Detection of Traffic Signal By Adaptive Approach and Shape Constraints

Vanniappan Balamurugan[1] and Senthamarai Kannan[2]
[1]Einstein College of Engineering, Tirunelveli, India
[2]Department of Statistics, Manonmaniam Sundaranar University, India

Abstract: *Thresholding plays a vital role in image segmentation. A wrong selection of threshold may lead to improper segmentation. Adaptive approach will be good enough for the selection of threshold in many occasions. This paper proposes an iterative approach for segmentation of traffic signal based on the prior knowledge about the size of the traffic signals. Region of Interest is found based on a tentative threshold and the threshold is varied according to the previously computed dimension of the identified object. Initially the input colour image is smoothed by applying morphological opening operation. The path information of the contour is used to find the coordinates of the clipping window. The image statistics of the ROI, viz. geometric area, pixel population and perimeter are used to extract the traffic signals from the input image. Here, the input colour image is divided into three channels and the threshold is applied to the red channel to extract the red as well as amber signal and green channel is processed to extract the green signal. The method is tested with 50 images and found successful.*

Keywords: *ROI, adaptive threshold, morphological opening, image statistics, and contour.*

Received June 6, 2008; accepted August 3, 2009

1. Introduction

Segmentation is one of the difficult problems in image processing. The segmentation of a digital image is the process of dividing the given image into disjoint parts, regions or classes so that each one of them has very concrete attributes or properties. Each of these classes represents an object of the image. Segmentation is also used to extract various interesting regions of an image. A region is a group of pixels that are homogenous in nature. Homogeneity depends on the objective of the segmentation process. Each pixel belongs to only one region. Image segmentation plays an important role in many fields which include pattern recognition, content based image retrieval, video data mining, etc. There are many segmentation methods based on different approaches such as histogram-based methods, boundary-based methods, region-based methods, hybrid methods and graph-based methods [6]. Here, the region based method is used to extract the traffic signals. Since the threshold is varied according to region's statistic, region based approach is chosen. Thresholding [3] may be viewed as an operation that involves tests against a function T of the form

$$T = T[x, y, p(x, y), f(x, y)] \quad (1)$$

In equation 1, $f(x, y)$ is the gray-level of point (x, y) and $p(x, y)$ denotes some local property of this point. If T depends on the spatial coordinates x and y, it is called adaptive threshold [3]. A single threshold may not suit well in all kind of situations. One may need to choose different thresholds to extract different objects. In the proposed method, the tentative threshold is set initially and the measures such as perimeter, pixel population and area regarding the shape of the traffic signal are used to vary the threshold. Further, morphological operations are also used to segment the image. Rest of the paper is organized as follows. In section 2, various research works related with the proposed work are given. In section 3, the proposed segmentation process to extract the region, containing the traffic signal is explained. In section 4, the implementation details and the experimental results are shown. Finally, conclusions and discussions are given in section 5.

2. Related Works

Many researchers have been working on segmentation using adaptive threshold as well as shape constraints. Numbers of approaches have been suggested by them to successfully perform the robust image segmentation and considerable achievement has been achieved in this area in the recent years [4, 5, 6, 7, 8]. Liao *et al.* [5] used the adaptive threshold and relative similarity with two-way connectivity for segmenting the image. The prior knowledge about the shape information plays a crucial role in the segmentation process [5]. Other researchers focus on local image statistics for fixing the threshold value. Yan *et al.* [8] used the local image statistics like mean and variance within a variable neighborhood, to vary the threshold. Navon *et al.* [6] worked on segmentation of color image by dividing the image into homogeneous regions by local thresholds and finding their values adaptively by an automatic process where local information is taken into consideration. In [6], segmentation is performed by watershed transformation and region merging. However, the application of watershed transformation on image always leads to over-segmentation. Hemachander *et al.* [4] worked on segmentation of image by adaptive threshold, where the image was divided into sub-images based on some standard image attributes and thresholding technique was employed over the sub-images. Gao *et al.* [2] focused on a few colors contained in the objects and also on particular color model. Zoller *et al.* [9] followed an integrated approach for image segmentation based on a generative clustering model combined with coarse shape information and robust parameter estimation. Bustince *et al.* [1] applied restricted equivalence functions to the computation of the threshold of an image and obtained a sequence of optimal thresholds in images with several objects in gray images. Vachier [7] focused on morphological scale-space approach to the problem of feature extraction. In this direction, this paper proposes a method that uses shape information and iterative threshold for image segmentation.

3. Methodology

The most common traffic signals consist of a set of three lights red, green and amber. In the proposed method, it is assumed that traffic scenes are always captured at a known range of distance. Therefore, the image statistics such as geometrical area, pixel population and perimeter of the signals will be in the predetermined range. Since the shape of the traffic signal is known, the features related to this shape can be useful in discriminating our ROI from other regions. The amber is an orange-yellow colour, occurs between red and yellow in the visible spectrum. However, as for as the primary colors are concerned, it is a color combination of red and green with more contribution from red and more or less half contribution from green. In ideal case, based on the RGB color model, the extent of color contribution of red, green and blue in *amber* is 255, 191 and 0 respectively. However, these values vary in real time scenarios and it can be used to extract the amber signal along with red signal. Therefore, the tentative threshold at the initial stage can be set in the range from 190 to 210. In our case it is chosen as 200. The RGB component of the image is separated into three channels at the initial stage. The processing of red channel itself will yield the red signal as well as amber signal. Further processing of green channel will lead to segmentation of green traffic signal. The process involved in detecting the traffic signal is explained the following subsections.

3.1. Morphological Opening

Morphological image processing operations reveal the underlying structures and shapes within binary and gray-scale images. By the use of combined morphological operations, specific information from an image can be easily extracted. Morphological opening is applied on all the three channels, to remove the small features (e.g., noise) within the image, yet maintaining the original sizes of the primary foreground features. Opening is a useful process for smoothing contours, removing pixel noise, eliminating narrow extensions, and breaking thin links between features. Morphological opening involves two operations called dilation and erosion [3]. Let E be a Euclidean space or integer grid and A be binary image in E. Let B be structuring element with A and B as sets in z^2, where $z \in E$, the dilation of A by B, denoted $A \oplus B$ is defined in equation 2.

$$A \oplus B = \left\{ z \mid (\hat{B})_Z \cap A \neq \Phi \right\} \tag{2}$$

Set B is referred as structuring element [3] in dilation as well as in morphological operation. The dilation of A by B is the set of all displacements z, such that B and A overlap by at least one element. For set A and B in z^2, the erosion of A by B, denoted $A \Theta B$, is defined in equation 3.

$$A \,\Theta\, B = \{ z \mid (\hat{B})_Z \subseteq A \} \tag{3}$$

Erosion of A by B is the set of all points z such that B, translated by z, is contained in A [3]. An alternative definition of the morphological opening is that, it is the union of all sets containing the structuring element in the original image where structuring element is a one, two, or three-dimensional array. The structure elements are interpreted as binary values, either zero or nonzero. The combination of thresholding and morphological opening operation will be very much useful in extracting the primary foreground features efficiently. After applying the morphological opening, suitable threshold is to be set. However finding a suitable threshold is not always an easy task. For this reason, a tentative threshold is used here.

3.2. Thresholding and ROI

Thresholding is a non-linear operation that converts a gray-scale image into a binary image where the two levels are assigned to pixels that are below or above the specified threshold value. In the proposed approach, the value of the tentative threshold is chosen as 200 and the image is subjected to morphological opening. In the resulting image, the search for the contours of the traffic signal is performed. The prior knowledge about the shape and the dimension of the signal regions are useful in identifying the contours.

There are many contouring algorithms available in literature. Since there is a need to label the regions, care should be taken to select the appropriate algorithm. Contour following algorithm has been used in the proposed method. It searches for each contour line, and then follows the line until it reaches a boundary or closes. After obtaining the contour, the regions are identified and labeled.

Once the regions are obtained and labeled, information such as contour path and region statistics can be calculated easily. The region statistics include geometric area of the region, perimeter and pixel population. These measures and the predetermined shape information are compared to identify our ROI. If the required region is not found at this threshold, the process is repeated with increase or decrease in the threshold i.e., $\pm\delta$, where δ is the deviation from the current threshold and the value of the δ may be set based on heuristic approach. In our case, δ is chosen as 5. After obtaining the region of interest, the coordinates are extracted and a clipping window is formed to clip the ROI. Figure 1 illustrates the flow diagram of the proposed method.

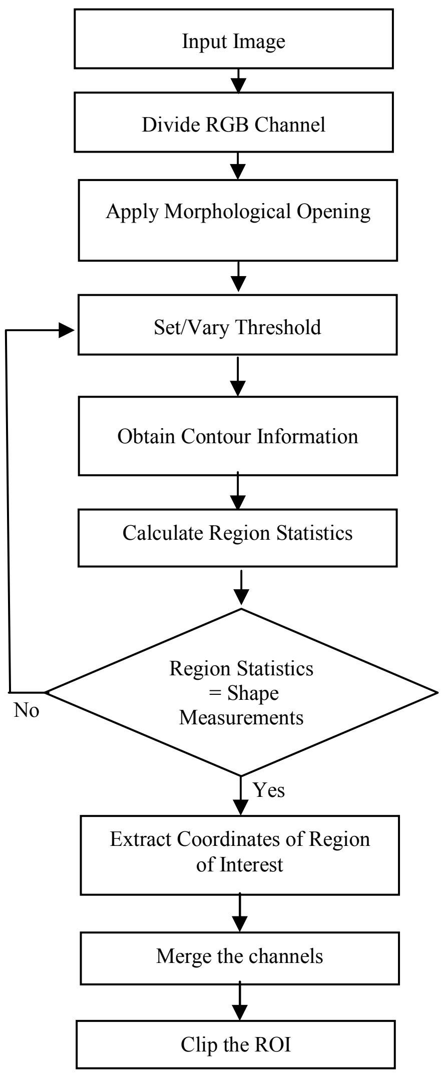
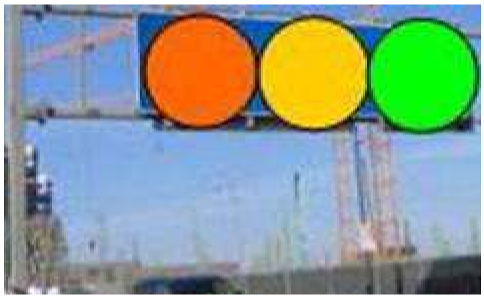


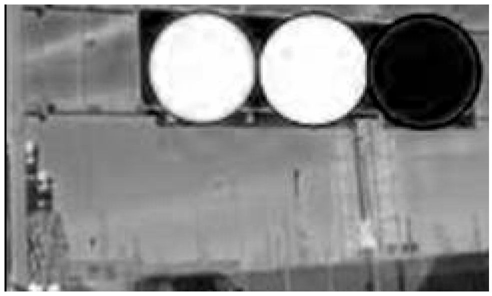
Figure 1. Flow diagram of proposed method.

4. Experimental Results

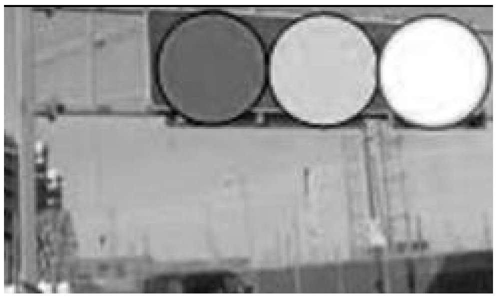
To verify the effectiveness of the proposed method, 50 images were taken at the distance of 10 meters and tested. Here we predetermine the geometric area of traffic signal as 4900 and pixel population as 2000. The pixel population depends on the resolution of the camera. This system is implemented using Interactive Data Language (IDL) and the results obtained are shown in Figures 2 and 3.



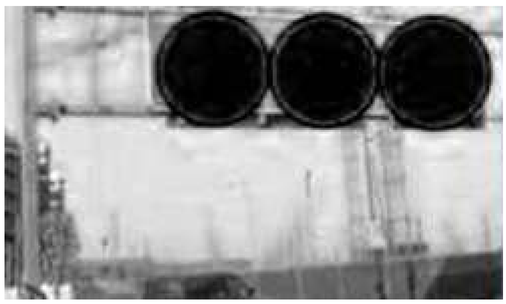
(a) Original image.



(b) Red channel.



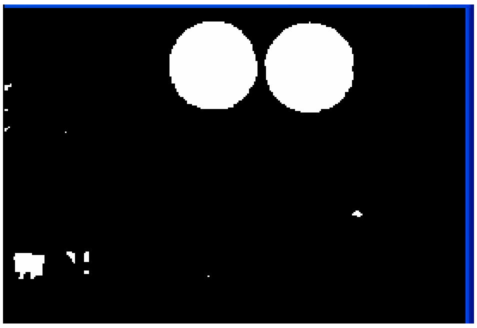
(c) Green channel.



(d) Blue channel.

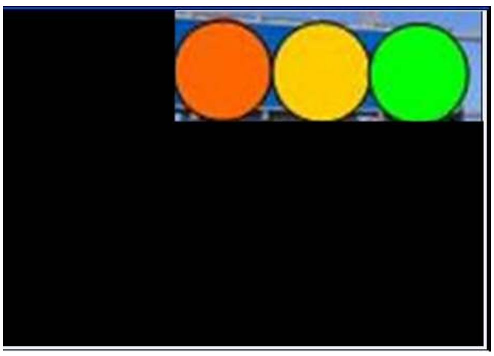
Figure 2. Resulting images.

Figure 3 shows the resulting images obtained after applying the morphological opening on red and green channels. In Figure 3(a) and 3(b), false candidate regions are also picked up along with our ROI. These false regions can be easily removed after obtaining the window coordinates. By finding the relationship between the image statistics like geometric area and the distance at which the image is captured, the system can be further modified to handle all the images, irrespective of the distance constraint. In real time, in country like India, the probability of the green light in glowing condition is very less than the probability of glowing condition of red or amber light. Therefore, the segmentation process can be carried out by using red channel first and green channel next. Another approach is to process the green and red channel simultaneously.



(a) Green channel after morphological.

(b) Red channel after morphological.



(c) Final output image.

Figure 3. Resulting images.

5. Conclusions and Discussion

This paper proposed an automatic traffic signal segmentation using iterative approach, morphological operation and shape information. The advantage of the method is as follows. First, it utilizes color information and prior knowledge about the shape measures fully. Second, the use of morphological operations leads to the extraction of our ROI effectively. Further, the use of prior knowledge improves the processing speed. The proposed method was implemented successfully and tested with 50 images. With minor modifications, the system can be implemented in the area like driver assistance system. Further in railway level crossings, the gate can be made to shut automatically based on the signal information. As a future work, the same method will be applied on Hue-Saturation-Value (HSV) model so that the new system will be illumination variant. There are some limitations such as the human intervention while capturing the image, bright background and poor visibility that hurdles the system performance. As a future work, it is proposed to include fuzzy logic when comparing the region statistics and shape measures.

Acknowledgements

I would like to thank Sadhguru Jaggi Vasudev for leading me in every walk of my life. I am grateful to Prof.K.Senthamarai Kannan for his valuable guidance and support in my research activities. I thank my family members for their cooperation. Thanks are extended to Dr.Cletus Babu (Chairman of the SCAD Group of Institution, Tirunelveli, India), Dr.K.Arulmozhi, Mr.P.Eswaran and the staff members of the Department of Statistics, Manonmaniam Sundaranar University, Tirunelveli for their moral support and motivation.

References

[1] Bustince H., Barrenechea E., and Pagola M., "Image Thresholding Using Restricted Equivalence Functions and Maximizing the Measures of Similarity," *Computer Journal of Fuzzy Sets and Systems*, vol. 158, no. 4, pp. 496-516, 2007.

[2] Gao X., Hong K., Passmore P., Podladchikova L., and Shaposhnikov D., "Color Vision Model-Based Approach for Segmentation of Traffic Signs," *EURASIP Journal on Image and Video Processing*, vol. 2008, no. 386705, pp. 1-7, 2008.

[3] Gonzalez R. and Woods R., *Digital Image Processing*, Pearson Education Inc, 2002.

[4] Hemachander S., Verma A., Arora S., and Prasanta P., "Locally Adaptive Block Thresholding Method with Continuity Constraint," *Computer Journal of Pattern Recognition Letters*, vol. 28, no. 6, pp. 119-124, 2007.

[5] Liao C., Zin T., Kaneko T., and Hama H., "Robust Segmentation of Road Traffic Signs Using Adaptive Thresholds," *Computer Journal of IEICE Electronic Express*, vol. 2, no.14, pp. 423-428, 2005.

[6] Navon E., Miller O., and Averbuch A., "Color Image Segmentation Based on Adaptive Local Threshold," *Computer Journal of Image and Vision Computing*, vol. 23, no. 2, pp. 69–85, 2005.

[7] Vachier C., "Morphological Scale–Space Analysis and Feature Extraction," *in the Proceedings of International Conference on Image Processing*, vol. 3, no. 3, pp. 676–679, 2001.

[8] Yan F., Zhang H., and Ronald C., "A Multistage Adaptive Thresholding Method," *Computer Journal of Pattern Recognition Letters*, vol. 26, no. 5, pp. 1183–1191, 2005.

[9] Zoller T. and Buhmann J., "Robust Image Segmentation Using Resampling and Shape Constraints," *Computer Journal of IEEE Transaction on Pattern Analysis and Machine Intelligence*, vol. 29, no. 7, pp. 1147–1164, 2007.

Senthamarai Kannan is currently working as a professor in statistics, at Manonmaniam Sundaranar University, Tirunelveli, Tamilnadu, India. He has more than 18 years of teaching experience a post–graduate level. He has published more than 30 research papers in international and national journals. He authored four books and visited Turkey, Singapore and Malaysia. He has been awarded TNCST Young Scientist Fellowship and SERC Visiting Fellowship. His area of specialization is 'Stochastic Process and their Applications'. His other research interests include stochastic modeling in the analysis of birth intervals in human fertility bio–informatics, data mining and precipitation analysis.

Vanniappan Balamurugan working as a professor in the Department of Computer Science and Engineering, Einstein College of Engineering, Tirunelveli, India. He has received his M.Tech in Computer and Information Technology from Manonmaniam Sundaranar University, Tirunelveli, India. He has completed his PhD under the guidance of Dr. K. Senthamarai Kannnan, Manonmaniam Sundaranar University, Tirunelveli. He possesses 16 years of experience in programming and 7 years in teaching. His research interests include time series data mining, content based retrieval, similarity search and image processing.