International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

Color Based Image Segmentation Using Adaptive Thresholding

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***Abstract*—**The segmentation of the image furnishes the foundation for further operations in image processing like object recognition, color recognition, object tracking, depth observation, etc. Adaptive thresholding, which is based on inter-pixel's intensity relationship of the image, is an efficacious method for carving out the required part or region of the image. An experimental analysis for implementing adaptive thresholding has been carried out to understand the working of adaptive threshold values on the segmentation results. RGB and HSV color models along with morphological operations are integrated with thresholding for better threshold values and better and smooth coverage of the selected color region in the segmented results. Comparisons of adaptive thresholding with global thresholding based segmentation and impact of various color models with thresholding has been made towards the end.

***Keywords*—** Adaptive thresholding, RGB thresholding, HSV thresholding, color segmentation, color detection.

I. INTRODUCTION

Image segmentation is a procedure of splitting the image into non-overlapping homogenous regions on the basis of selected property of the image. Some of such properties of image are its color tint, color intensity, texture, depth of object, motion, etc. The results obtained by segmentation basing these properties are different from one another. As per the objective of the study, appropriate property is chosen and is adhered for the segmentation procedure. There are numerous techniques that can be used to segment the image like edge detection, thresholding, region growing, clustering, artificial neural network, region splitting and merging, etc. [1][2]. Techniques like distance measuring techniques are also used for segmentation [3]. Among segmentation techniques, thresholding is the most simple and versatile technique that decides for each pixel value of the image that whether it belongs to region of interest or not. Thresholding can be utilized in applications like extracting out the objects from video using background subtraction [4]; eye glint detection, where threshold parameters are utilized for edge detection [5], [6].

The two major types of thresholding are global thresholding and adaptive thresholding. In global thresholding, a single threshold value is selected for the entire image. In this technique the pixels are partitioned depending on their intensity value f(x, y). Using the threshold T, the output binary image is given by g(x, y) in Eq.1:

$$g(x,y) = \begin{cases} 1, \text{if } f(x,y) > T; \\ 0, \text{ if } f(x,y) \le T. \end{cases} \quad (1)$$

Application of global thresholding includes image binarization of image, for example the binarization is carried out by iterative partitioning of image in [7]. Global thresholding perform fairly well when the pixel values of the components in the foreground and the background of image are coherent with respect to the entire image. When the image has low contrast and poorly illuminated then the global thresholding is inefficient [8]. In multispectral images also, the global threshold does not produce any results [9].

Other type of thresholding is adaptive thresholding, in which different threshold values are selected dynamically over the image. It overcomes the limitations posed by global thresholding to a great extent. For example, in [9] the Niblack's and Sauvola's algorithms which are adaptive thresholding techniques produce better results than global thresholding. In [10] limitations of global thresholding are presented along with the comparison of various adaptive threshold techniques. Some of the other major areas where adaptive thresholding technique is applied are - document image binarization for its analysis [11], where authors have improved Niblack's method for adaptive thresholding by preventing its limitations like inability to adapt to high illumination variation and providing unnecessary details in output by finding the appropriate element that controls the standard deviation at run-time; color image segmentation, for example in skin color segmentation using dynamic thresholding [12], where with the help of eye detection technique individual thresholds are obtained for each person in the image; color segmentation with other technologies, for instance in [13] and [14] watershed algorithm is integrated with adaptive thresholding for segmentation and in [15] neural networks are used alongside adaptive thresholding, etc.

There is enormous variety of applications of the image segmentation, particularly of the colored ones in the digital world today. One of the significant applications is the detection and segmentation of the specific color from the multiband images. In colored images there is an often a need of studying and analyzing specific part(s) of it. These parts may be of different shape, color, texture, depth, etc. as the aim of the study requires. Using segmentation such parts of interest can be extracted out of the image. Such type of segmentation can be used in the color based information retrieval system [16] [17]; color based object identification [18]; color based object tracking [19][20]; color identification for visually disabled people [21]. As discussed earlier,

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thresholding can be very efficiently applied on such multiband or colored images as well to segment out the region needed for the further processing. Besides thresholding in colored images, significant properties of various color models like RGB, HSV, HSI, YUV, etc. can be employed for image segmentation. RGB image taken as input is converted into improved HSI (IHSI) color space for the color segmentation of traffic sign boards by using the information provided by the IHSI model [22]. HSV model can be used to segment the colored image by the clustering method in which the similar pixels are grouped into a same regions. This is achievable by computing the appropriate saturation and value information of the pixels of the image [23].

In this paper, standard global thresholding technique-Otsu thresholding, which statistically and heuristically evaluates the threshold value for the image, has been used. This technique categorizes each pixel of the image into two classes, which are- foreground and background. It aimed at finding the minimum intra-class variance and maximum inter-class variance as shown Eq.2 and Eq.3 respectively.

$$\sigma^2_w(t)=w_0(t)\,\sigma^2_0(t) + w_0(t)\,\sigma^2_0(t) \quad (2)$$

$$\sigma^2_b(t)= w_0(t)\,w_1(t)[\mu_0(t)- \mu_1(t)]^2 \quad (3)$$

Where, σ^2_w is the intra-variance of a class, $w_{0,1}$ is the class probability, σ^2_b is the inter-class variance and $\mu_{0,1}$ is the class mean [24]. The technique can be applied on each band (red, green, blue) of RGB image for three respective threshold values. Using this utility of Otsu technique, a very efficient and robust color detection and segmentation scheme is presented in this paper.

II. Adaptive Thresholding

Adaptive or local or dynamic thresholding is a technique of finding the different threshold values for different regions of the image.

Though the threshold values selected for each band of RGB image with Otsu technique are reliable but sometimes when the intensity of the image or the saturation of color in the image varies throughout the image, the result obtained by mere single threshold value cannot bring the accurate results for the image. Therefore, there is a need of selecting multiple threshold values for different regions of the image and hence, we use adaptive thresholding. There are many ways to implement the adaptive technique, some of which are given in following subsection.

A. Adaptive Thresholding Approaches

There are various techniques by which adaptive form of thresholding selection can be utilized, but the aim of all the ways is to find the appropriate threshold for different regions in the image. Some of the techniques are given below:

- Dividing the image into n x m blocks: In this case, the image is divided into n x m blocks, overlapping or non-overlapping as the objective desires, where $\{n, m \in N| n, m > 0\}$. Then global thresholding is applied on each block which provides varying thresholds for each block. For example in [25], the authors have executed adaptive thresholding using this procedure and have compared the result obtained with global thresholding. In [26], the authors divide the image into array of overlapping sub-image blocks and study their histograms to generate threshold values.
- Statistically studying the neighborhood: In this case, each pixel of the image is checked against threshold obtained by statistically examining the neighborhood pixel of each pixel. In [9] author has compared such type of adaptive thresholding with Otsu's global thresholding and iterative thresholding. Similar type of thresholding filters is used in [27] to remove noise from the image.
- Component based threshold selection: Adaptive nature of thresholding is exploited by selecting different threshold values for different components of image. For example, in [12] authors have used different threshold values for skin detection in different persons by selecting the threshold value from the face skin of the person. The dynamic threshold is generated by two sided confidence level interval of 95% for normal distribution $N(\mu, \sigma^2)$, where μ, σ^2 are mean and standard deviation of array of smooth region respectively.
- Thresholding along with other technologies: Technologies like watershed algorithm, fuzzy logic, neural network, etc. when used in combination with the thresholding techniques gives new aspect to the research in image segmentation. For example, in [13] thresholding selection is used in watershed algorithm to prevent its problem of over-segmentation. Use of neural network alongside of thresholding in [15] provides number of objects automatically in the image which enables the labeling of objects without the prior knowledge of the image.

III. Objectives

As discussed above, thresholding is a significant technique for carrying out segmentation of binary as well as multiband or colored images. Keeping this into consideration, following objectives are set for the study-

- To understand different thresholding techniques in relation to image segmentation.
- To apply adaptive thresholding on the colored image for the red, green and blue color based image segmentation.
- To exploit the properties of color models like RGB (Red Green Blue) and HSV (Hue Saturation Model) for efficient color segmentation.
- Comparing the results obtained by adaptive form with global form of thresholding.
- Comparing the results obtained by segmentation using RGB and both RGB and HSV color models along with thresholding.

IV. Proposed Work

The following section describes the proposed work for implementing adaptive thresholding on multiband or colored images for color based segmentation. In the work, properties of RGB and HSV color models are utilized along with adaptive thresholding for better color segmentation.

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IJSTA
International Journal of Scientific and Technical Advancements
ISSN: 2454-1532

As discussed in section II-A, RGB image is taken as input and then is divided into n x m sub-images blocks, where each block is processed separately to prepare a mask, which is applied towards the end to extract out the region of interest. Individual mask is applied on the blocks and the resulting blocks are again combined to form the desired output image. Following subsection A to F gives the description of important processes taken out for color based segmentation followed by the flowchart in figure 1.

A. Image into n x m blocks

The input colored image is divided into n x m sub-images blocks, where {n, m ∈ N| n, m > 0 and n, m<7}. Here, values for n and m are kept small because further higher for them will give the stagnant results. Otsu's global thresholding [18] is applied on each sub-image blocks separately to obtain more appropriate threshold values for it. Each block in such a way has its own threshold values which make the thresholding procedure adaptive in nature. The transformation of image into n x m blocks is given in Eq.1.

Block = mat2cell (Image, R, C, b) (1)

Where, R and C are the number of blocks in a row and column respectively. In further steps B to F mask is prepared, which will be applied on each of these blocks towards the end.

B. RGB Thresholding using Otsu

The RGB bands of the input colored image are extracted out and the Otsu thresholding technique is applied on each of the band individually. The histogram obtained for red, green and blue bands correspond to respective pixel's color intensity distribution of the image.

C. Thresholded RGB to Hue conversion

In this step, the characteristics of the HSV (Hue, Saturation, and Value) color space are utilized by working on Hue value. The hue has the benefit of better covering of the intensity and saturation variance in the image than the RGB thresholding. The conversion formula RGB to the Hue is given in Eq. 4.

$$H=\begin{cases} \text{Undefined, if } C=0; \\ \frac{(G-B)}{C} \text{mod6 if } M=R; \\ \frac{(B-R)}{C}+2 \text{ if } M=G; \\ \frac{(R-G)}{C}+4 \text{ if } M=B; \end{cases} \quad (4)$$

Where, C=M-m; M=max(R, G, B) and m=min(R, G, B) and R, G, B are the computed values for red, green and blue from the respective threshold values obtained from step- B. This is a crucial step as the computed Hue value ensures the segmentation of a selected color more expeditiously than alone RGB threshold value had done.

D. Saturation and value thresholding

The RGB image is converted into HSV image format using standard Matlab code. The Saturation and the Value bands are extracted and Otsu thresholding technique is applied on both of them. Thresholding the Value prevents the selection of very dark to black region and thresholding the Saturation prevents the selection of very light to white region if not needed.

E. Morphological operations

Morphological operations are applied on the structure or shape of the image to alter it in the desired manner. In this proposed work the operations like closing(), fill(), bwareaopen() are used. The final mask is prepared by incorporating these operations. These operations assist in producing more smooth and clean segmentation. The prepared mask is applied separately on each block to segment the desired color.

F. Combine the image blocks

In the last step all the masked blocks are recombined to form the color based segmented image of the original image.

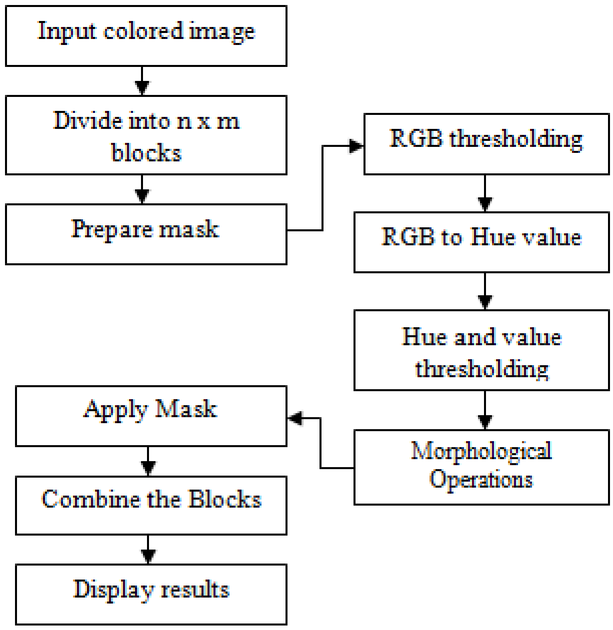


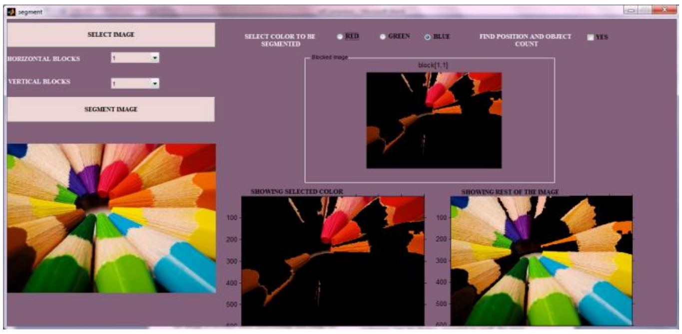
Fig. 1. Proposed methodology.

V. RESULTS AND DISCUSSIONS

The proposed methodology has been applied to different colored images ranging from images with medium to high brightness, computer generated images, natural images, remote images, etc. One such colored image is segmented using above mentioned proposed methodology, whose segmentation results are shown in figure 2.

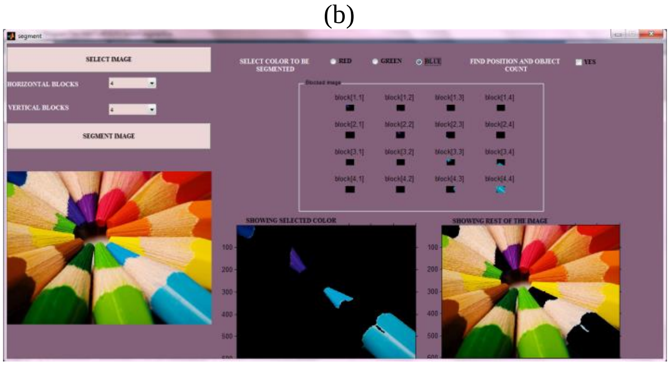
A. Comparison with Global techniques

As discussed in section II, global thresholding has the limitations when there is a high variation in the brightness of the image. Using thresholding adaptively throughout the image overcomes these shortcomings and brings out the better results. In figure 3 the comparison has been done for the segmentation result of remote image of the earth obtained by applying adaptive thresholding technique to global thresholding technique.



(a)

(b)



(c)

Fig. 2. Red, green and blue based adaptive threshold segmentation shown in (a), (b) and (c) respectively.

(a) (b) (c)

(d) (e) (f)

Fig. 3. Original image (a) and (d); (b), (e) and (c), (f) shows the segmented image with blue color only and without blue color respectively using global (upper row) and adaptive thresholding (lower row).

Some more comparison on results obtained by adaptive thresholding and global thresholding are shown in table I and their differences are tabulated in table II.

From these results it can be established that adaptive thresholding along with RGB and HSV model produces better results than global thresholding. The threshold values of three bands of RGB are utilized to find the hue limits, which provide more uniform coverage of selected color for segmentation. The region of required color is segmented out more flawlessly as can be seen in the results

TABLE I. Segmentation results obtained by global and adaptive thresholding

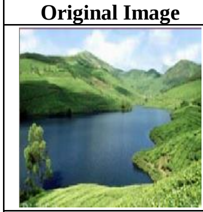
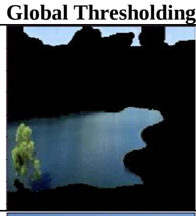
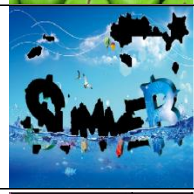
Original Image	Global Thresholding	Adaptive Thresholding
		
		
		
		
		

TABLE II. Comparison of segmentation results.

Image	Global Thresholding	Adaptive Thresholding
	Some blue region is missing; unwanted green color is also segmented.	Blue color is more uniformly segmented out; no green color is in the result.

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	Some unwanted green region is also segmented.	No green region is segmented.
	Unwanted red color is also segmented out in result.	No unwanted red color is segmented out in result.
	Unwanted colors other than blue are segmented out	Only blue color is segmented out in results
	Unwanted white color is also segmented out in result.	Less white color is segmented out in result.

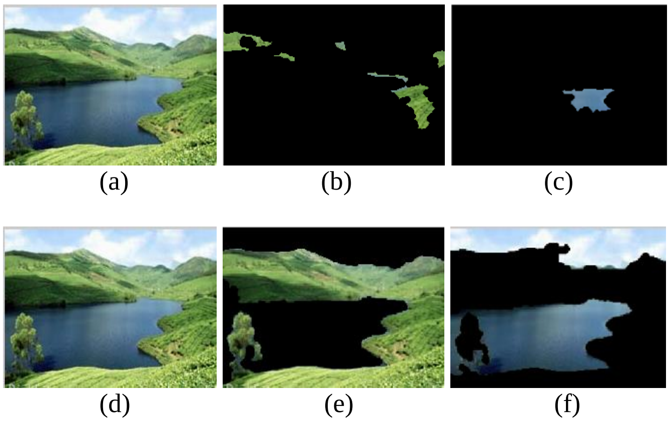

Figure 4: Original image (a) and (d); (b), (e) and (c), (f) shows the green and blue segmented images respectively using RGB model only (upper row) and both RGB and HSV model (lower row).

VI. Conclusion

A fresh method for color detection and segmentation of colored images using adaptive thresholding is suggested in this paper. The primary colors- red, green and blue are extracted out more cleanly by using properties of color models like RGB and HSV integrated with adaptive thresholding. The proposed segmentation process is robust to variety of image samples. Limitations of Global thresholding method and RGB model based thresholding are also are outlined in this paper. This technique can be further extended to work for more regular colors.

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