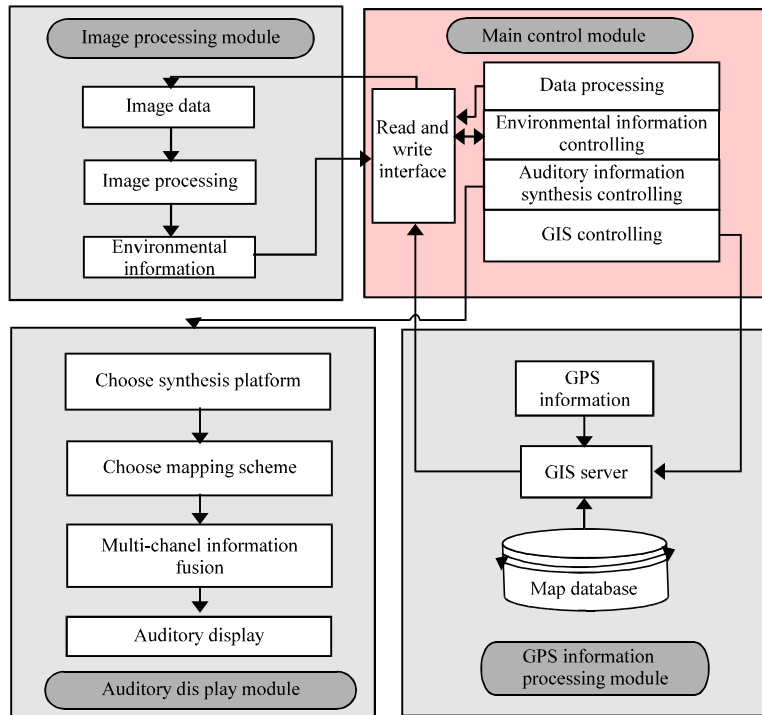


Fig. 2. Architecture of AudioGuide

modules via a read-and-write interface. Figure 2 shows the overall system architecture:

- The main control module aims to coordinate data communication among other three modules. It consists of four sub-modules, namely a data processing sub-module, an environmental information controlling sub-module, an auditory synthesis sub-module and a GIS controlling sub-module. The data processing sub-module is to process all the data from the other three modules and the other three sub-modules are used to control the writing and reading between the main control module and other respective modules
- The image processing module records the video data from the camera, based on which road, turning direction and other environmental information can be extracted using imaging processing techniques. These pieces of valuable information are then transmitted to the main control module for further analysis
- The GPS information processing module obtains the location information from GPS receivers and then sends it to the GIS server. The GIS server can deal with both location information and command information from the user, including destination

inquiries and navigation inquiries. Based on the map database, it can provide route information and time needed from the starting point to the destination

- The auditory display module maps the environmental information from the main control module into auditory information, including both speech and non-speech information, based on the mapping strategy selected by the user

DESIGN AND IMPLEMENTATION OF TRAFFIC SIGNAL LIGHT DETECTION ALGORITHM

Overall design of algorithm: Traffic signal detection is mainly using webcam to gather images and through the image processing technique to determine the existence of traffic lights information and traffic lights types. After that, according to the results of image processing, turning the information into sound and feedback to blind user. The data flow chart is shown in Fig. 3. Because the traffic light is the most main target signal light, we mainly detected traffic signal light.

Color space conversion: The color difference is the most significant characteristic of pedestrian traffic light, therefore, color recognition is the main method to identify the traffic light. Generally, most of the color images are

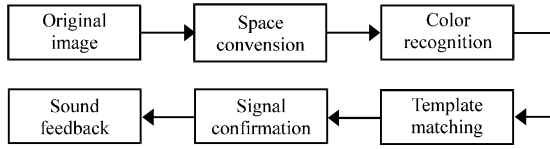


Fig. 3: System data flow chart

RGB color space, which is suitable for the color performance of the images. However, RGB's color value distribution is dispersed and its three components are interrelated changing, so it is not suitable for special image recognition. HSI color space is more close to our eyes' perception of color, it separates the collected color information into hue (H), saturation (S) and intensity (I). The H component in HSI color space can accurately reflect the kind of colors and it is not sensitive to light, shadow. Meanwhile, the separating of intensity and chrominance also benefit the accuracy of color recognition. The space conversion formula from RGB to HSI is as follows:

$$\begin{aligned}
 H &= \begin{cases} \theta, B \leq G \\ 360^\circ - \theta, B > G \end{cases} \\
 \theta &= \arccos \left\{ \frac{1/2[(R-G) + (R-B)]}{[(R-G)^2 + (R-G)(G-B)]^{1/2}} \right\} \\
 S &= 1 - \frac{3}{R+G+B} [\min(R, G, B)] \\
 I &= \frac{1}{3} (R+G+B)
 \end{aligned}$$

Color recognition: Because most of the traffic lights are LED high brightness lamp, we use the hue (H) component to identification the target region and then use intensity (I) component to extract the non-high brightness red and green signals. H, S, I component scope's comparison that in different signal light images are shown in Table 1.

Firstly, define a single frame image as F_b , which is shown as follows:

$$F_b = \begin{bmatrix} f_{H,b}(x, y) \\ f_{S,b}(x, y) \\ f_{I,b}(x, y) \end{bmatrix}$$

(x, y) said the position of plane coordinate in image, f_H , f_S and f_I each said the component of hue, saturation and intensity.

Secondly, let red signal light is R_t and green signal light is G_t , each is shown as follows:

$$\begin{aligned}
 R_t &= \{g_b(x, y) \in F_b | g_H(x, y) \leq \alpha_H \text{ and } g_I(x, y) \geq \alpha_I\} \\
 G_t &= \{g_b(x, y) \in F_b | g_H(x, y) + 2\pi/3 \leq \alpha_H \text{ and } g_I(x, y) \geq \alpha_I\}
 \end{aligned}$$



Fig. 4(a-b): Signal light's candidate region extraction

Among them, the red light signal is R_t , the output value $g_t(x, y)$ is the input image color value g_H 's range at 0 degree positive and negative threshold value of α_H , this range is set to 15 degree and the strength value of g_I is greater than the threshold value of α_I , according to the analysis of Table 1, the threshold can be set to 0.8 (0~1.0). The green light signal is G_t , the output value $g_t(x, y)$ is the input image color value g_H 's range at 120 degree positive and negative threshold value of α_H , this range is set to 35 degree and the strength value of g_I is greater than the threshold value of α_I , this threshold value is 0.8 (0~1.0), too.

Based on the characteristics of the traffic signal light to extract the color information and then, we can extract the candidate region of the traffic signal light on the basis of the color information. As shown in Fig. 4.

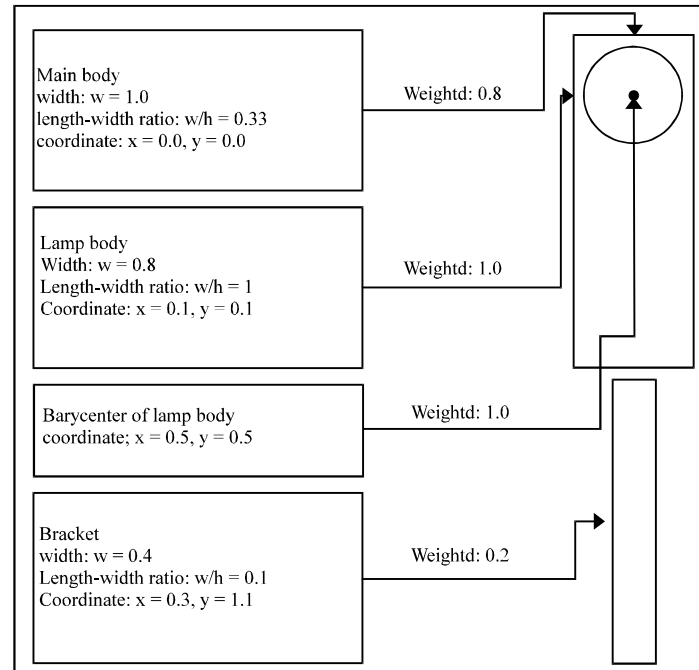


Fig. 5: Adaptive template's geometry decomposition diagram

Table 1: Image information's comparison

	Value H	Value S	Value I
Red Light	[0,40]∪		
[350,360]	[0.13,1]	[100,255]	
Green Light	[160,180]	[0.60,1]	[100,255]

Adaptive template match: Wang and Yang (2008) noted that adaptive template match is mainly recognizing by using correlation between template and the original image's candidate region.

Firstly, we separate the 3D signal light to 2D graph: Main body, lamp body and bracket, As shown in Fig. 5. The rectangle of traffic signal light is treated as the main body, which is the parent element of lamp body. Treat the round lamp body and the barycenter of lamp body as child element, meanwhile, normalize the parent element's width.

The figure is vertical red light's template and the left side is parameters of template elements. For the yellow light and the green light, only need to modify the coordinate parameters. The template is not only applicable to the vertical traffic signal light, but also suitable for hanging traffic signal light. For the pedestrian traffic signal light, we just consider parent element of main body, child element of the lamp body's barycenter and bracket and modify the corresponding parameter values.

Signal light recognition: Further screening of the images which come from template match, the screening conditions are as follows:

- The number of pixels in lamp body region = 10
- The rectangular box size of main body region = 100
- If the length-width ratio of bright pixels form is greater than 1.5 or less than 0.8, that is not the signal light region
- If there is blank region in bright pixels form, that is not the signal light region
- If the proportion of the bright pixels in lamp body center region in the bright pixels in the rectangular frame which contains the lamp body center region is lower than 70 percent, that is not the signal light region

As the traffic signal light region is much smaller than the interference background and the size of rectangle contains the traffic signal light region in the image will not exceed 100, therefore, we can remove most of the non traffic signal light region.

In addition, the red, yellow and green lights on the traffic signal light has its changeless position, the left side is red light, the middle is yellow light and the right side is green light, as shown in Fig. 6. When one lights up, the other two lamp will definitely not light up, so we, respectively define the red, yellow and green lights on the traffic signal light according to this characteristic.

The definition of red lamp lights up:

- The brightness of red lamp area > the brightness of yellow lamp area

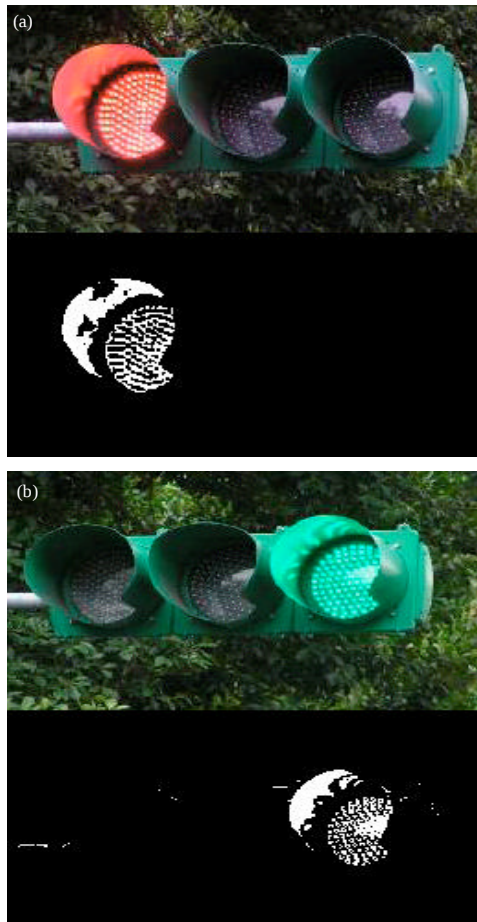


Fig. 6: Traffic signal light's color recognition-result diagram

- The brightness of red lamp area > the brightness of green lamp area
- The brightness of yellow lamp area = 100
- The brightness of green lamp area = 100
- The brightness of yellow lamp area-the brightness of green lamp area|<20

It can determine the block for the red signal light region when satisfies all the five conditions and we can judge the yellow and green signal light region at the same way.

If we detect two different traffic lights, we will compare the size of traffic light blocks, the size of the region from the traffic light we close is larger than the traffic light far, so we conclude that the traffic light in larger range is our target traffic signal light at present.

TEST AND ANALYSIS

Selected 100 pictures and tested in different color space. Here, the definition of True Positive (TP) as the

Table 2: Comparison of different color space and shooting distance

Color space	TP (%)	TN (%)	FP (%)	FN (%)
RGB	83	82	18	17
HSI	98	95	5	2

Table 3: Different traffic light's detection rate in different environments

Different environments	TP (%)	TN (%)	FP (%)	FN (%)
Day, shine	98	97	3	2
Day, overcast	94	92	8	6
Day, rain	95	92	8	5
Night	97	95	5	3

actual green light and the judgment result is also green light; the definition of True Negative (TN) as the actual red light and the judgment result is also red light; the definition of False Positive (FP) as the actual red light but the judgment result is green light; the definition of False Negative (FN) as the actual green light but the judgment result is red light. The test result is shown in Table 2.

The test result shows, the recognition accuracy rate by HSI color space which we put forward is significantly higher than RGB space, because HSI divides color into Hue (H), Saturation (S) and Intensity (I) and processes them separately so that we can easier to extract color information. Moreover, the detection-accuracy rate of green light is slightly higher than red light, this is because the car lights and other background lamps easy to interfere red signal light.

Meanwhile, Selected 100 pictures and tested in different environments, the test result is shown in Table 3.

From the table, we can conclude that it has good accuracy in most weather conditions and the average accuracy rate is 95 percent. Among these, the dusk weather condition is controversial and we acquiesce dusk into night, so it is more accurate that the range selects by the night-color capture defined. Because the dusk intensity is low and easy be affected by the car's brake lamp in front, the judge criterion is unstable compared with other weather conditions.

CONCLUSION

This study presents a traffic signal light detection algorithm which is used in our model system of portable and intelligent travel aid system. The algorithm is based on color and template. This study also describes the situations appeared and methods to solve. Firstly, the algorithm judges the image's pixels by the clustering characteristics in HSI space to separate traffic signal light region and background. Then, estimate the candidate region of traffic signal light for subsequent identification and recognition, so that avoid the complex calculation process in the whole image and reduce execution time. It

has good effect and high accuracy in rough face detection, single and multiple image detection by adaptive template.

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