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A New Efficient Color Image Segmentation Approach Based on Combination of Histogram Equalization with Watershed Algorithm

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Abstract— Image segmentation is an important part of any image analysis process. Meyer's Watershed algorithm is one of the classical algorithms used for this purpose. But, the results of this algorithm usually suffer from over segmentation problem. To solve this problem, in this paper a new approach for color image segmentation is presented. In this approach, first the input RGB image is converted into HSV one and then the V channel of the later has been extracted. The histogram of the extracted V channel has been equalized to enhance the hidden edges. Here, through experiments, we have found that together Otsu's thresholding with Sobel Filter forms a better preprocessing step for an image than any of them alone. So, focusing on this fact, the resultant equalized image is thresholded with Otsu's method and after that filtered by Sobel filter. The filtered image is then sent as input to the watershed algorithm which produces the final segmented image. The output found is free from the over segmentation. Also, the evaluated values of the other image quality metrics like AMBE, NAE, MSE and PSNR show the efficiency of the proposed approach.

Keywords- Image Segmentation, Color Image Segmentation,Histogram Equalization, HSV Color Space, Otsu's Method, Sobel Filter and Watershed Algorithm.

I. INTRODUCTION

In image analysis process, "image segmentation" plays a very important rule on determining the final result of the analysis process. This can be defined as a process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. The image segmentation process divides an image into a set of segments which are homogeneous with respect to some criteria like color, intensity, or texture [1]. In [2][3], the definition of image segmentation can be found as follows: Let I be the given image. As a result of image segmentation, it will be partitioned into 'n' disjoint partitions R_i (i=1,2,..,n) so that the following properties will be satisfied :

$$(i)\ \bigcup_{i=1}^{n} R_i = R$$

$$(ii)\ R_i \bigcap R_j = \Phi$$

$$(iii)\ H(R_i) = TRUE\ \forall i$$

$$(iv)\ H(R_i \cup R_j) = FALSE\ \forall R_i\ \&\ R_j \text{adjacent.}$$

Here, H(R) denotes the homogeneity attributes of pixels over region R on the basis of which the whole segmentation process is carried out. So, it is obvious from (iii) that pixels within a cluster (region) must share the same featured components. And the property (iv) implies that if pixels belong to two different clusters then their featured components must also be different from each other.

The approach for any image segmentation task can be preceded with either (1) Discontinuity Based or (2) Similarity Based [4]. Edge detection techniques comes under discontinuity based and region growing techniques comes under similarity based. Our proposed approach is a combination of both.

Also, depending on the image concerned, image segmentation may be gray or color. But, usually human eyes tend to more adjustable to brightness, so, can identify thousands of color at any point of a complex image, while only a dozens of gray scale are possible to be identified at the same time [5]. So, we consider color image segmentation in our case. Color image segmentation uses color as homogeneity criteria for segmentation.

The research paper is organized as follows:

In the section (II), a review on literature is given on previous works done in the field. The flowchart of the proposed approach is given in the section (III). Then discussions on the topics concerned in the approach are presented in the respective sections from section (IV) to section (VII). The experiments and results are discussed in the section (VIII). Finally conclusion and future enhancement is discussed in the section (IX).

II. Literature Review

In [6], the authors presented an image segmentation method which applies the modified histogram equalization technique for enhancement of under illuminated color image and then mean shift segmentation is applied on this enhanced image. The method uses the lightness component in YIQ color space that is transformed using sigmoid function, and then the traditional histogram equalization (HE) method is applied on Y component. Then the enhanced image is segmented with mean shift segmentation. The experiments result better image segmentation in comparison to without enhanced image.

In [7], the authors proposed a technique for an automated blood vessel segmentation algorithm using histogram equalization and automatic threshold selection. The proposed method implements the contrast enhancement as preprocessing technique. The main modules of the algorithm are: Color image (RGB) to gray/green conversion, contrast enhancement, background exclusion, and thresholding and post-filtration. The experimental results show that the proposed algorithm performs better than the other known algorithms in terms of accuracy. Also, the proposed algorithm being simple and easy to implement, is best suited for fast processing applications.

In [8], the authors proposed an image segmentation technique where the image quality is first enhanced using contrast limited adaptive histogram equalization method, and then histogram thresholding is used to segment the objects. For comparing the performance, mean square error and SNR are used as parameters. The results found are satisfactory.

In [9], a regional contrast enhancement scheme, popularly known as Contrast Limited Adaptive Histogram Equalization (CLAHE) to aid the detection of retinal changes in Diabetic Retinopathy (DR) imagery is proposed. CLAHE is an adaptive extension of Histogram Equalization followed by thresholding, which helps in dynamic preservation of the local contrast characteristics of an image. Following CLAHE, median filtering of DR images is carried in order to smoothen the background noise. Results of the proposed algorithm show a considerable improvement in the enhancement of DR image.

In [10], the authors proposed a dualistic sub-image histogram equalization based enhancement and segmentation techniques. Here, the medical image is lineated and extracted out so that it can be viewed individually. The method has been tested and evaluated on several medical images. The results, after analyzing with the performance measures such as completeness and clearness, demonstrate that the proposed algorithm is highly efficient over hierarchical grouping technique.

In [11], an integrated approach of k-means algorithm and watershed algorithm for color image segmentation is proposed. Here, k-means algorithm is applied with 'cosine' distance measure to optimize the segmented result. The color segmentation is performed on HSV color space. The result of the k-means algorithm is filtered by sobel filter and then filtered image is sent as input to the watershed algorithm. The result obtained here is again filtered by median filter at the last to make the segmented image noise free that may occur during the whole process. The result of the proposed approach is found quite satisfactory.

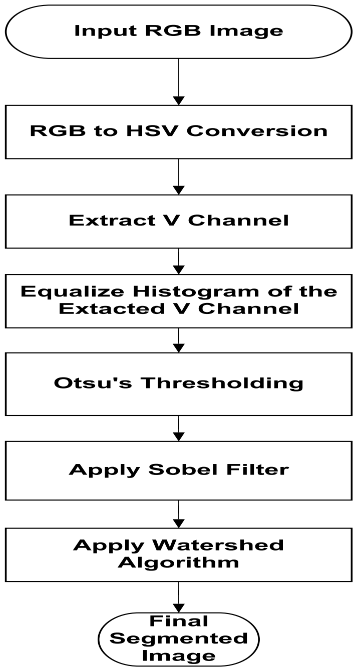
In [12], a modified version of watershed algorithm is presented where an adaptive masking and a threshold mechanism are used over each color channel to overcome the over segmentation problem of watershed algorithm, before combining the segmentation from each channel to the final one. The approach is enhancing the segmentation result and also result is found more accurate as per the obtained values of image quality assessment metrics such as PSNR, MSE and Color Image Quality Measure (CQM) based on reversible YUV color transformation.

In [13], the authors introduced a new semi-automated cell segmentation algorithm combining a histogram-based global approach with local watershed segmentation. The proposed procedure requires very little prior knowledge or user interaction. Preliminary results of accurate segmentation of the nucleus from the cell are presented to demonstrate potential application of this algorithm in cytological evaluation of abnormal nuclear structure.

In [14], the authors proposed a novel method for enhancing watershed segmentation by utilizing prior shape and appearance knowledge. The proposed method iteratively aligns a shape histogram with the result of an improved k-means clustering algorithm of the watershed segments. Quantitative validation of magnetic resonance imaging segmentation results supports the robust nature of the method.

III. FLOWCHART OF THE PROPOSED APPROACH:

The steps involved in the proposed approach can be diagrammatically shown as below:



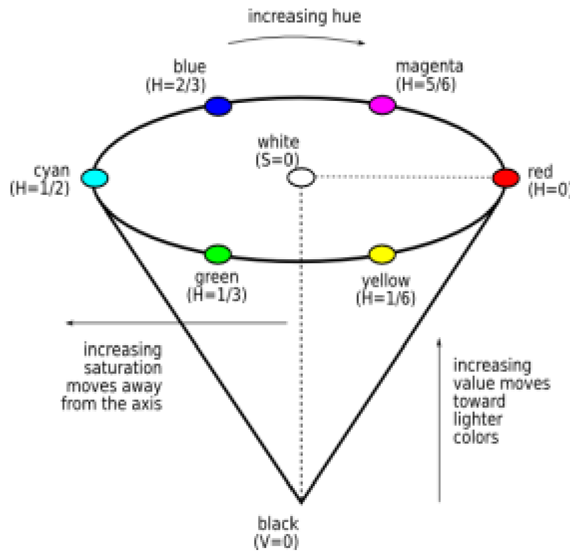


Figure1. HSV Color Space

IV. HSV COLOR SPACE

HSV color space is a frequently chosen color space for its ability to enhance the color image segmentation [15]. The HSV stands for Hue Saturation and Value. The color space can be represented by a hexacone in three dimensions where the central vertical axis represents the intensity [16]. The "Hue" is defined as an angle in the range [0,2π] relative to the red axis with red at angle 0, green at 2π/3, blue at 4π/3 and red again at 2π[17]. The Saturation describes how pure the hue is with respect to a white reference that can be thought of as the depth or purity of color and is measured as a radial distance from the central axis with values between 0 at the center to 1 at the outer surface. For S=0, as one moves higher along the intensity axis, one goes from black to white through various shades of gray. On the other hand, for a given intensity and hue, if the saturation is changed from 0 to 1, the perceived color changes from a shade of gray to the most pure form of the color represented by its hue[17]. Now, lastly the Value is a percentage that goes from 0 to 100. This range (from 0 to 100) can be thought as the amount of light illuminating a color [15]. For example, when the hue is red and the value is high, the color looks bright. On the other hand, when the value is low, it looks dark. So, value represents brightness and as brightness can be considered as a synonym of intensity, hence, in our approach, we have extracted the V channel of the HSV converted image, so that the histogram equalization can be applied on it. A Diagrammatic view of the HSV color space is [16]:

V. HISTOGRAM EQUALIZATION

By "histogram", we mean a graph which shows frequency of occurring of data in the whole data set. An image histogram acts as a graphical representation of the tonal distribution in a digital image. It plots the number of pixels for each tonal value [18]. So, it represents the frequency distribution in an image. Consider an image with G total possible intensity levels. Then, the histogram of the image in [0, G-1] is defined as a discrete function:

$$p(r_k) = \frac{n_k}{n}$$

Where,

r_k is the k^{th} intensity level in the interval.

n_k is the number of pixels in the image whose intensity level is r_k.

n is the the total number of pixels in the image.

Histogram equalization is an image enhancement technique used to enhance the contrast of the image by spreading the intensity values over full range [19][20]. The main goal of the histogram equalization is to spread out the contrast of a given image evenly throughout the entire available dynamic range. This can be achieved by a transformation function T(r), which can be defined by the Cumulative Distribution Function (CDF) of a given Probability Density Function (PDF) of a gray-levels in an image[20].

Here, we have two cases:

(A) Continuous Case: This is for intensity levels that are continuous quantities normalized to the range [0, 1].

Let, $P_r(r)$ is the PDF of the intensity levels. Then, the required transformation on the input levels to obtain the output level S is:

$$S = T(r) = \int_0^r P_r(w)dw$$

where, w is a dummy variable of integration. Then, it can be shown that [19], the PDF of the output levels is uniform, i.e.,

$$P_s = \begin{cases} 1, \ for 0 \le s \le 1 \\ 0, otherwise \end{cases}$$

The above transformation generates an image whose intensity levels are equally likely and also, it covers the entire range [0, 1]. This intensity level equalization process results an image with increased dynamic range with a tendency to have higher contrast.

(B) Discrete Case: In the case of discrete quantities, we deal with summations [19] and hence, the equalization transformation becomes:

$$S_k = T(r_k) = \sum_{j=1}^{k} P_r(r_j)$$
$$= \sum_{j=1}^{k} n_j / n \text{, for k =1, 2, 3,…, L}$$

where, S_k is the intensity value of the output image corresponding to value r_k in the input image.

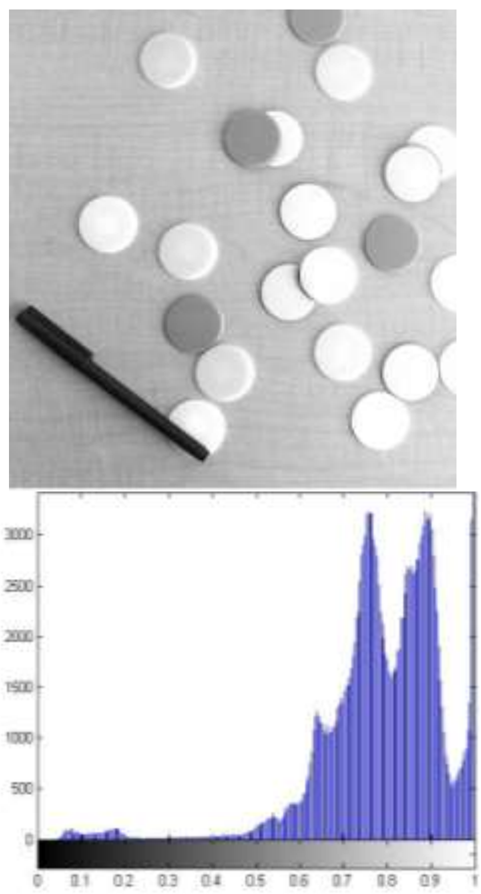


Figure 2(a): The V Channel and Its Respective Histogram

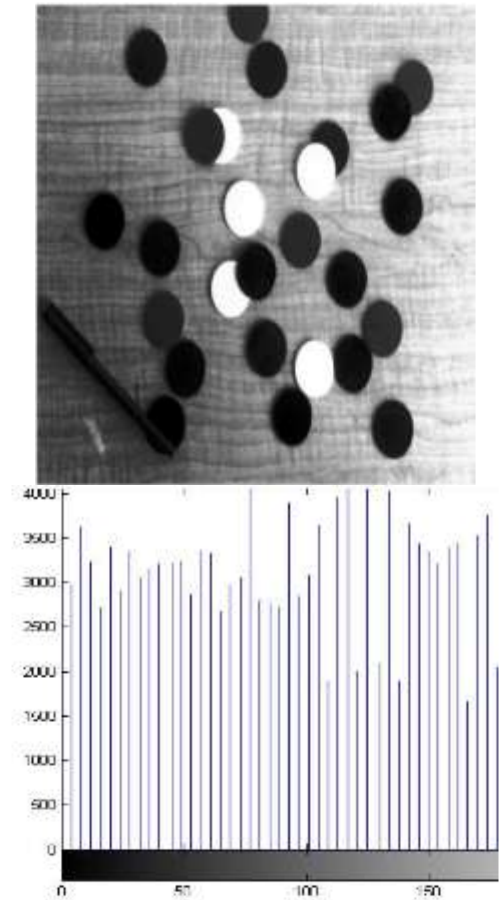


Figure 2(b): The Histogram Equalization Effect on the V Channel and Its Respective Histogram

We have used histogram equalization as the first pre processing criteria before watershed segmentation because it improves the signal contrast in a discriminative manner and as a result of which, edges become more distinct and clear [21].

VI. OTSU'S THRESHOLDING

For thresholding, an optimal gray-level threshold value is selected for separating objects of interest in an image from the background based on their gray-level distribution [20]. It replaces each pixel in an image with a black pixel if the image intensity I_{ij} is less than some fixed constant T (i.e., I_{ij}<T) or a white pixel if the image intensity is greater than that constant (I_{ij}>T)[22]. Mathematically, it can be defined as[20]:

Say, g(x, y) is a threshold version of f(x, y) at some global threshold T,then,

g(x, y) = 1 if f(x, y) ≥ T

= 0 otherwise

Thresholding operation can be defined as: T = M [x, y, p(x, y), f (x, y)], where, T stands for the threshold; f(x, y) is the gray value of point (x, y) and p(x, y) denotes some local property of the point such as the average gray value of the neighborhood centered on point (x, y)[23]. We have two types of thresholding methods:

1. Global Thresholding: Here, T depends only on f(x, y)(means, only on gray-level values) and the value of T solely relates to the character of pixels[24]. This type of thresholding technique is called "Global Thresholding".

2. Local thresholding: When T depends on f(x, y) and p(x, y) both, then it is called local thresholding. This method divides an original image into several sub regions, and chooses various thresholds T for each sub region reasonably [25].

We have chosen "Otsu Thresholding Technique" for our approach- which is a global thresholding technique [25][26]. The reason for choosing Otsu's method is because of its capability of better threshold selection for general real world noisy images with regard to uniformity and shape measures [27][28].

(a)

(b)

Figure 3(a): Noisy Version of Lena Image & Figure 3(b): Image Thresholded using Otsu's Method

V. SOBEL FILTER

Sobel filter is one of the popular edge detecting algorithms [29]. This is a discrete differentiation operator which computes an approximation of the gradient of the image intensity function. The computation is based on convolving the image with a small, separable and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations [30]. As an orthogonal gradient operator, its gradient corresponds to first derivative and gradient operator is a derivative operator [31]. Here, we have two kernels: Gx and Gy , where Gx is estimating the gradient in x-direction while Gy estimating the gradient in y-direction. So, the absolute gradient magnitude will be given by:

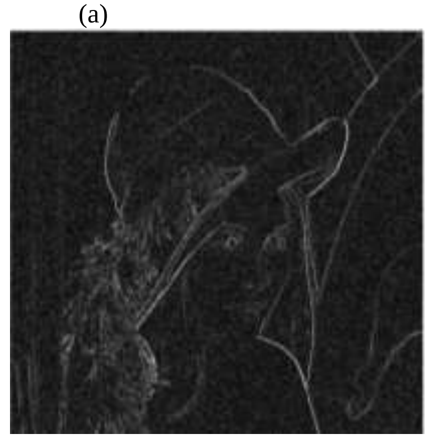
$$|\mathbf{G}| = \sqrt{(\mathbf{Gx}^2 + \mathbf{Gy}^2)}$$

But, more often, this is approximated with [28][29] :

$$|\mathbf{G}| = |\mathbf{Gx}|+|\mathbf{Gy}|$$

We have chosen sobel operator because of its capacity of smoothing effect on the random noises of an image. The edge elements, being differentially separated by two rows and columns on both sides, become enhanced which offer a very bright and thick look of the edges.

(a)



(b)

(c)

Figure 4(a) Noisy Version of Lena Image ; (b) Image Obtained After Applying Sobel Filter; (c) Image Obtained After Applying Sobel Filter on the Thresholded Image of (a).

On the above figures(figure 4), we have seen that mere applying sobel filter on a noisy image detects edges not up to a satisfactory level; while applying sobel filter on the thresholded version of the same noisy image(thresholded by Otsu's method) gives a better identification of edges with more sharpen and thicker edges. This means together Otsu's thresholding and sobel filter forms a better pre processing step for an image than any of them alone.

VII. WATERSHED ALGORITHM

Watershed algorithm is a powerful mathematical morphological tool for image segmentation task. By the term "watershed" in geography, we generally mean a ridge that divides areas drained by different river systems [19]. When an image is considered as geological landscape, then the watershed lines determine boundaries which separate image regions. The watershed transform computes catchment basins and ridgelines (also known as watershed lines), where catchment basins corresponding to image regions and ridgelines relating to region boundaries [28][32].

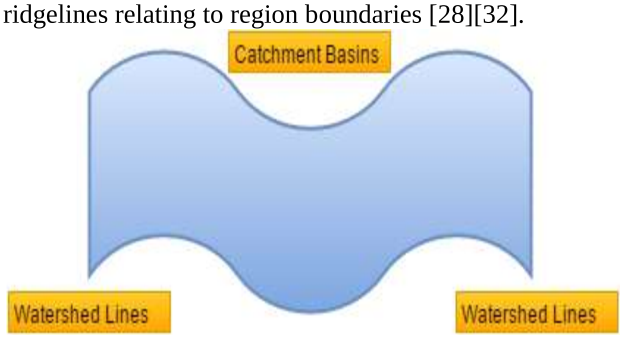


Figure 5: Watershed Lines and Catchment Basins.

In our proposed approach, we have implemented Mayer's Watershed Algorithm. The basic steps involved in this algorithm are [32][33] :

1. *Add neighbors to priority queue, sorted by value.*
2. *Choose local minima as region seeds.*
3. *Take top priority pixel from queue*
    1. *If all labeled neighbors have same label, assign to pixel*
    2. *Add all non-marked neighbors*
4. *Repeat step 3 until finished.*

VIII. EXPERIMENTS

The proposed approach has been implemented in Matlab. The images used for the experiments are collected from Berkeley Image Segmentation Dataset and Matlab Demo Images [34]. We have evaluated our results and compared with the previously existing watershed method on the basis of the following criteria: 1> Visual Perspective; 2> Absolute Mean Brightness Error; 3> Normalized Absolute Error; 4> MSE and PSNR.As human eyes are more sensitive to color and has the ability to detect separate segments in a color image, so we have first analyzed the result of the proposed approach by bare eyes (i.e., by means of visual perspective). Then, other mentioned quality metrics are calculated and analyzed to compare the results. First, a brief introduction of the used quality metrics are given below and then the experimental results are shown sequentially with respect to different image data.

(I) Absolute Mean Brightness Error (AMBE):

This is an objective measurement to rate the performance in preserving the original brightness. This can be defined as the absolute difference between the mean of the input and the output images and is proposed to rate the performance in preserving the original brightness [35, 36, 37]. The formula for calculating AMBE is:

$$AMBE = |E(\boldsymbol{X}) - E(\boldsymbol{Y})|$$

Here, X and Y denotes the input and output image, respectively, and E (.) denotes the expected value, i.e., the statistical mean. The above equation clearly shows that AMBE is designed to detect one of the distortions–excessive brightness changes [35][36]. A Lower AMBE indicates the better brightness preservation of the image.

(II) Normalized Absolute Error (NAE):

Normalized Absolute Error (NAE) is defined as follows [38]:

$$NAE = \sum_{j=1}^{M}\sum_{k=1}^{N} | x_{j,k} - x'_{j,k} | \Big/ \sum_{j=1}^{M}\sum_{k=1}^{N} | x_{j,k} |$$

A large value of NAE implies the image is of poor quality.

(III) Mean Squared Error (MSE) And Peak Signal to Noise Ratio (PSNR) :

The MSE (Mean Squared Error)is the cumulative squared error between the compressed and the original image, whereas PSNR(Peak Signal to Noise Ratio) is the peak error[39]. MSE can be computed using the following formula [38] [39] is:

MSE $=\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y)-I'(x,y)]^2$

where, I(x,y) is the original image, I'(x,y) is its noisy approximated version (which is actually the decompressed image) and M,N are the dimensions of the images value for MSE implies lesser error.

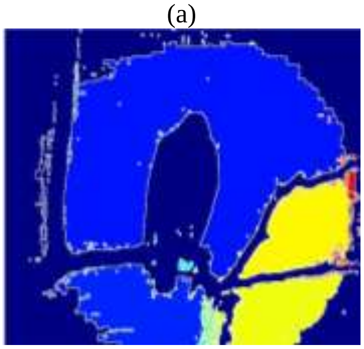
The formula for PSNR[38] is:

PSNR = $10\log_{10}(MAXi^2/MSE)$

Where, $MAXi$ is the maximum possible pixel value of the image. A higher value of PSNR is always preferred as it implies the ratio of Signal to Noise will be higher. 'signal' here is the original image, and the 'noise' is the error in reconstruction.

1> Image-1(Eagle Image):

(a)



(b)

Figure 6: (a) Original Image; (b) Final Segmented Image

MSE	Watershed Approach	Proposed Approach
MSE(:,:,1)	3.16E+03	4.0740E+03
MSE(:,:,2)	6.76E+03	4.7972E+03
MSE(:,:,3)	6.77E+03	1.4337E+03

Table 1(a): Comparison of MSE Values between Watershed Approach and Proposed Approach

PSNR	Watershed Approach	Proposed Approach
PSNR(:,:,1)	9.826	12.0306
PSNR(:,:,2)	9.8298	11.3210
PSNR(:,:,3)	13.1369	16.5663

Table 1(b): Comparison of PSNR Values between Watershed Approach and Proposed Approach

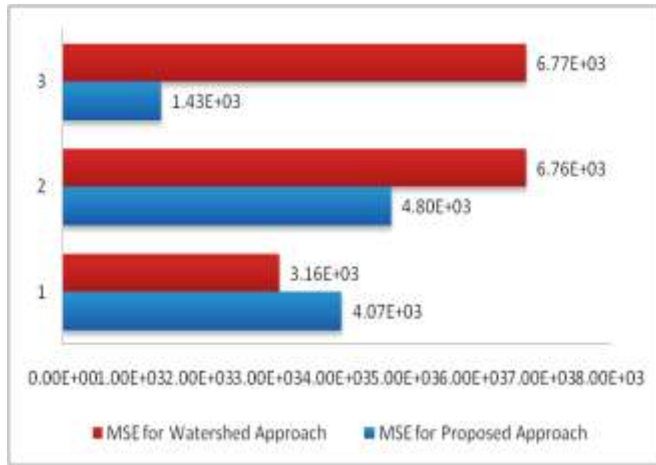


Chart 1(a)

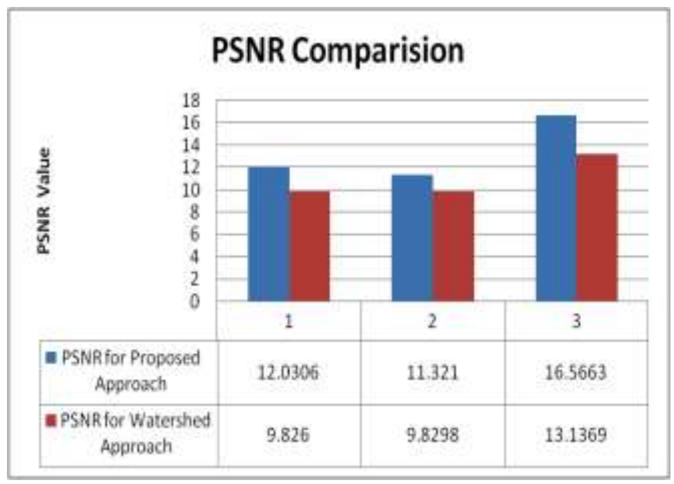
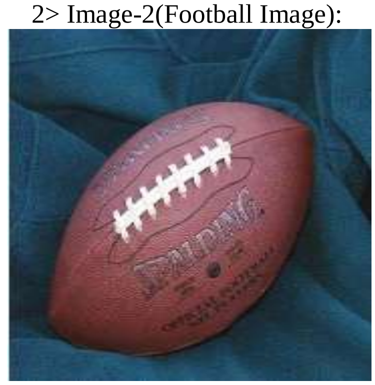
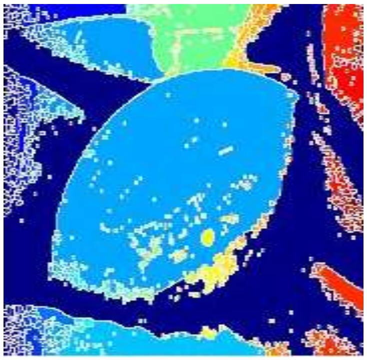


Chart 1(b)

2> Image-2(Football Image):



(a)



(b)

Figure 7: (a) Original Image; (b) Final Segmented Image

MSE	Watershed Approach	Proposed Approach
MSE(:,:,1)	3.7465E+03	2.3521E+03
MSE(:,:,2)	3.6685E+03	1.7495E+03
MSE(:,:,3)	2.4934E+03	2.2516E+03

Table 2(a): Comparison of MSE Values between Watershed Approach and Proposed Approach

PSNR	Watershed Approach	Proposed Approach
PSNR(:,:,1)	12.3945	14.4162
PSNR(:,:,2)	12.4860	15.7016
PSNR(:,:,3)	14.1629	14.6059

Table 2(b): Comparison of PSNR Values between Watershed Approach and Proposed Approach

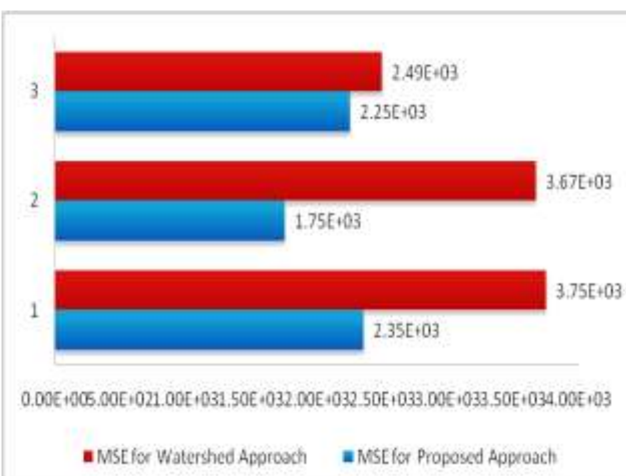


Chart 2(a)

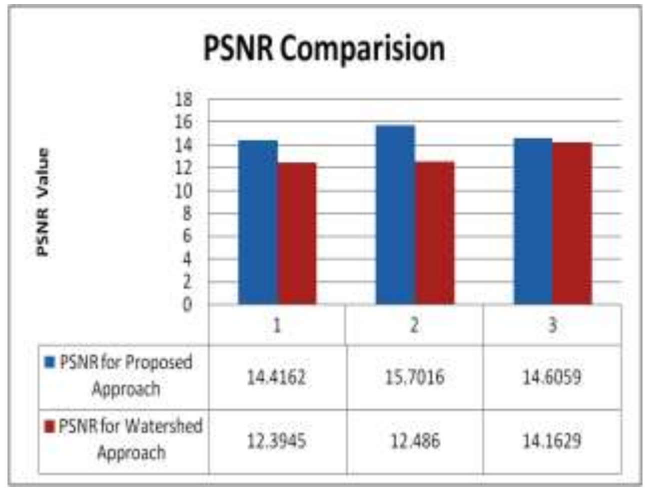
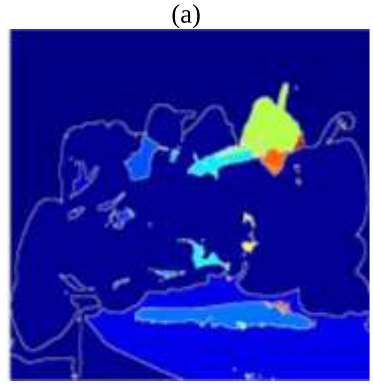


Chart 2(b)

3> Image-3(Peppers Image):

(a)



(b)

Figure 8: (a) Original Image; (b) Final Segmented Image

MSE	Watershed Approach	Proposed Approach
MSE(:,:,1)	3.0102E+03	3.9220E+03
MSE(:,:,2)	5.0355E+03	1.7055E+03
MSE(:,:,3)	4.3078E+03	2.7904E+03

Table 3(a): Comparison of MSE Values between Watershed Approach and Proposed Approach

PSNR	Watershed Approach	Proposed Approach
PSNR(:,:,1)	13.3449	12.1958
PSNR(:,:,2)	11.1104	15.8124
PSNR(:,:,3)	11.7883	13.6742

Table 3(b): Comparison of PSNR Values between Watershed Approach and Proposed Approach

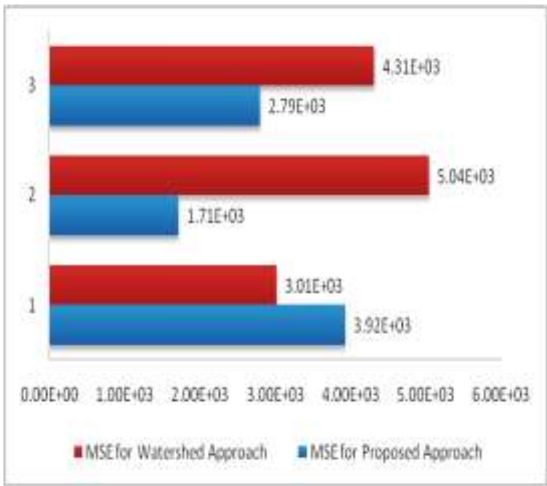


Chart 3(a)

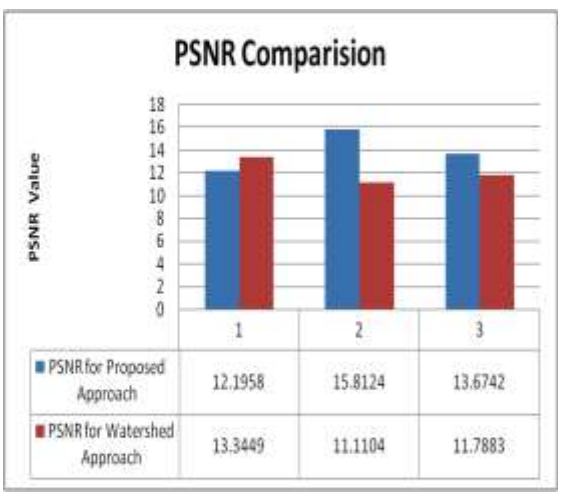


Chart 3(b)

So, it is seen from the experimental results that the segments are clearly visible with sharp and clear edges. The "over segmentation" problem that is commonly occurred for watershed approach is not occurring for the proposed approach. Also, on average the MSE values calculated for the proposed approach are comparatively lower than that of the classical Mayer's watershed approach. And the PSNR values for the proposed approach on average are greater than those of the watershed approach. This indicates a better performance of the proposed approach than the watershed approach.

Comparison of Absolute Mean Brightness Error (AMBE) Between Watershed Approach and Proposed Approach:

Image	Watershed Approach	Proposed Approach
Image-1	84.45	47.0572
Image-2	26.9635	18.3324
Image-3	33.5709	12.0067

Table 4: Comparison of AMBE Values between Watershed Approach and Proposed Approach

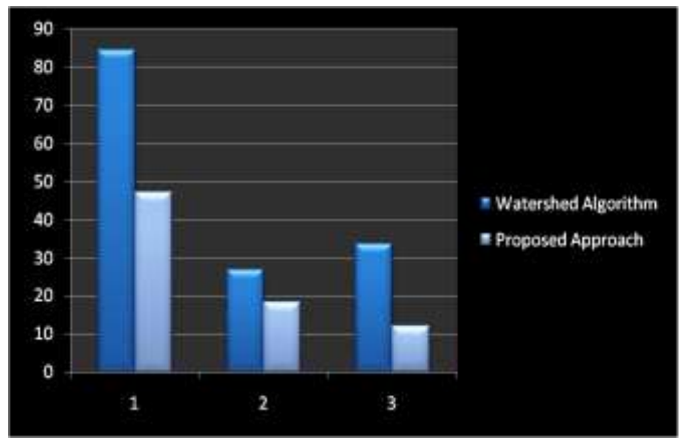


Chart 4: AMBE Values Comparison

So, it is found that the AMBE values calculated for the proposed approach are comparatively lower than the same calculated for the watershed approach. This means the proposed approach succeeds to keep a better brightness preservation of the images.

Comparison of Normalized Absolute Error (NAE) Between Watershed Approach and Proposed Approach:

Image	Watershed Approach	Proposed Approach
Image-1	.3478	.3476
Image-2	.3761	.1913
Image-3	.4952	.2847

Table 5: Comparison of NAE Values between Watershed Approach and Proposed Approach

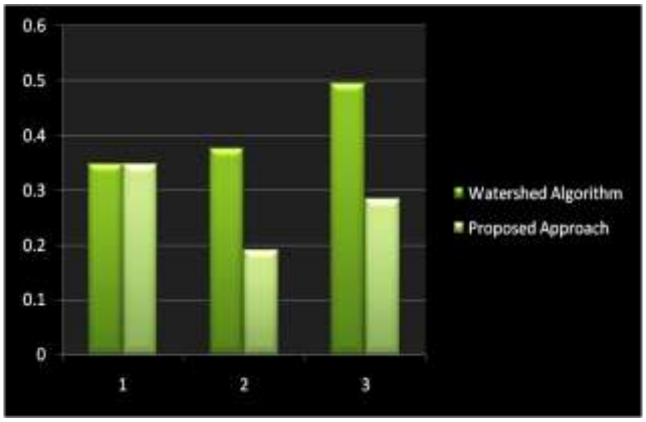


Chart 5: NAE Values Comparison

The computed NAE values for the proposed approach are less than the same for the Watershed approach. Hence, the resultant segmented image of the proposed approach is of much better quality than the same for the watershed approach.

IX. CONCLUSION AND FUTURE ENHANCEMENT

In this paper, a new approach for watershed based color image segmentation is proposed. The proposed approach is developed with an aim to deal with the over segmentation problem that results from the classical watershed algorithm based color image segmentation. For this, the main focus is given on the pre processing issues for the same algorithm. Here, as color image segmentation is concerned, so, HSV color space is chosen because of its notable performance on the same. The input RGB image is first converted to HSV one. The V channel of the HSV converted image is undergone a histogram equalization effect for enhancing the contrast of the image by spreading the intensity values over full range. This helps to brings out those edges of the image which are otherwise hidden. After that, through a few experiments, we have proved that together Otsu's thresholding with Sobel Filter forms a better pre processing step for an image than any of them alone. So, here, the image obtained after histogram equalization is thresholded with Otsu's method first and then filtered by Sobel filter. With this, our preprocessing step is complete and the filtered image is sent as input to the watershed algorithm which in turn produces the final segmented image of the original input image. The proposed has been applied to around 20 different color images collected from Berkeley Image Segmentation Dataset and Matlab Demo Images. It is found that the approach succeeds to overcome the "over segmentation" problem of the classical watershed algorithm. Also, the evaluated MSE, PSNR, AMBE and NAE values show the better performance of our proposed approach in comparison to the watershed algorithm.

As a future enhancement, we will try to include some post processing steps to our proposed approach in order to further increase the efficiency of the same. Also, as a future research topic, efforts will be given to create a novel histogram equalization technique that will be more suitable for the proposed approach.

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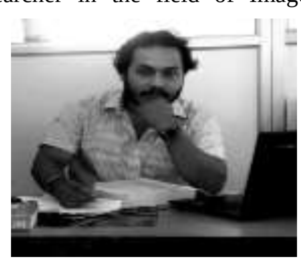
Authors Profile



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