A Novel Robust Method for Automatic Detection of Traffic Sign

Bo Peng, Juan Wu

A novel robust method for automatic detection of traffic sign

Bo Peng[1], Juan Wu[1]

[1] College of Information and Electrical Engineering, China Agricultural University, Beijing, 100083, China
pengbo_cau@126.

Abstract. Considering the requirement of high accuracy and robustness for traffic sign detection in real-world environments, this paper proposed a novel method for automatic detection of traffic sign. There are three main stages in the proposed algorithm:1)segmentation by adaptive threshold in HSI color space to find the region of interest;2)eliminate the noise present in the binary image and the small objects with morphological operations and mean filter;3)contour extraction and curve fitting for a better contour by the least square method. Experimental results show a high success rate and demonstrate that the proposed framework is invariant to illumination，deformation，and partial occlusions.

Keywords: traffic sign; detection; morphology; contour extraction; fitting

1 Introduction

Auto traffic sign detection is an essential part of advanced Driver Assistant System(DAS). Traffic signs provide warnings and instructions, having remarkable contrast with the background and characteristics like distinct shape and color. Being easily detected and recognized, traffic signs play an important role in safe driving. However, traffic signs are normally set in the right front side, resulting in the limitation of rotation quantity and geometric distortion. Therefore, traffic sign detection is facing a number of difficulties. (:) The illumination variations (including range of brightness, low visibility in twilight condition, fog weather and shadow, etc.), blurred images caused by car shaking, fuzzy signs, partial occlusion, as well as interferences of similar objects[1]. Both false detection of distractors and failure in detection of the real traffic signs could have negative effect on drivers. As a result, the high detection accuracy a key in the traffic sign detection.

There are three methods of traffic sign detection by locating the region of interests. The first method is color threshold segmentation. By using non-RGB color model to segment traffic sign, like HSV[2], CIECAM97[3], YUV[4], this method could minimize the effect of the glare, weak light or bad weather, such as fog. The second method is shape detection[5], such as using Hough transform[5]. However, it calls for massive calculation. The third method is detection based on feature (characteristics?), such as Haar feature[7], Hog feature[8][9], etc. In order to detect the red circle traffic sign accurately under different real circumstances, this paper presents a robust traffic sign detection method. Three steps are involved: first of all, segment the image by threshold to get a binary image; Then eliminate the noise with morphological operations and mean filter. Finally, contour extraction and curve fitting for a better contour by the least square method.

2 Color Transformation

Color, which has high separability, is invariant in size and angel. By color segmentation of a traffic sign, we can detect its location in the image approximately. However, this method --- color threshold segmentation is easily affected by daylight, bringing problems like color reduction, light reflection and so on.

RGB color space model is the most intuitive color space. In this study, we transform RGB space model into HIS space model, since RGB space can be affected seriously by lightness and there are strong correlation among its three components. On the contrary, HIS color space model is visual uniform and consistent with human visualization. By using hue and saturation, it could eliminate the effect of illumination changes[10]. HIS color space model divides each pixel into hue, intensity and saturation. The transformation from RGB to HIS color space is as following:

$$\mathrm{H} = 1 - \sqrt{3}(G - B)/[(R - G) + (R - B)] \tag{1}$$

$$\mathrm{S} = 1 - \min(\mathrm{R}, \mathrm{G}, \mathrm{B})/(\mathrm{R} + \mathrm{G} + \mathrm{B}) \tag{2}$$

$$\mathrm{I} = (\mathrm{R} + \mathrm{G} + \mathrm{B})/3 \tag{3}$$

3 Noise elimination

Noises could affect the detection accuracy by misleading the system into choosing the wrong targets. Therefore, it is important to suppress even eliminate the noises but still keep all the image details. Besides mean filter, this study also uses morphological erosion and dilation operation to eliminate the noises., and removes small sundries by setting aspect ratio afterwards. During the process, a dilation operation of the original image is first performed; and then-an erosion operation is used on the image when the contour is filled.; finally, the mean filter is used ito smooth the image.

3.1 Mean Filter

Mean filter is a typical linear filtering algorithm. The basic principle is to construct a model on the target pixel in the image by adjacent picels. Then the original pixel is replaced by the average value of pixels in the model. For example, a 3*3 filter model is constructed by 8 pixels around the target pixel.

3.2 Dilation and Erosion

Dilation and Erosion are two commonly used basic mathematics morphological operations. Dilation could fill the poles in the images as well as the dents on the edge.

Erosion could not only reduce the size of original image, but also eliminate some small components in the image.

Suppose A represents a binary image while B stands for structural elements. A dilated by B is defined by formula (4) (shown below). Suppose Z represents two dimensional integer space. Each element of the set is a black or white pixel whose coordinate is (x,y). We focus on black pixels since this study turns objects into black while turning background into white. The rule of dilation is that, if a point of B falls in the area of A after one to one correspondence between the center of structural element B and each single points of A, this point will be turned into black. A dilated by B is represented by $A \oplus B$. According to figure. 1, after dilated by structural element circle, a dark clue square is truned into a light blue square with round corner.

$$A \oplus B = \{z \mid (\hat{B})_z \cap A \neq \varnothing\} \tag{4}$$

The definition of erosion is shown by formula (5). The result of B erode A is the full set of Z. The result will still falls in the area of A after B is translated the distance of Z. A eroded by B is represented by $A \ominus B$. Contrary to dilation, the rule of erosion is that, if all the points of B fall in the area of A after one to one correspondence between the center point of B and each single points of A, this point will be saved, otherwise it will be erased. According to figure 2, after eroded by structural element circle, the dark blue square is turned into the inside smaller light blue square.

$$A \Theta B = \{z \mid B_z \subseteq A\} \tag{5}$$

Figure 1. Dilation Operation

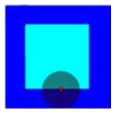

Figure 2. Erosion Operation

3.3 Sundries Removal

Sundries removal aims at eliminating the small objects after image processing, by calculating the outline aspect ratio and the area of each small object. Take the circle traffic sign as an example. Considering factors like deformation and angel etc., which may affect removal process, we change the aspect ratio of the circle traffic sign from 1:1 to 0.8-1.3. If an object is beyond this range or its area is smaller than 1/500 of the whole image, we consider this object is unnecessary and can be eliminated. The same method can apply to other shape traffic signs, such as triangle, octagon as well as rectangle. By setting corresponding range, we can eliminate those small objects effectively and increase the detection accuracy.

4 Contour Extraction and Curve Fitting

In order to extract the sign contour clearly and accurately, this study uses an extraction method by merging Canny operator and Snake model[11]. In 1986, John

Canny presented the very popular three criteria of detectors: good detection, good localization and only one response to a single edge. Based on the three criteria, he developed the optimal edge detection operator: Canny edge detection operator. The basic idea of Canny operator is to smoothing filter the original image by Gaussian filter., then to use Non-Mamima Suppression (NMS) to get the final edge image. Canny operator can achieve good localization accuracy. However, it could also cause fake edges and lost edges. Snake model is an active contour model which is brought by Kass in 1987. The principle of Snake model is that, by setting an initial curve around the target and moving the curve under both internal and external forces, the curve could finally converge to the real contour when it reaches the lowest energy. Snake model can achieve a closed contour. However, it lacks of good localization. As a result, the merge of Canny operator and Snake model is an effective way to solve the problems during contour extraction.

The images of traffic sign could lose certain information for some reasons, such as occlusions, which have negative effect on localization. Therefore, in this study, the curve fitting was done by least square method. The principle of least square method is to find a optimal matching function for a set of data by minimizing the sum of error squares. It uses the simplest way to get some absolutely unknowable truth value with minimum sum of error squares[12]. As a result, in the case of round traffic sign, we could use the least square method to fit circle center and radius by minimizing the sum of error squares.

5 Results and Discussion

5.1 Results

Detecting real images by the method mentioned above., Figure 3 shows the major steps of the detection process. Figure 3(a) is the original image; The green circle in Figure (f) shows the detection result, from which we can tell that the traffic sign has been detected clearly and accurately.

(a) (b) (c) (d) (e) (f)

(a) original image (b) HIS transformation、binary image (c) noise elimination (d) contour extraction (e)curve fitting (f) result detection

Figure 3. The Detection Process of Real Traffic Sign

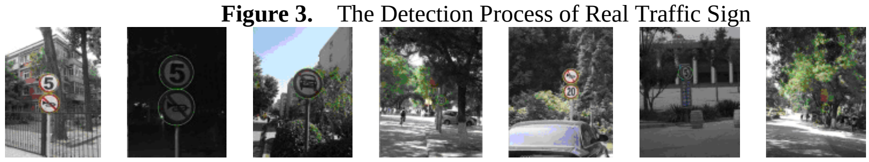

Figure 4. Detection Results under different conditions

The experiment takes pictures of real images under different lightness and weather conditions. Running on 1G internal memory computer, the result shows that: During the day, the detection accuracy of the red circle traffic sign is above 98% and the False Positive Probability(FPP) is less than 2%. While taking the same sign during the night, the detection accuracy can still reach 96% with 4% False Positive Probability(FPP). By detecting the red circle traffic sign accurately, this result demonstrates that our new method could solve problems brought by illumination variation, deformation, rotation as well as occlusion and detect the traffic sign effectively.

5.2 Discussion

Without considering color segmentation, some different signs can look the same when turned into grey. Therefore, it is necessary to take color into account for traffic sign detection. The method based on color segmentation is fast and intuitive, however, it could be affected by illumination variation. Considering this, this study transforms RGB color space into HIS color space, which is robust and insensitive to illumination variation. This method could bring about high costs of calculation since the transformation is nonlinear. However, we can avoid this problem effectively by calculating space transformation in advance and saving it into look-up table. The limitation of this method, is that it is not robust to color and can be susceptible to interference from other objects with similar color.

Mean filter has a good effect on eliminating Gaussian noises. However since all the pixels are averaged during the process, the details of the image will be obscured. The erosion operation can erase the boundary points effectively and make the contour more converging and clear, while dilation operation can fill the spaces among the regions effectively and increase the continuity of the image. The difficulty of erosion and dilation operation is to choose structural elements. Choosing structural elements of small size can keep details of the contour but lose the efficiency in eliminating noises. While the effect of choosing structural elements of large size is just the opposite. In order to obtain more useful information, we can choose structural elements with protrusion shape, such as square, cross, etc, while the circle structural elements have minor effect on contour quality.

The contour extraction method of merging Canny operator and Snake model has high stabilization and localization accuracy. Besides, it could avoid the interference from fake edges and also fix the broken edges. The least square method has high robustness~~.~~, solving problems like shape incomplete due to occlusions effectively during curve fitting.

4 Conclusion

This study proposes a novel, robust method of traffic sign detection. This method is insensitive to illumination variations and can avoid being affected by occlusion, rotation, deformation, etc to some extent. Based on the study of red circle traffic sign, this method segments red region threshold and gets the binary image in the first place by transforming the RGB color space into HIS color space. Then by eliminating noises with morphological operator and mean filter, as well as contour extraction and curve fitting, this method could effectively reduce the False Positive Probability(FPP) and achieve an accurate localization of the red circle traffic sign and any other real images. Experiments demonstrate that this algorithm has high rate of success, good localization accuracy, as well as high robustness to illumination variation, deformation and partial occlusions.

References

1. REN F, HUANG J, JIANG R and KLETTE R .General Traffic Sign Recognition by Feature Matching :proceedings of the 24rd International Conference on Image and Vision Computing New Zealand,2009[C]. Wellington: IEEE, 2009: 409–414.
2. MALIK R, KHURSHID J, and AHMAD S. Road sign detection and recognition using color segmentation, shape analysis and template matching: proceedings of International Conference on Machine Learning and Cybernetics,2007[C].Hong Kong: IEEE,2007: 3556–3560.
3. GAO XW, PODLADCHIKOVA L,SHAPOSHNIKOV D, *et al*. Recognition of traffic signs based on their color and shape features extracted using human vision models.[J].Journal of Visual Communication and Image Representation,2006,17(4):675-685.
4. MIIURA J, KANDA T, NAKATANI S, *et al*. An active vision system for on-line traffic sign recognition [J]. IEICE TRANSACTIONS on Information and Systems, 2002, E85-D(11): 1784–1792.
5. BELAROUSSI R, TAREL JP. Angle vertex and bisector geometric model for triangular road sign detection: proceedings of Workshop on Applications of Computer Vision, 2009[C]. Snowbird, UT: IEEE, 2009: 1–7.
6. WANG Y, SHI M, WU T. A Method of Fast and Robust For Traffic Sign Recognition: proceedings of the Fifth International Conference on Image and Graphics, 2009[C]. Xi'an, Shanxi: IEEE, 2009:891-895.
7. BAHLMANN C, ZHU Y, RAMESH V, *et al*. A system for traffic sign detection, tracking, and recognition using color, shape, and motion information: proceedings IEEE Intelligent Vehicles Symposium, 2005[C]. Las Vegas, Nevada, USA: IEEE, 2005: 255–260.
8. CREUSEN IM,WIHNHOVEN RGJ, and HERBSCHLEB E, *et al*. Color exploitation in HOG-based traffic sign detection: proceeding of the 17th IEEE International Conference on Image Processing,2010[C]. Hong Kong: IEEE, 2010, 2669–2672.
9. OVERETT G, PETERSSON L. Large-scale sign detection using HOG feature variants: proceeding of IEEE Intelligent Vehicles Symposium, 2011[C]. Baden-Baden: IEEE, 2011, 326–331.
10. FLEYEH H. Shadow and Highlight Invariant Color Segmentation Algorithm for Traffic Signs: proceeding of IEEE Conference on Cybernetics and Intelligent System, 2006[C]. Bangkok: IEEE, 2006, 1–7.
11. ZHANG Yi,SUN Hu-yuan,SUN Li-juan,SUN Xiao-guang, “Combination of active contour with passive edge detection in contour extraction”, COMPUTER ENGINEERING AND APPLICATIONS, 2009, 45(26), pp.160-162.