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COLOR IMAGE SEGMENTATION USING DISCRETE WAVELET TRANSFORM AND IMPROVED SALIENCY MAP

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Abstract
The main objective of this paper is to apply Self-Organizing Map (SOM) based Enhanced Fuzzy C-Means (EFCM) algorithm to color image segmentation which is a crucial problem in computer vision and pattern recognition. Discrete Wavelet Transform (DWT) is applied on the color image. The decomposition level is set to 3. Approximation coefficients are extracted from the decomposed image. Improved Saliency Map (ISM) is computed. Self-Organizing Map (SOM) is trained with approximation coefficients along with ISM values. The resultant image is clustered with EFCM algorithm. Proposed method is validated on Berkeley segmentation dataset and other natural color images. Performance of the method is evaluated by using accuracy, precision, recall, entropy and time. Simulation results showed that the proposed method can achieve good segmentation results with low computational complexity than other methods considered for comparison from the literature.

Keywords:
Color Image Segmentation, Discrete Wavelet Transform, Improved Saliency Map and SOM Enhance Fuzzy C-means Clustering

1. INTRODUCTION

In recent years, due to the rapid growth in the computer vision technology, image processing has shown significant growth. Researchers often only interest in certain parts of the image scene understanding and analysis. Similarly, in medical field, physician often only interest in some parts of image for diagnosis of any disease [1]. These regions or parts are called as foreground region or objective, the other regions are known as background region. Image segmentation is used to identify and extract the object of interest from the image. Image segmentation is the act of dividing an image into many uniform and non-overlapping regions based on some attributes like color, texture and pixel intensity [2]. Segmentation has a variety of applications which includes online product inspection, image analysis, computer vision, remote sensing, security surveillance, geographical information system and biomedical image analysis [3].

Generally, image segmentation performed on the basis of two characteristics namely intensity and similarity. Intensity refers to the discontinuity or the sudden changes in intensity like edge. Similarity involves the segmentation of an image into different regions based on some pre-defined criteria. Color image segmentation is one of the popular and widely used method of assigning pixels of image into smaller regions which share similar attributes [4]. Color image segmentation is a crucial part of various computer vision problems including pattern recognition. There are many algorithms have been devoted for color image segmentation [5]. However, no one the algorithm works well for all kinds of images. Therefore, it is necessary to develop an algorithm for color image segmentation.

The main focus of this paper is to develop an efficient color image segmentation method. Proposed segmentation consists of phases. At phase 1, input color image separated into red, green and blue components. Each component is divided into approximation and detailed coefficients by applying Discrete Wavelet Transform (DWT). Decomposition level is set to 3. Decomposition process is used to remove the unwanted or redundant information from the image and also improve the quality of the image. During phase 2, improved saliency map is calculated. At phase 3, approximation coefficients of all the components are combined to obtain the color image. Self-organizing Map (SOM) is trained with approximation coefficients along with saliency map. The output of SOM is clustering by employing Enhanced Fuzzy C-Means (EFCM) algorithm. Simulation results demonstrated that the proposed color image segmentation method outperform the other methods.

The remainder of the paper is structured as follows: section 2 provides some literature reviews on image segmentation. Section 3 explains the proposed color image segmentation method. In section 4, quantitative performance analysis and achieved results are presented. Section 5 concludes the paper and give some future directions followed by relevant references.

2. LITERATURE REVIEW

Various image segmentation methods have been found in the open literature involving thresholding [6], edge detection [7], region growing and region merging [8] and some soft computing techniques like Genetic Algorithms(GAs) [9], Fuzzy logic [10] and Artificial Neural Network (ANN) [11] based methods.

Tan and Isa [6] presented a hybrid method for color image segmentation. This method is based on histogram thresholding and FCM. Histogram thresholding is used to extract the regions which have same color. Subsequently, FCM is used to enhance the compactness of the clusters. Results showed promising results.

Sakarya et al. [12] used fuzzy clustering approach for color image segmentation. F and Q measures are used to access the quality of segmentation results.

Yu et al. [13] investigated the ability of FCM-ant colony algorithm for image segmentation. Proposed method overcome the FCM’s sensitiveness to the initialization condition of cluster centroids and centroid number. However, this approach does not seek for very compact clustering result in the feature space.

Rajaby et al. [14] developed a color image segmentation technique which is based on FCM with weighted hue and intensity. The authors used neighborhood weighted FCM algorithm for clustering. Experimental results demonstrated that weighted FCM achieves better segmentation performance and also runs faster than similar methods.

Chi [15] partitioned an image into many regions by using SOM based fuzzy k-means clustering and modified saliency map. In this approach, pixel features of intensity and $l*u*v*$ color space is trained with SOM and followed by a k-means method to cluster the prototype vectors, which are filtered with hits map. Proposed method can achieve better segmentation results with less computational load and without human intervention.

3. PROPOSED METHOD

Image segmentation is a method of dividing an image into its component objects. It plays a very important role in image analysis especially in medical field. The level to which separation is done relies on the problem being solved. Framework of color image segmentation using wavelet and saliency map is depicted in Fig.1. In this approach, each component of color image, red, green and blue is separated. Each component is divided into approximation and detailed coefficients by adopting DWT. The decomposition level is set to 3. Then, third level approximation coefficients of each component are combined to get the color image. Modified saliency map is computed. Approximation coefficients along with modified saliency map is used to train the SOM. Finally, clustering is performed by Enhanced FCM. In the forthcoming sections, proposed color image segmentation process is explained in detail. Proposed segmentation scheme consists of four major process:

- Decomposition
- Improved saliency map
- Self-organizing map
- Enhanced FCM

3.1 DECOMPOSITION

Wavelet Transform (WT) is a mathematical tool that converts original signal or image into different domains for analysis and processing. Recently, WT has gained substantial attention in many fields and applications such as engineering, physics, medical signal and medical image processing. Moreover, WT allow signal or image to be stored more efficiently than Fourier transform. Proposed scheme uses WT as preprocessing tool to remove the unwanted data. Haar wavelet transform is used to decompose the image and the decomposition level is set to 3.

The Haar WT of the signal x is given by the set of average and difference value for the last decomposition level. In frequency domain, the coefficients corresponding to the result of low pass filter resents the approximation coefficients whereas the coefficients corresponding to the output of high pass filter represents the detailed coefficients [16] [17]. In this scheme, the signal is 2D color image, time domain is the locations of pixels and frequency domain is the color variation between neighboring pixels.

For an $N \times M$ image, WT divides an image into four sub bands of image size $N/2 \times N/2$. The resultant sub bands are labeled as LL, LH, HL and HH, where, LL represents the approximation coefficients. LH, HL and HH are the detailed coefficients. The first, second and third component of detailed coefficients refer to the horizontal, vertical and diagonal coefficients respectively. The second level transformation level decomposes the approximation sub band (LL) into four sub bands (HL, LH, HH) of image size $N/4 \times M/4$ and so on. The Fig.2 shows the wavelet decomposition. Color image decomposed by WT (up to third level) is illustrated in Fig.3.

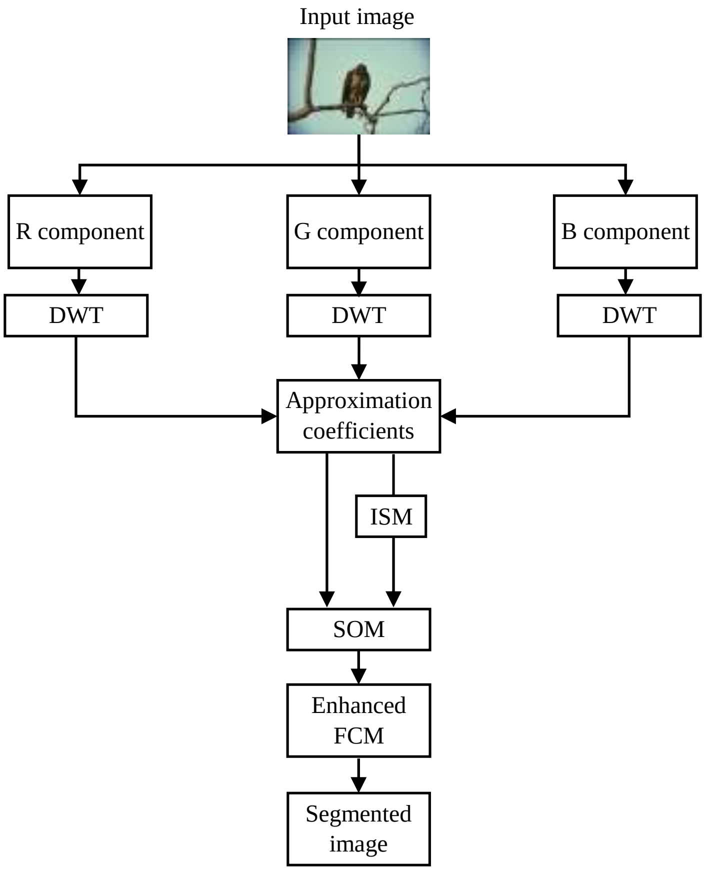


Fig.1. Block diagram of proposed color image segmentation

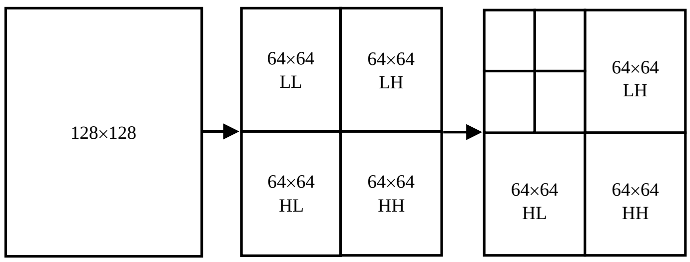


Fig 2. Wavelet Decomposition

Fig.3. Image Decomposition

Decomposition of an image can be expressed as,

$$R = [LL_R, HL_R, LH_R, HH_R] \quad (1)$$

$$G = [LL_G, HL_G, LH_G, HH_G] \quad (2)$$

$$B = [LL_B, HL_B, LH_B, HH_B] \quad (3)$$

3.2 IMPROVED SALIENCY MAP

Efficiency of any image segmentation method is depending the extraction of image components or objects of interest in image. Saliency map is the topographic representation of saliency which refers to the visual dominant locations. Saliency map plays a vital for image understanding or image analysis. Though saliency map used for image segmentation, some studies showed the poor results like over segmentation or under segmentation [18]-[23].

To deal with this issue, proposed scheme employs Improved Saliency Map (ISM) for object detection. ISM improve salient regions in a natural color image in order to avoid broken regions of an object. After decomposition, color image is obtained by concatenating approximation coefficients of each components. Color image I is calculated as,

$$I = (LL_R + LL_G + LL_B)/3 \quad (4)$$

Mathematically, R, G, B and X components are defined as,

$$R = LL_R - \frac{LL_G + LL_B}{2} \quad (5)$$

$$G = LL_G - \frac{LL_R + LL_B}{2} \quad (6)$$

$$B = LL_B - \frac{LL_G + LL_R}{2} \quad (7)$$

$$x = \begin{cases} \frac{(LL_R + LL_G)}{2} - \frac{|LL_R - LL_G|}{2} - LL_G \\ \frac{(LL_R + LL_G)}{2} - \frac{|LL_R - LL_G|}{2} - LL_B > 0 \\ 0\frac{(LL_R + LL_G)}{2} - \frac{|LL_R - LL_G|}{2} - LL_G \le 0 \end{cases} \quad (8)$$

In ISM a new component X is added because there exists a color double opponent system, where in the center of the irrespective fields, neurons are excited by one color and inhibited by another color, while the converse is true in the surround. Such special and chromatic opponency exists for the red/green, green/red, blue/yellow, and yellow/blue.

3.3 SELF-ORGANIZING MAP

SOM is a kind of commonly used unsupervised neural network [22] [24] [25]. The input vector of m dimension, $x = (x_1, x_2, x_3, \ldots, x_m)$ is connected in parallel to the neurons in the output layer. The strength or weight is associated with each neuron is $w_i = (w_{i1}, w_{i2}, w_{i3}, \ldots, w_{im})$. For each input sample x, a winner node, C, is chosen, using the similarity rule,

$$C = \arg\min_i \{\|x - w_i\|\} \quad (9)$$

The winner node C weight together with the weights of neighbor nodes, is updated according to the Eq.(10),

$$w_i(t+1) = w_i(t) + h_{Ci}(t)[x(t) - w_i(t)] \quad (10)$$

where, t, $x(t)$ and h_{Ci} are represents the epochs, input sample of current epoch t and neighborhood function of the winner node C respectively. Learning rate, $\alpha(t)$ is the difference rate between node i and the winner node C. The relation between learning rate $\alpha(t)$ and neighborhood function h can be expressed as,

$$h_{Ci}(t) = \alpha(t)h(\|r_C - r_i\|, t) \quad (11)$$

where, r_i represents the position of node i and r_C denotes the winner node in the topological map.

3.4 ENHANCED FCM CLUSTERING

Clustering is a method of grouping large sets of data or information into clusters of smaller sets of data which have similar attributes. FCM is a popular and widely used technique for image segmentation. In this scheme, Enhanced FCM (EFCM) are utilized to image the segmentation accuracy. EFCM uses neighborhood distance to perform clustering and denoising in parallel. Neighborhood distance can be computed as,

$$d_{xr,v} = \sum |x_r(l) - v(l)| \quad (12)$$

$$d_N(x_k, v) = \sum_{r \in N_k} \omega_{kr} d_{xr,v} \quad (13)$$

where, $x_r(l)$ is the l^{th} element of array x, $v(l)$ denotes the l^{th} element of array v, x_k is the pixel of the image and x_r is the neighborhood of $x_k \cdot \omega_{kr}$ is the similarity between pixel k and its adjacent pixel r. According to [24] and [25], similarity between k and r are obtained by using Eq.(14),

$$\omega_{kr} = \frac{\exp\left(-\frac{\left\|G_\tau \times \left(W(N_k) - W(N_r)\right)\right\|^2}{\lambda_g \sigma_k^2}\right)}{\sum_{r \in N_k} \exp\left(-\frac{\left\|G_\tau \times \left(W(N_k) - W(N_r)\right)\right\|^2}{\lambda_g \sigma_k^2}\right)} \quad (14)$$

$$u_{kc} = \frac{\left(\sum_{r \in N_k} \omega_{kr} \|x_k - v_c\|\right)^{-\frac{2}{(m-1)}}}{\sum_{j=1}^{C}\left(\sum_{r \in N_k} \omega_{kr} \|x_k - v_j\|\right)^{-\frac{2}{(m-1)}}} \quad (15)$$

$$v_k = \frac{\sum_{k=1}^{n} \delta_k u_{kc}^m}{\sum_{k=1}^{n} u_{kc}^m} \quad (16)$$

$$\delta_k = \sum_{r \in N_k} \omega_{kr} x_r \quad (17)$$

The algorithmic steps of the proposed color image segmentation are presented.

Step 1: Read an image I

Step 2: Separate the color components R, G and B

Step 3: Set the decomposition level to 3.

Step 4: Apply DWT on each component of color imge

Step 5: Extract the approximation coefficients of each components.

Step 6: Combine aproximation coefficients of all the components to obtain color image.

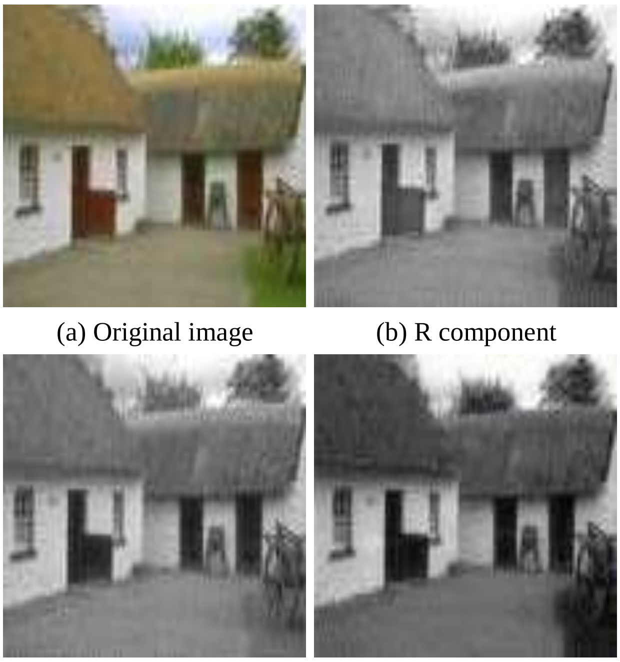
Step 7: Compute the ISM using Eq.(5) – Eq.(8)

Step 8: Train the SOM with approximation cofficients and ISM

Step 9: Perform clustering by using EFCM

4. NUMERICAL RESULTS AND DISCUSSION

Proposed color image segmentation scheme is applied to a variety of color image like natural scenes, geometrical objects and Berkeley segmentation dataset [26] to demonstrate the capability of algorithm. Precision, accuracy, entropy, recall and time are employed to measure the efficiency of the proposed segmentation algorithm. Entropy measures the uniformity. Lower value of entropy indicates good segmentation. Higher value of precision and recall shows the better result. Segmentation accuracy is also measured to quantitatively measure the performance of the method. Additionally, we implemented some related works to compare the proposed algorithm efficiency against other related FCMs which includes FCM [6], weighted FCM [14], SOM based k-means algorithm [15], SOM-FCM [25] and FCM-spatial information [26]. All the methods are implemented and tested using MATLAB platform. The Fig.2 shows the original image and its color components. The Fig.5 depicts the resultant output of the proposed image segmentation method.



(a) Original image (b) R component

(c) G component (d) B component

Fig.4. Sample image

Efficiency of the proposed color image segmentation scheme in terms of evaluation parameters are mentioned above are given in Table.1. The Fig.6 graphically compares the segmentation accuracy of the proposed scheme with the other existing methods taken for analysis.

Fig.5. Example of segmentation results

Table.1. Comparison of performance of the proposed with other methods

Methods	Time	Accuracy	Precision	Recall	Entropy
Tan and Isa [6]	0.75	87.56	0.56	0.34	0.47
Rajaby et al. [14]	0.65	90.12	0.48	0.65	1.25
Chi [15]	0.67	93.25	0.53	0.68	1.22
Zaixin et al. [25]	0.73	88.63	0.41	0.56	0.31
Wang et al. [27]	0.59	91.25	0.55	0.64	1.34
Proposed	0.45	95.46	0.62	0.79	0.11

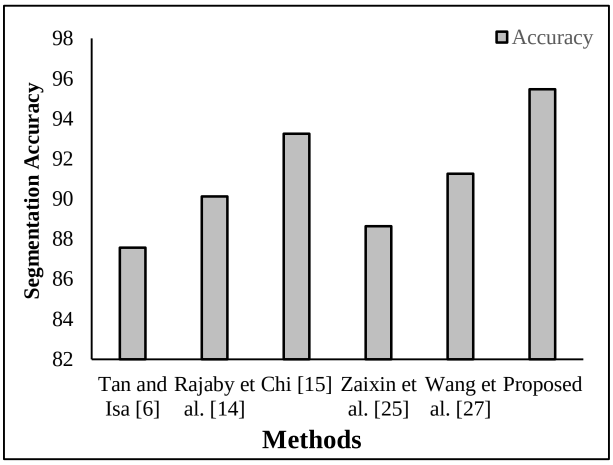


Fig.6. Comparison of segmentation accuracy

5. CONCLUSION

This paper presented a novel color image segmentation method based on DWT, ISM and EFCM. In this method, SOM is trained by two important components coefficients and saliency map to enhance the segmentation accuracy. Memory required and computation cost is reduced due to the use approximation coefficients instead of input color image. ISM and EFCM also improve the convergence speed. Empirical findings proved that the proposed method performance superior to the other existing methods considered for analysis in terms of evaluation measures.

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