An Efficient Color Image Segmentation Using Texture Features and Improved Saliency Map

M. Sivasubramanian, M. Sivajothi, P. Kumar

Abstract--- ***Image segmentation is the process of partitioning an image into many regions based on some characteristics like color, texture and intensity. It plays a very important role in image analysis. This paper presents an efficient technique for color image segmentation. Proposed technique utilizes Integer Wavelet Transform (IWT) and Self-Organizing Map (SOM) based Enhanced Adaptive Kernelized FCM (EAKFCM) algorithm. Low frequency components of color image are extracted using IWT. Five texture features are derived from the low frequency components. Improved saliency map is calculated. Texture features and ISM are used as an input to the SOM which is an unsupervised neural network. The segmentation of homogenous regions is obtained employing EAKFCM algorithm. Proposed segmentation technique is tested on natural images and Berkeley segmentation dataset. Efficiency of the proposed technique is measured using five widely used statistical measures such as precision, accuracy, recall, entropy and time. Results demonstrated that the efficiency of the proposed color image segmentation technique is superior to other methods in terms of evaluation metrics.***

Keywords-Color image segmentation, clustering, lifting scheme, Integer wavelet transform, self-organizing map, improved saliency map.

I. INTRODUCTION

Computer vision is the branch of science that aims to understand, analyze and process the images in the same way that human vision does, and then provide an appropriate output. In computer vision, images are playing pivotal role to convey information [1]. Computer vision is concerned with the automatic feature extraction, analysis and understanding of useful information from a single image or sequence of images. Digital Image Processing (DIP) is a technique to enhance the quality of raw image received from sensors or cameras. It is used in many fields including medical, forensic, remote sensing and military etc. [2]. The various image processing methods are image enhancement, image segmentation, feature extraction, feature reduction and classification. Among many image processing, image segmentation is one of crucial step in computer vision since it plays an important role in object recognition and classification [3].

Image segmentation is a powerful technical for extracting useful information from an image. It is the process of dividing an image into its constituent objects or parts based on its features or attributes such as color, texture, shape etc. Level of partition depends on the problem being solved. Segmentation is stopped when the Region of Interest (ROI) in an application have been isolated. Color being directly attached to the regions of an image. Color image segmentation might provide better results compared to the gray scale or monochrome image. Many different methods for color image segmentation have been reported in the literature[4] [5]. Unfortunately, none of the segmentation method gives better results. Some studies showed color image segmentation based on color, texture and saliency map provided better performance[6]. Gray Level Co-occurrence Matrix (GCLM), Auto correlation function, Generation Co-occurrence matrices (GCM) and second order spatial averages are commonly used texture analysis. [7].

Image segmentation methods can be classified into four groups namely region-based segmentation, color clustering method, histogram threshold and soft computing methods like fuzzy methods and ANN. Zhao et al. [3] presented a color image segmentation using fuzzy SVM and saliency map. In this approach, fuzzy adopted to enhance SVM classification ability. However, this method is not suitable for images with complex background or containing many objects. In 2017, Zhang et al. [5] presented a detailed surely of color image segmentation techniques based on saliency map. Kumar et al. [8] proposed a color image segmentation method which is based on wavelet transform. Raw image is divided into approximation and detailed coefficients using wavelet transform. The authors used only approximation coefficients for segmentation. After decomposition, mean, variance, Probability Distribution function (PDF) and shaping parameter are computed. Segmentation performed by Maximum Likelihood (ML) estimation. The advantage of the method is low computational cost. Celik et al. [9] designed an unsupervised color image segmentation method using Dual-Tree Complex Wavelet Transform (DT-CWT). DT-CWT employed to extract the edge information. Subsequently, morphological operators are adopted to detect the seed points from edge information. Segmented image is obtained utilizing region growing and region merging algorithm in L*a*b* space. Proposed method is easy to implement and provided better results.

Manuscript received February 01, 2019

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Wavelets- SOM based color image segmentation algorithm developed by Jaffer et al. [10] in 2009. In this algorithm, DWT is applied to decompose the input image into approximation and detailed coefficients and the decomposition level is set to 2. Second level approximation coefficients of each color component are combined to get a color image. Combined coefficients are taken as feature vectors to be trained by SOM. Trained SOM is employed to segment the test image. Results showed that the use of wavelet-SOM in color image segmentation outperforms the other algorithms. Objective identification in color image is a tough task due to background and lighting conditions. Ganesh et al. [11] proposed a new algorithm for object detection from the color image. Proposed algorithm consists of 2 stages. At stage 1, Input image is compressed using two different wavelet transforms namely DWT and IWT and identified the suitable transform that can perform better process to compress the input image. At stage 2, resultant image is segmented using K-means clustering algorithm. The results are promising but the efficiency of the algorithm is not tested against noise. An accuracy of image classification is based on extraction of ROI. This can be achieved by identifying salient object and removing unwanted details. Saliencycolor map-based segmentation technique is introduced by Jabarullah and Babu [12] in 2015. Proposed technique used quadrants and cluster center window of the image without performing domain conversion in order to reduce cost and time. Performance of the technique is compared with other methods interms of precision, recall and accuracy.

II. PROPOSED METHODOLOGY

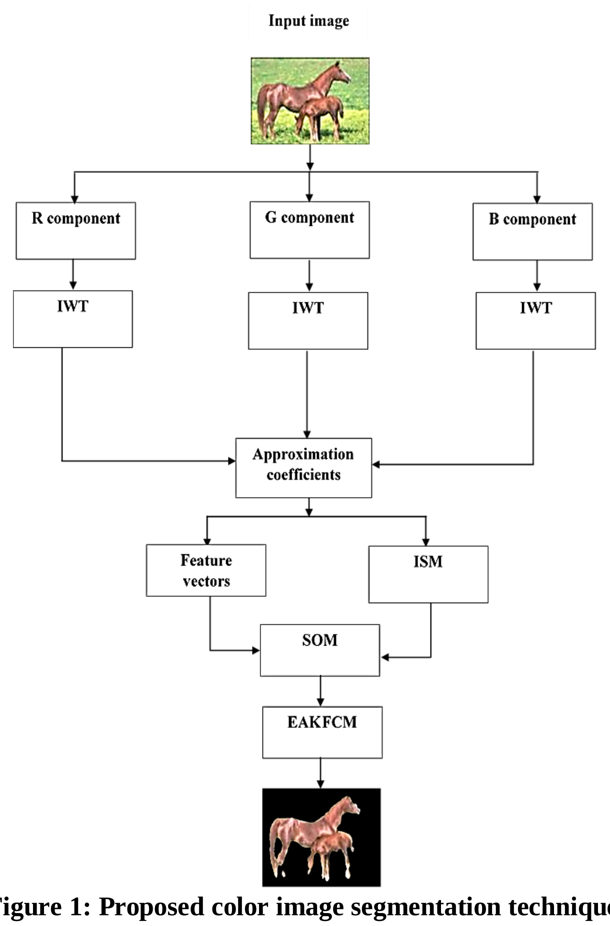

Figure 1: Proposed color image segmentation technique

In this paper, we presented an efficient color image segmentation technique to solve the aforementioned constraints, which uses IWT and SOM based Enhanced Adaptive Kernelized FCM (EAKFCM) algorithm. The motivation for employing IWT is due to its ability to identify the edges better than DWT. Improved saliency of each component is computed. Approximation coefficients of each component are fused to make a color image and then texture features are calculated. Texture features and ISM are used as input to the SOM. Finally, clustering is performed using EAKFCM algorithm.

The rest of the paper is organized as follows. Section 2 presents the proposed color image segmentation technique. Numerical results and performance comparison are given in section 3. Finally, Section 4 concludes the paper followed by relevant references.

Fig.1 depicts the overview of the proposed color image segmentation scheme. Initially, each component of the color image is separated. IWT is applied to all the components. It decomposes an image into low frequency (approximation coefficients) and high frequency (detailed coefficients). In this technique, Haar wavelet transform is due to its simplicity and easy implementation and decomposition level is set to 3. Third level approximation coefficients of all the components are combined to get a color image. Subsequently, textures features are computed. ISM is also calculated. ISM and texture features are taken as feature vectors and applied to the SOM network followed by EAKFCM clustering algorithm to perform the segmentation task.

A. Integer wavelet transform

Discrete Wavelet Transform (DWT) is an attractive tool for extracting the information from different types of data. Though DWT is a good candidate for many image operations, it has some drawbacks like floating point precision. To overcome such issues, IWT is employed in this study. IWT is a kind of wavelet transform which maps integer data set with another integer data set. Haar wavelet transform is popular for its simplicity and have been found to perform well in practice [11]. In this study, Haar transform is employed and the decomposition level is set to three.IWT has the important property that its coefficients have the same dynamical range as the original signal. This makes easier implementation.

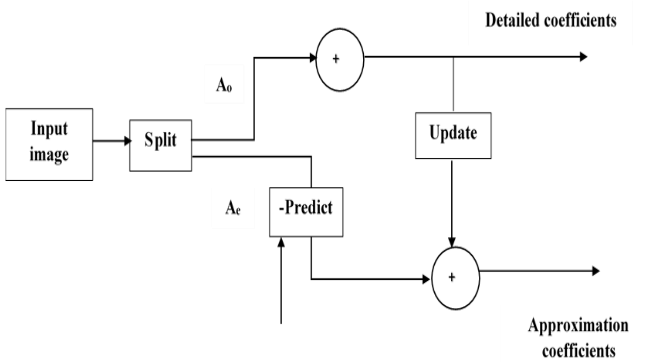

Figure 2: IWT decomposition

ISSN: 2277-3878, Volume-7 Issue-5S3, February 2019

Integer wavelet coefficients are obtained via lifting scheme. Lifting scheme is shown in Fig.2. Constructing wavelets using lifting scheme consists of three process namely splitting, prediction and updated. Split phase divides the input data into odd and even data. Odd set is predicted from even set in prediction. Prediction process ensures polynomial cancellation in high pass filter. Update phase will update even set using wavelet coefficient to calculate scaling function. Update process ensures preservation of moments in low pass filter. The detailed steps of IWT is as follows:

Step 1: Divide the input data A into odd and even samples[11]

$$D_{i+1} = A_o = \{A_{2j+1}\} \quad (1)$$

$$S_{i+1} = A_e = \{A_{2j}\} \quad (2)$$

Step 2: Predict the even sample A_e with odd sample A_o and replace by prediction error

$$D_{i+1} = D_{i+1} - P(S_{i+1}) \quad (3)$$

Step 3: S_{i+1} is updated with D_{i+1} and replaced with updated value

$$S_{i+1} = S_{i+1} + U(D_{i+1}) \quad (4)$$

B. Feature extraction

Texture provides an information about the spatial arrangements of color or intensities of an image[7]. Texture feature extraction is one of the most important techniques used in image analysis. After decomposition, low level frequency (approximation coefficients) of all the components are combined to get the color image and then five texture features are extracted. Table 1 lists the texture features along with their formula used in this study.

Table 1: Texture features

Feature	Formula
Energy	$\sum_{i=1}^{N}\sum_{j=1}^{N}(P_{ij})^2$
Entropy	$\sum_{i=1}^{N}\sum_{j=1}^{N} -\ln(P_{ij})P_{ij}$
Contrast	$\sum_{i=1}^{N}\sum_{j=1}^{N} P_{ij}(i-j)^2$
Correlation	$\sum_{i=1}^{N}\sum_{j=1}^{N} P_{ij}\frac{(i-\mu)(j-\mu)}{\sigma^2}$
Angular Second Moment (ASM)	$\sum_{i=1}^{N}\sum_{j=1}^{N} P_{ij}^2$

C. Improved saliency map

Proposed color image segmentation technique uses improved saliency map to identify the salient objects [1][12]. The reason of choosing ISM is to overcome the limitations of standard saliency map like over or under segmentation. After decomposition, color image is obtained by concatenating approximation coefficients of each components. Color image I is calculated as,

$$I = \frac{LL_R + LL_G + LL_B}{3} \quad (5)$$

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

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

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

$$B = LL_B - \frac{LL_G + LL_R}{2} \quad (8)$$

$$X = \begin{cases} \frac{(LL_R + LL_G)}{2} - \frac{|LL_R - LL_G|}{2} - LL_B & \frac{(LL_R + LL_G)}{2} - \frac{|LL_R - LL_G|}{2} - LL_B > 0 \\ 0 & \frac{(LL_R + LL_G)}{2} - \frac{|LL_R - LL_G|}{2} - LL_B \leq 0 \end{cases}$$

In ISM, a new component X is added because there exists a color double opponent system, where in the center of their receptive 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. Five groups of Gaussian pyramid level $I(\sigma)$, $R(\sigma)$, $G(\sigma)$, $B(\sigma)$, and $X(\sigma)$ are generated from *I*, *R*, *G*, *B*, and X, respectively, where σ is Gaussian pyramid level index, $\sigma \in [1, 2, 3, 4, 5]$.

Four different mask M0, M45,M90 and M135 are created and convolved with the intensity image[17].All the saliency maps are combined to obtain an oriental saliency map, $O(\sigma)$.To improve the high salient region and restrain the low salient region, the saliency map is square power transformed,

$$ISM = \frac{(I(\sigma) + R(\sigma) + G(\sigma) + B(\sigma) + X(\sigma) + O(\sigma))^2}{6} \quad (10)$$

D. Self-organizing map

SOM is a type of unsupervised training, in which the networks learn to form their own classifications of the training data without external help. The principal goal of SOM is to transform an incoming signal pattern of arbitrary dimension into a one- or two-dimensional discrete map, and to perform this transformation adaptively in a topologically ordered fashion [14]. Texture feature along with ISM are used input to the SOM network.

E. Enhanced adaptive kernelized FCM

The output of SOM is a coarsely segmented image that is further processed to refine the segmentation result. EAKFCM adopted to perform fine segmentation. Standard FCM assign pixels to many clusters without labels. Standard FCM failed to provide good segmentation result when the image is corrupted by heavy noise, outliers and artifacts. It requires more time for executing algorithm and updating centres. To rectify these drawbacks, EAKFCM is introduced in this study. In this algorithm, the regularization term uses the approximation of the first order derivative with a filter which can preserve the shape of the gain field while suppressing noise[15]. It also avoids solving large differential equation and gives much faster computational speed.

Algorithm for EAKFCM

Step 1: Initialize gi with i (i=1,2,3…M) and cluster centres Ck (k=1,2,3…..N) with random

values within the image intensity, where N is the number of clusters.

Step 2: Update the membership function by using Equation (11)

$$U_{ik} = \frac{\|K(y_i, g_i, c_k)\|^{\frac{2}{q-1}}}{\sum_{l=1}^{N}[K(y_i, g_i, c_l)]^{\frac{1}{q-1}}} \quad (11)$$

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Step 3: Update the cluster centers ck,

$$c_k = \frac{\sum_{i\in D} U_{ik}^q G_i y_i}{\sum_{i\in D} U_{ik}^q G_i^2} \times g_i \sum_{k=1}^{N} U_{ik}^q \langle c_k, c_k\rangle - \sum_{k=1}^{N} U_{ik}^q \langle y_i, c_k\rangle + \frac{\tau}{N}\sum_{i\in D}\{(g_i - (g_i - (H\times g)_i))\} = 0 \qquad (12)$$

Step 4: Calculate the gain filed g_i

$$g_i = \frac{\sum_{K=1}^{N} U_{ik}^q \langle y_i, c_k\rangle}{\sum_{K=1}^{N} U_{ik}^q \langle c_k, c_k\rangle} \qquad (13)$$

Step 5: Update the gain field

$$g_i = (H\times g)_i \qquad i \in D \quad (14)$$

If (change of $U_{ik}<$ Specified U) and (change of $g_i<$ specified G)

Break;

else

Go to step 2.

The detailed steps of the proposed color image segmentation are presented in Table 2

Table 2: Color image segmentation algorithm

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 IWT on each component of color imge
Step 5:Extract the approximation coefficients of each components.
Step 6:Concatenate aproximation coefficients of all the components to obtain color image.
Step 7:Compute the ISM using Equation (10)
Step 8: Train the SOM with approximation cofficients and ISM
Step 9:Perform clustering by using EAKFCM

III. EXPERIMENTAL RESULTS AND DISCUSSION

The performance of the proposed color image segmentation techniques is evaluated using Berkeley database[16](50 images)and other natural images. Efficiency is compared with other existing methods including saliency map[1], DWT-FCM [13], SOM-FCM [17],FCM [18], DWT-Texture based segmentation [19] and DWT-K means [20]in terms of precision, accuracy, entropy, recall and time. Table 3 shows the efficiency of the proposed technique in terms of statistical metrics. It is observed that the proposed method gives good result and robust.

Table 2: Efficiency comparison

Authors	**Methods**	**Time**	**Accuracy**	**Precision**	**Recall**	**Entropy**
Umredkaret al.[1]	Saliency map	0.43	77.90	0.68	0.57	0.41
Bhattacharyaet al.[13]	DWT-FCM	0.55	90.53	0.84	0.81	1.01
Chi [17]	SOM-K	0.67	93.25	0.53	0.68	1.22
Singh et al.[18]	FCM	0.83	79.63	0.53	0.61	1.78
Valliammal et al.[19]	DWT-Texture	0.72	86.45	0.71	0.764	1.93
Halder et al.[20]	DWT-Kmeans	0.63	89.34	0.78	0.71	1.67
Proposed	**IWT-Texture - EAKFCM**	0.31	98.56	0.89	0.90	0.11

Figure 3 graphically compares the proposed method with the other methods in terms of time, precision, entropy and recall. It is found that the proposed method outperforms the other methods by providing higher values for precision and recall and lower value for entropy. Segmentation accuracy of the proposed method is compared with the other methods, as shown in Figure .4.Proposed method achieved higher segmentation accuracy than other methods. It again confirmed the efficiency of the proposed method. Segmentation result of the proposed technique is shown in Figure.5.

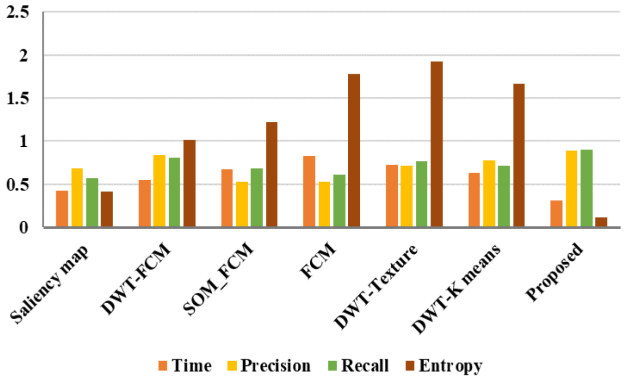

Figure 3: Efficiency comparison

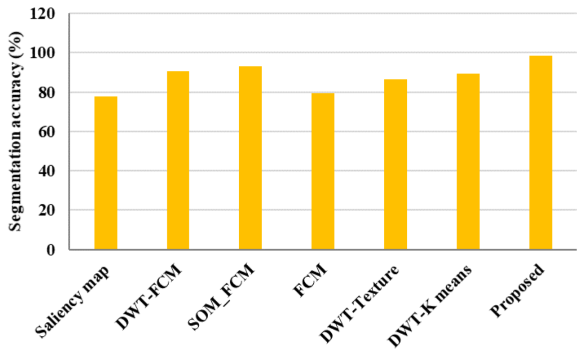

Figure 4: Comparison of segmentation accuracy

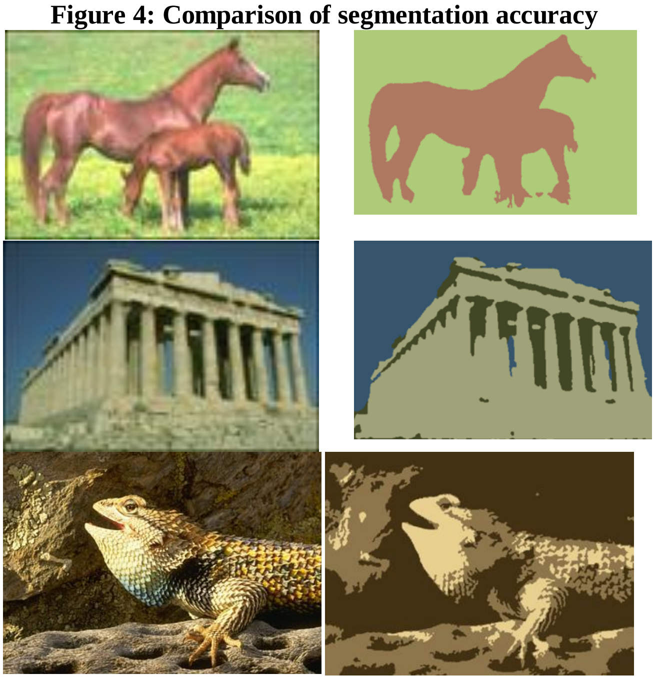

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Figure 4: Sample of segmentation result

IV. CONCLUSION

This paper presented a color image segmentation technique which is based on IWT, ISN and SOM based EAKFCM algorithm. Haar integer transform is used to decompose the image into low frequency and high frequency components. Only low frequency components at third level of each component are concatenated to make color image. IWT is good not only in avoiding floating point problem, it also retains the important information between regions. In addition to this, it reduces the computational time. ISM overcome the drawbacks of standard saliency map. It enhances the segmentation result. EAKFCM also improves the segmentation result. Results showed that the proposed method provides better segmentation result with less computational overhead.

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