Circular Traffic Signs Detection in Natural Environments

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Keywords: Traffic sign detection, Color/Shape processing, Image segmentation.

Abstract: This paper describes an efficient method for the detection of circular traffic signs on color images in different natural environments. First, a RGB image was converted into HSV color space which was segmented by the hue and saturation thresholds, so that we can extract the region of interests (ROIs). Due to which, A Circular Hough Transform (CHT) based algorithm is proposed to find circles in the image, after that the traffic signs are detected from the images under natural scenes. Experiments were conducted for the detection of traffic signs which involved two traffic sign image databases. The experimental results indicate that the proposed algorithm possess of high detection accuracy, and good robust performance.

Introduction

Traffic sign detection and recognition system could provide traffic information for the drivers in time, which allows the driver to cope with unexpected situations, so as to avoid or reduce the occurrence of traffic accidents. In generally, traffic signs are designed to enhance their visibility for drivers by made them with predefined colors and shapes that distinguish them from their surroundings. In terms of shape, there are Circular, Triangular, Rectangular, Square etc. Various colors have been employed to distinguish from the cluttered surroundings. However, real traffic scenes are complicated and changeable in the complicated traffic scenes, such as the light condition, weather condition, partial occlusion, similar background color and shadow interfering make the research of traffic sign recognition far from mature.

In this paper, the colors and shapes of traffic signs are used as cues to selectively concentrate on the traffic sign regions in a traffic scene. First, regions of interest (ROI) containing the candidate traffic signs are detected based on color segmentation, which help to distinguish traffic signs from other objects appearing in the natural road environment. Then, the ROIs consists in circular traffic signs that using Circular Hough Transform (CHT) based algorithm have been detected.

Related Studies

Since, traffic signs are mainly consisting of distinctive features of color and shape information; it is convenient to use those features to decide the candidates.

Color-based Approaches

Color thresholding segmentation is one of the earliest techniques used for traffic signs image segmentation. Thresholding is done to classify pixels of an image into traffic sign pixels or background pixels [1]. There are different color spaces for traffic signs image thresholding, such as red-green-blue (RGB) [2], Hue-Saturation-Intensity (HIS) [3], hue-saturation-value (HSV) [4]. RGB color space is very sensitive to illumination. The HSV color space is most popular one used by researcher because it is based on human color perception, which can remove the noise of similar colors in the natural environment. However, its calculation is more complicated. YCbCr color space has also been used in the traffic signs detection because it is the native color space of many cameras, which makes color space conversion unnecessary [5].
Shape-based Approaches

Shape, being an important attribute of traffic signs, is generally unaffected by image quality. Regarding shape, the shape-based candidate detection approaches mainly base on the parameters of the shape such as corner, area and perimeter, Fast Fourier Transform (FFT) signatures of candidate signs, the number of sides of a given shape and hole based approach are used to determine the appropriate shapes [6]. The histogram of oriented gradients (HOG) is a feature descriptor used in computer vision and image processing for capturing the shape of the object [7]. To improve the detection rate, recent works have combined both color segmentation and shape recognition techniques. The survey by Møgelmose et al. provides detailed analysis on the most recent developments [8]. Be aware that neither color or shape based methods all depend on resolution of the image.

System Description

Color segmentation

Considering images of real world scenes, it is not always possible to obtain colored traffic signs regions by applying thresholds directly to RGB color space, because it is easily affected by illumination and complex weather environment. For this purpose, HSV (Hue, Saturation and Value) space is used for detecting candidate regions. As a result, a method for traffic signs focuses entirely on the HSV image’s hue layer. Firstly, the original traffic signs image is transferred from RGB to HSV color space. Based on a large number of experimental segmentation results for traffic image, we found that thresholding image by setting a range of HSV to three components of them filtered without complex color distance calculation, this can save a lot of time in the computing. For detection of blue and yellow traffic signs pixels, the binarization process can be formulated as Table 1:

<table>
<thead>
<tr>
<th>Color component</th>
<th>Blue</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hue</td>
<td>200°-255°</td>
<td>25°-55°</td>
</tr>
<tr>
<td>Saturation</td>
<td>0.4-1</td>
<td>0.4-1</td>
</tr>
<tr>
<td>Value</td>
<td>0.3-1</td>
<td>0.3-1</td>
</tr>
</tbody>
</table>

After the candidate regions are obtained by applying color segmentation, features of each region are to be extracted in order to correctly differentiate the TR regions from others. Next step of proposed algorithm is labeling the connected components according to the pixel’s 8-connectivity. Finally, eliminate the noise present in the binary image and the small objects with morphological operations and mean filter, too small regions and too big regions are discarded.

Hough Transform

Hough transform (HT) for straight lines is applied in order to detect circular signs. we decided to adopt the HT-based method for further experiments presented in this paper. A straight line in the xy-plane with a distance to the origin $\rho$ and the angle of the normal line to this straight line passing through the origin, with the abscissa axis $\theta$ can be expressed as (1).

$$x \cdot \cos(\theta) + y \cdot \sin(\theta) = \rho$$  \hspace{1cm} (1)

Where the parameter space, $p = (\rho, \theta)$, must be quantized. If the origin of the co-ordinate system is placed in the center of the image, the largest possible distance between a point in the image and the origin is $R$. Hence, in order to generate any straight line of an image, $\rho$ may be varied between $-R$ and $+R$, and $\theta$ may be varied between 0 and $\pi$ radians. The parameter-space is quantified and expressed in a 2D accumulation matrix $A$ with dimensions $m \times n$, where $m$ is the number of values assigned to $\rho$ and $n$ is the number of values assigned to $\theta$. For circumference detection the accumulator $A$ will be a three-dimensional matrix with all elements initially set to 0.
The element $A_{i_0}(\chi, \psi, \rho_t)$ is incremented by 1 for every feature point $(x_i, y_i)$ in the image-domain, contained in the circumference with center $(\chi, \psi)$ and radius $\rho_t$ as expressed in (2), and as shown in figure 4 where a precision margin for the radius $\varepsilon$ is introduced to compensate for quantization error when digitizing the image [9].

$$\left| (\chi_i - x_i)^2 + (\psi_i - y_i)^2 - \rho_t^2 \right| < \varepsilon $$  (2)

The analysis of every contour is performed and the Hough transform is applied only to the points belonging to the color candidate region. Hence, the information of a segmentation image obtained already in a previous stage is used and the center of the circumference is searched in the environment of the centroid of the corresponding binarization process. So that the number of iterations is considerably lowered without loss of reliability. The algorithm scheme for traffic signs detection is shown in Figure 1.

![Figure 1. Procedure of traffic sign detection.](image)

**Experimental Results**

To evaluate the proposed traffic sign detection method, practical experiments with the traffic sign image database have been carried out. Some typical scenes from the samples are then shown in Figure 2. The image database contains 48 images of size 360x270 pixels in PNG format, each representing a traffic scene. The images are grouped in 3 classes, each class corresponding to a different template traffic sign [10].

![Figure 2. Some image examples in traffic signs database.](image)

Figure 3-4 show three example of traffic sign detection performance using the HSV traffic sign color models. A total of 36 traffic signs included in the traffic signs database were used for the experiments. In most cases, the best detection performance could be obtained by the traffic sign-color models from the HSV color spaces if there have a distinct separation of blue signs from the rest of the image. The correct detection rate is 71.25%. Even so, there is still a great deal of noise in these images. To deal with this, a morphological filter is applied followed by a carefully chosen threshold to filter out undesirable pixel values.
Conclusion

Generally, the traffic sign recognition system could be divided into two stages: the detection stage, which finds the region of interest containing the traffic signs from an image, and the classification stage where the detected signs are classified into one of the road signs. In this paper, only the detection stage is described. The proposed method detects the location of the sign in the image, based on its color information in HSV space under natural scenes. From the resulting color candidate regions that have been cut off all small areas based on defined thresholds, the final candidate regions are then detected by Circular Hough Transform (CHT) based algorithm. The experimental results indicate that the proposed algorithm possess of high detection accuracy, and good robust performance. The proposed method works well that regions relating to traffic sign colors were efficiently filtered and the other regions were well removed by most of the HSV sign-color models. In future, a new segmentation method can be developed based on analysis of color similarity between neighbor pixels and not be strictly oriented to the segmentation of color.

Acknowledgment

This work was supported by the National Natural Science Foundation of China (Grant No. 61472173), the grants from the Educational Commission of Jiangxi province of China (Grant No. GJJ151134) and Natural Science Foundation of Jiangxi Province of China (Grant No. 20161BAB202042)

References


