A new night traffic light recognition method

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Abstract. This paper proposed an effective recognition algorithm for night traffic lights. The algorithm first carries out the pre-processing of collected night traffic light images, and then makes the RGB color space of images transfer into the HSI, further removing noise through morphological operations to extract candidate regions, and last realizes night traffic light identification based on template matching and regional pixel information. The experimental results show that this algorithm has a higher identification accuracy than other ones.

1 Introduction

Traffic lights play an important role in safe driving. At present, most researches are aimed at the identification of traffic lights under common environment. However, the detection and recognition of night traffic lights become more complex because of different intensities of illumination at night. As shown in figure 1, different shapes of traffic lights are shown. This paper proposed an effective recognition algorithm for night traffic lights. The second part describe the proposed algorithm in detail. Besides, the third part analyses and discusses the simulation results. In addition, the fourth part gives a summary.

2 The Proposed Algorithm

The flow chart of the recognition algorithm for night traffic lights is mainly consisting of four
2.1 Pre-processing

After inputing video images of night traffic lights, Pre-processing is an effective method to enhance night traffic light images to extract traffic light regions accurately. This paper adopts a power-law transformation method to adjust the contrast enhancement of the videos. The form of power-law transformation is as follows:

\[ s = c \cdot r^\gamma \]  

\( r \) represents the original pixel values, \( s \) represents the magnified value, \( c \) is the constant, and \( \gamma \) is set to 0.6. The example of enhancing night traffic light images through the power-law transformation method is shown in figure 2.

![Fig.2.](image)

(a) original traffic light image  (b) enhanced traffic light image

2.2 The Extraction of Color Information

(R, G, B) is transformed into (H, I, S) as shown below. The H channel of RGB color space can be extracted through the following expression \([2, 3]\):

\[
\theta = \begin{cases} 
\theta & \text{if } B \leq G \\
360 - \theta & \text{if } B > G 
\end{cases}
\]  

(2)

Among it,

\[
\theta = \cos^{-1}\left( \frac{1}{2} \sqrt{\frac{(R-G)+(R-B)}{(R-G)^2+(R-B)(G-B)}} \right)
\]

The calculation of saturation S:

\[
S = \frac{3}{(R+G+B)} \min (R,G,B)
\]  

(3)

The calculation of intensity I:

\[
I = \frac{1}{3} (R+G+B)
\]  

(4)

Suppose that the value of RGB is normalized to [0, 1] range, \( \theta \) can be measured by the red axis of the HSI space. The example of transforming RGB into HSI color space is shown in figure 3.

![Fig.3.](image)

(a) (b) (c)

The RGB color space is transformed into the HSI one. (a) H component (b) S component (c) I component
After the RGB color model is transformed into the HSI one, the candidate regions of traffic lights are extracted through threshold segmentation based on whether the pixels have red, yellow or green attributes, and the following expression is proposed:

$$E(x, y) = \begin{cases} 
\text{Red} & \text{if } (T_y < H(x, y)) \cup (I(x, y) > T_h) \\
\text{Yellow} & \text{if } (T_y < H(x, y) < T_w) \cup (I(x, y) > T_h) \\
\text{Green} & \text{if } (T_y < H(x, y) < T_w) \cup (I(x, y) > T_h) \\
0 & \text{otherwise}
\end{cases}$$

(5)

Among this expression, $E(x, y)$ represents the processed result of color threshold, $H(x, y)$ the hue value, $I(x, y)$ the intensity value. $T_y$ and $T_h$ represent the color thresholds. The result of $E(x, y)$ is the candidate region of red, green and yellow traffic lights. (a) and (b) in figure 4 shows the result of obtaining different thresholds through color segmentation. Due to the hue value’s meet of Gauss distribution, this paper adopts to manually mark the traffic light region of the image, and calculates the means and variances of red, yellow and green pixel hues of the region, obtaining the pixel values of the hue threshold. The train image is also applied in the calculation of saturation and intensity thresholds.

2.3 The Extraction of Candidate Regions

The corrosion operation can remove the edge points of the objects and eliminate small objects. In addition, close operation is used to fill the tiny cracks inside the objects, connect adjacent objects and fill the holes within the traffic light regions. What’s more, the organizational structure of 3*3 is adopted in close operation. The result of the morphological process method is shown in figure 4 (c).

After observing the shapes and attributes of the light source parts of traffic lights, it is found that the enclosing rectangles of both circular traffic lights and arrow-shaped traffic lights are regular. If image blocks larger than certain areas appear and don’t cross with any enclosing rectangle boxes, they are traffic lights. The expression proposed is shown as follow:

$$\lambda_1 \leq \frac{Se}{Sr} \leq \lambda_2$$

$$\frac{Se}{Sr} > T_h$$

(6)

Among it, $Se$ represents the extracted block area, and $Sr$ is the area of the enclosing rectangle box.$T_h$ is the threshold. The shapes of traffic lights in the images change continuously due to the change of environmental illumination, the distance between the vehicle and traffic lights, and shakes, etc. Therefore, the setting of the threshold is determined by specific driving environment.

Fig.4. (a) and (b) calculated results of color threshold (c) transferred binary image, (d) proposed candidate region.
2.4 The Detection and Recognition of Traffic Lights

This paper first obtains the detective regions of traffic lights by adopting template matching method, and next recognize traffic lights based on regional pixel information. The pixels in circular regions meet:

\[
\text{Region}(i) = \begin{cases} 
(x, y) \in \text{Region}(x, y) & W(x, y) \in \{R, G, B\} \\
W = H, S, I & \\
|R(x, y) - G(x, y)| > \text{Th} \text{ or } |R(x, y) - B(x, y)| > \text{Th} \\
\text{or } |G(x, y) - B(x, y)| > \text{Th} 
\end{cases}
\]  

(7)

The pixels in arrow-shaped regions meet:

\[
\text{Region}(i) = \begin{cases} 
(x, y) \in \text{Region}(x, y) & W(x, y) \in \{R, G, B\} \\
W = H, S, I & \\
|x - X_i| + |y - Y_i| \leq \text{Th} 
\end{cases}
\]  

(8)

\(W(x, y)\) represents the value of the pixel \((x, y)\) corresponding to H, S and I, \(x, y\) and \(X_i, Y_i\) the center point and \(\text{Region}(i)\) of each region, respectively.

3 The Result of the Experiment

The experimental result of the proposed recognition algorithm for night traffic lights is given in this section. All simulation experiments are run on MATLAB simulation platform, using 2.20 GHz Inter dual-core processor and 4GB of memory. This paper proposes to obtain images and videos by using digital and fixed surveillance cameras in roads, intersections, schools and communities, and download the collected image sequence to the computer. The recognition process of night traffic light recognition system is shown in figure 5.

![Traffic light recognition system](image)

**Fig.5.** the detection of rainy night traffic light recognition under new algorithm

To compare the performance of the proposed algorithm and traditional ones, this paper uses several video images taken by car camera and fixed camera. A ground truth editor is used in the experiment to identify the position and state of all traffic lights in the image. Table 1 shows the accuracy of recognition, that is, the recognition result obtained by comparing the proposed method in this paper with the detection result of the algorithm proposed in reference [4], [1], and the manually labelled traffic light data in the ground truth file. It can be noticed from the table that the new algorithm is more effective than the traditional ones for different night traffic light recognition.
Table 1 Recognition results of the new and other algorithms

|                | New algorithm | The algorithm of reference [4] | The algorithm of reference [1] |
|----------------|---------------|-------------------------------|-------------------------------|
| ground truth   | 724           | 724                           | 724                           |
| recognition    | 588           | 539                           | 487                           |
| accuracy       | 81.22%        | 74.45%                        | 67.27%                        |

To evaluate the time consumption of the new algorithm at each processing stage, the proposed algorithm is executed in real time. The average processing time of the four processing steps in the algorithm is shown in table 2. In order to carry out real-time video processing, the proposed algorithm must run on a faster hardware platform. In general, the simulation results show that the new algorithm can distinguish night traffic lights more effectively. In addition, compared with other traditional recognition algorithms, the proposed algorithm has a higher accuracy.

Table 2 The processing time of each processing step in the new algorithm(unit:ms)

|                  | preprocess | extract color information | extract candidate regions | Detect and recognize traffic lights | Total elapsed time |
|------------------|------------|---------------------------|--------------------------|-------------------------------------|--------------------|
|                  | 6.33       | 9.58                      | 7.02                     | 10.82                               | 33.75              |

4 Conclusions

This paper launches research based on the problem of difficult recognition of night traffic lights, and proposes a new recognition algorithm for night traffic lights by combining color information with the pixel information based on regions. The algorithm is executed in different night traffic light scenes in various environment. The simulation results show that the proposed algorithm is effective and useful for different illumination and weather conditions (eg: rainy days).

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