Efficient 3-class Fuzzy C-Means Clustering algorithm with Thresholding for Effective Medical Image Segmentation

Sunil Kumar¹, Prof. R. R. Ahirwar², Prof. Y. K Jain³

¹, ², ³Department of Computer Science & Engineering, SATI, Vidisha, India

Abstract— Medical image segmentation is a method of extracting the desired parts and features from the input medical image data. The conventional FCM algorithm is an efficient clustering algorithm that is used in medical image segmentation. But FCM is extremely susceptible to noise since it uses intensity values for clustering the image. This paper aims to develop 3-class FCM algorithm with thresholding which is noise efficient. The proposed 3-Class FCM method improves efficiency of image by modifying the initialization of fuzzy petition matrix this method uses normally distributed pseudorandom numbers generator with Gaussian distribution for initial estimates of petition matrix. The thresholding with FCM is used to generate the logical segmented images. As another improvement in this paper, colour segments are generated by utilizing the results of FCM. And the results of the proposed FCM method are tested upon the variety of medical images and compared with the widely used Global thresholding and Otsu’s method. The performance is also evaluated for comparison of FCM with different distance masers.

Keywords—Color segment’s, Medical Image segmentation, Fuzzy C-mean Clustering, Thresholding, Entropy.

I. INTRODUCTION

In the last two decades with the development of various scanning technologies it has become possible to capture a large variety of images of human or animal anatomy. Image segmentation is widely used in a variety of applications such as robot vision, object recognition, geographical imaging and medical imaging. The medical imaging methodology broadly includes Ultrasound images, Computed Tomography (or CT scan), X-ray images, Optical sonographic images and Magnetic Resonance Imaging (MRI). Segmentation permits us to efficiently analysis and comprehensively manipulate the medical images especially for radiological evaluation, computer aided diagnosis, 3D visualization of objects, disease identification and surgical planning.

The goal of image segmentation is to partition an image into a set of disjoint regions with uniform and homogeneous attributes such as intensity, color, tone or texture, etc. Many different segmentation techniques have been developed and detailed.

Surveys can be found in references [1–3]. According to reference [1], the image segmentation approaches can be divided into four categories thresholding, clustering, edge detection and region extraction. Basically segmentation is considered as the first stage of pattern and feature recognition process [21] used for object isolation as shown in Figure.1. Therefore efficiency of the feature extraction and image classification depends open the efficiency of the segmentation.

Figure 1 Basic process of segmentation [21]

Segmentation algorithms are basically based on two basic properties of intensity images namely discontinuities and similarity. In the first category partition an image based on abrupt change in intensity such as [14] edges in an image. The approaches in the second category are based on partitioning an image into regions that are similar according to the set of pre-defined criteria. Region growing [10], region splitting and merging [9], and Thresholding [7, 18, 21] are the examples of methods in this category.

In thresholding approach the objects and backgrounds are separated based on the selected intensity threshold. For segmenting the well defined regions thresholding based segmentation has proved to be effective and fast. Therefore in medical imaging, thresholding based methods [7, 9, 12, 18 and 21] has been widely used for many medical application such as segmentation of tissue, background removal in Magnetic resonance imaging (MRI), extraction of bones in radiography, for identifying the skin cancer. Since from the 70s, an Otsu’s method is widely used [4], adaptive thresholding method.
Fuzzy C Means (FCM) algorithm is the most popular method used in image segmentation because it has robust characteristics for ambiguity and can retain much more information than the conventional FCM algorithm works well on most noise-free images, it has a serious limitation it does not incorporate any information about spatial context, which cause it to be sensitive to noise and imaging artifacts.

In this paper, a clustering based method for image segmentation is proposed to be considered. An efficient method of medical image segmentation is proposed which uses the improved 3-Class FCM with thresholding for image segmentation. Figure 2 gives an example of 3-class FCM. Each class represents a color group.

![Figure 2 Example of clustering with 4 clusters a) original Skin-3 image b) clustered image.](image)

It is clear that the desired object belongs to the particular class as shown in red colour oval in Figure 2. Actually clustering method finds the regions of close boundaries based on similarity measures.

The prim aims of this paper are;
1. To speed up the FCM method by modifying the initialization of fuzzy partition matrix Method uses normally distributed pseudorandom numbers generator and normal distribution for initial estimates of membership function.
2. Adjust the exponent of the fuzzy membership function for better segmentation.
3. The conventional method of thresholding with FCM generates the logical segmented images. Therefore as another improvement in this paper, Colour segments are generated by utilizing the results of FCM. And the results of the proposed Clustering method are tested upon the variety of medical images and performance is evaluated for comparison of FCM with different distance masers.

The rest of this paper is organized as follows. Section II briefly describes the theory of FCM and thresholding algorithms. The proposed 3-Class FCM algorithm is presented in Section III.

Experimental results and comparisons are given in Section IV. Finally Conclusions is drawn in Section V.

II. REVIEW OF RELATED THEORY

The clustering based medical image segmentations have been widely used by researchers in the past [1, 4, 7, 9, and 17]. Jun Zhang et al. [4] used Otsu’s adaptive thresholding based segmentation for histogram based analysis. But this method is not consistent and needs additional pre processing to improve the image quality in many cases. D. Patil et al. [9] have presented a brief review of the various medical image segmentation methods based on region growing, clustering and histogram based thresholding. The clustering based method works efficiently for medical images. G. Padmavathi [17] implemented a fuzzy c means clustering method with thresholding for segmenting the medical images. Paper compares the standard fuzzy c means clustering algorithms with their proposed method for medical images. The quantitative statistical measures have been used for evaluating the nonlinear image region segmentation. Qualitative measures used are, the gray level energy, discrete entropy, relative entropy, mutual information and information redundancy. But clustering is less effective for large number of diagnosis images with non uniform brightness conditions such as in medical images. Therefore, thresholding is widely used to improve the efficiency of the standard FCM. Radhika et al. [18] have proposed a method of the segmentation of dark areas in SAR images to detect the oil spill. They have used FCM with 3 class thresholding [21], which perform efficiently.

A. Fuzzy C –Means Clustering

In fuzzy clustering, the membership function of extracted features for each pixel at each cluster change proportional to zonal mean of membership values and gradient mean of adjacent pixels. The direction of membership variations are specified using human interaction. Their segmentation approach was applied for segmentation of texture and documentation images and the results have shown that the human interaction eventuates to clarification of texture and reduction of noise in segmented images.

G. Sudhavani and Dr. K. Sathyaprasad have described the application of a modified fuzzy C-means clustering algorithm to the lip segmentation problem this algorithm works by assigning membership to each data point corresponding to each cluster centre on the basis of distance between the cluster centre and the data point. More the data is near to the cluster centre more close is the membership towards the particular cluster centre.
Clearly, summation of membership of each data point should be equal to one. After each iterations membership and cluster centers are updated according to the formula

$$\mu_j = \frac{1}{\sum_{k=1}^{c} \left(\frac{d_j}{d_k}\right)^{2(m-1)}}$$  \hspace{1cm} (1.a)

$$v_j = \left(\frac{\sum_{i=1}^{n} (\mu_{ij})^m \cdot x_i}{\sum_{i=1}^{n} (\mu_{ij})^m}\right), \forall j = 1,2,....c$$  \hspace{1cm} (1.b)

Where, \(n\) is the number of data points.

\(v_j\) represents the \(j^{th}\) cluster center.

\(m\) is the fuzziness index \(m \in [1, \infty]\).

\(c\) represents the number of cluster center.

\(\mu_{ij}\) is membership of \(i^{th}\) data and \(j^{th}\) cluster center.

\(d_{ij}\) Euclidean distance within \(i^{th}\) data and \(j^{th}\) center.

The Jafar et al.[19] have explained the Chi square distance measure between vector \(x\) and canters \(v\) is give as;

$$d(x_i, v_j) = \sqrt{\frac{\sum_{j=1}^{c} (x_i - v_j)^2}{x_i + v_j}}$$  \hspace{1cm} (2)

B. Thresholding

Thresholding is the simplest and widely used method for segmenting the medical images. It is useful for discriminating foreground objects from the background [7, 21]. By selecting an adequate threshold , the gray scale image can be converted to a binary image. The binary image should contain all of the essential information about the position and shape of the objects of interest (foreground). During the thresholding process assume an object to be brighter than the background, and then individual pixel in an image is marked as “object” pixels if their value is greater than threshold \(T\) else as “background” pixels. This is known as above threshold. Typically, an object pixel is given a value of “1” while a background pixel is given a value of “0.” Finally, a binary image is created by converting image to black and white image. Various methods of thresholding are used by the researchers out of these methods Global thresholding [5] and Otsu’s [4] thresholding have gained popularity.

C. Global Thresholding

The common way to convert gray level image to a binary image is to select a single global threshold value from image histogram, than all the gray level values below this will be classified as black (0), and those above will be white (1). The segmentation problem becomes one of selecting the proper values for the global threshold. This technique can be expressed as:

$$T = T[p(x, y), f(x, y)]$$  \hspace{1cm} (3)

Where: \(T\) is the threshold value, \(x, y\) are the coordinates of the threshold value point. Where \(p(x, y), f(x, y)\) are gray levels of the image. Threshold image \(g(x, y)\) can be defined as:

$$g(x, y) = \begin{cases} 1 & \text{if } f(x, y) > T \\ 0 & \text{if } f(x, y) \leq T \end{cases}$$  \hspace{1cm} (4)

An example of the global threshold selection and segmentation is given in the Figure 3. It can be seen that in this case the threshold can be selected easily as point of separating the background and object.

![Figure 3 Example of global thresholding for weather cancer MRI brain image](image)

D. Otsu’s Thresholding

The Otsu method [2, 4, and 18] is widely used thresholding based segmentation method which defines within class variance \(\sigma_w\), the variance between class \(\sigma_B\), and the total class variance \(\sigma_T\). Then finding the optimal threshold by minimizing the ratio \(\eta = \sigma^2 \sigma_T^2\).
Where
\[ o_T^2 = \sum_{i=0}^{L-1} \left[ 1 - \mu_T \right]^2 P_i \mu_T = \sum_{i=0}^{L-1} \left[ P_i \right] \]  
(5)

\[ o_B^2 = W_0 W_1 (\mu_0 \mu_1)^2, \quad W_0 = \sum_{i=0}^{L-1} P_i, \quad W_1 = 1 - W_0 \]  
(6)

\[ \mu = \frac{\mu_T - \mu_0}{\mu_0}, \quad \mu_0 = \frac{\mu_T}{W_0}, \quad \mu_T = \frac{1}{\sum_{i=0}^{L-1} P_i} \]  
(7)

But this method needs initial pre processing for improving image quality and does not performs well for noisy images.

Figure 4 Failure case of the global thresholding

III. PROPOSED METHODOLOGY

In this paper the proposed 3-class FCM algorithm with thresholding. Clustering algorithm is used to segment the dark areas. The block diagram of the proposed segmentation method is shown in Figure 5.

The clustering used because it gives a high level of understanding with the present number of data sets that do not have a common behavior between each other. The performance of FCM method is improved by modifying the initialization process of partitioning function. Proposed method also has flexibility of selecting the exponent of the fuzzy membership function. Usually the method of FCM with thresholding [21] generates logical (black and white) images. In the proposed method an improved FCM based logical output is used to extract the colour segment from the original image by negative masking. Flow chart of proposed segmentation method is given in the method is given in the Figure 6.
A. Proposed 3-Class FCM Clustering Algorithm

The ideal FCM method divides the image into \( c_n \) clusters with every cluster having different centre. Each data point in the particular dataset belongs to each cluster up to a certain degree of extant. For example, consider a certain data point that lies closer to the centre of the cluster, it will have a high degree of belonging or membership to that cluster and the data point which lies far away from the cluster centre it will have a lower degree of belonging or membership to that cluster.

The proposed 3-Class FCM clustering algorithm is sequentially given as follows:-

1. Define the number of clusters \( Q \geq 2 \), the total number of data points given by \( N \), and the minimum desired improvement \( Min - imp \). Randomly initialize the initial fuzzy partition matrix \( U_i \), and also define its exponent \( Exp \).

2. The initial estimate of fuzzy membership function is defined as product of initial fuzzy partition matrix and exponent as;

\[
mf = U_i \ast Exp
\]

3. Where, \( d_{ik} \) is the measured distance value between object and cluster centers. In this paper it is defined as squared Euclidean distance given as;

\[
d_{ik}(d_k, C_i) = \|d_k - C_i\|^2
\]

Compute the new membership function \( M^n_{ik} \) as;

\[
M^n_{ik} = \frac{1}{\frac{1}{2} d_{ik}^{-Exp - 1}}
\]

4. The fuzzy objective function represents the distance from cluster centre to any data point weighted with the membership grades of that data point's. Calculate the objective cost function for FCM as;

\[
F_m(U_n, C_n, D_n) = \sum_{i=1}^{Q} \sum_{j=1}^{N} M^n_{ik} d_{ik}^2
\]

Where \( U_n \) defines the new updated set of fuzzy partition matrix, \( C_n = [c_1, c_2, c_3, ..., c_Q] \) is the updated set of clusters centres. And \( D_n = [d_1, d_2, d_3, ..., d_p] \subseteq R^p \) is defined as the image data set of the \( p \) dimensional vector space. Where, \( M_{ek} \) is given as the degree of membership corresponding to the data \( d_k \) in the \( i^{th} \) cluster, \( Exp \) is the exponent of membership function. Method calculates the distance matrix using the Euclidean distance between each row in centre and each row in data, and returns a distance matrix out of size \( M \) by \( N \), where \( M \) and \( N \) are row dimensions of centre and data, respectively, and gives the output as distance between centre and data. Therefore equation (11) may be re written as;

\[
F_m = \sum_{i=1}^{Q} \sum_{j=1}^{N} M^n_{ik} \|x_k - V_i\|^2
\]
FCM clustering method begins with an initial assumption for the cluster centers, which are usually to select the mean location of each cluster. For initial estimate of fuzzy partition matrix U, the uniform pseudo random generator is commonly used. But in our proposed method in order to speed up the iterations it is proposed to use the pseudo random generator with normal distribution. In terms of threshold selection Normal integer generator performs similar to the pseudo random generator but since it has a Gaussian distribution it generates the higher initial estimates for the fuzzy partition matrix as described briefly in the Figure 7.

\[
V_i = \frac{mf * D}{\sum_{k=1}^{N} u_{ik}}
\]  

(13)

Thus proposed FCM method generates the two output images correspond to each threshold level \( T \), and their Performance is compared with the standard Otsu threshold method [3].

An example of 3 classes of FCM partitioned clusters and the respective threshold images are given in the Figure 8. It can be observed that each class represent the different features of the image. But since clustering based methods are sensitive to noise thus thresholding is used to improve the efficiency.

C. Colour Segment Extraction

As another improvement in this paper the segmented output of FCM method are used to generate the colour segmented results. Now in order to segment the colour segment first the logical output image of the FCM stage is inverted and the process is named as negative masking. The procedure of negative masking is as follows;

1. Find the maximum of the segmented output image.

\[
C = \max (\max (I_{FCM}))
\]  

(17)

2. Take the difference of segmented output and its maximum value as;
3. Convert B from logical matrix to gray matrix.
4. Now extract the colour segment by using B as convolving mask. The colour segments are extracted individually in RGB colour spaces and then merged together.

\[
B = C - I
\]  
(18)

\[
Sg_1 = im(:,;1) \ast B
\]  
(19)

\[
Sg_2 = im(:,;2) \ast B
\]  
(20)

\[
Sg_3 = im(:,;3) \ast B
\]  
(21)

\[
sgm(:,;1) = Sg_1; \quad sgm(:,;2) = Sg_2;
\]

\[
sgm(:,;3) = Sg_3;
\]  
(22)

Where, \(I\) represents the input true colour image and \(\ast\) represents the convolution sign. \(S\) is the segmented image. Therefore, proposed method gives 8 fuzzy segmented images of the same object. Out of which four are logical images and rest are colour segments. Thus it helps doctors to identify the diseases better

IV. SIMULATION RESULTS

In this section some of simulation results for the 3 class FCM with thresholding are presented. The MATLAB used as platform for the implementation. Figure 9 shows the data base of input original medical images used for the performance evaluation in this paper.

![Figure 9](image)

All four images are acquired from different scanning techniques in variant environments. Therefore each input image is containing some unique features.

The MRI Brain scan image and Skin image 3 are the colour images with distinct features thus are used for representing the visual segmented results. For statistical evaluation all four images are considered.

![Figure 10](image)
Figure 11 Results of proposed segmentation method for the MRI Brain Image. (a) Original RGB image (b) Otsu level=0.400000 (c) FCM0, level=0.249020 (d) FCM1, level=0.684314, e) Proposed colour segmented image at the FCM0, f) Colour segmented image at the FCM1.

Figure 12 Comparison of the different thresholding based segmentation results for CT scan image a) Original gray level image b) Global threshold with T=50, c) threshold with T=100, d) Otsu level=0.313725 e) segmented with proposed method at the FCM0, level=0.225100 f) FCM1, level=0.0507968

Segmentation results of the proposed colour segments with 3-class FCM are presented for each level of thresholding in Figure 10 for Skin image 3. The input RGB image is first converted to gray image and then the gray image is segmented using the 3-class FCM based thresholding. It can be seen that each threshold image contains different features. The object may sometimes belong to FCM level 0 or may belong to FCM level 1.

Since the threshold image is a logical image thus colour segmented images are generated from threshold images by using it as a matching mask on original image. Mostly the object is dark compared to background thus negative masking is not required and the color segments can be directly generated from the threshold results.

In this case since the object is brighter than the background thus negative masking is not required and the color segments can be directly generated from the threshold results.

Figure 12 have compared the results of proposed 3-class FCM clustering with thresholding to the results of existing Otsu thresholding [4] method and Global thresholding [5] for the CT scan image. It can be seen, that proposed method improves the threshold level significantly, thus contains the more information. And method also performs well where Otsu’s method fails to detect the object as clear from the Figure 12 (c). The level threshold represents the value between 0 to 1. The corresponding comparison of level thresholds, energy .and entropy with the proposed FCM method along with the Otsu’s threshold and global threshold are presented in the Table 1 below.
The Table 2 shows that the use of normal pseudo random generation minimizes the number of iterations required to achieve optimized objective function without changing the threshold levels. This is because the normal distribution is a Gaussian distribution and is defined for entire range. Since the initial value of objective function is randomly generated thus the number of iterations is different every time the simulation is run.

**TABLE 2**
COMPARISON OF THE NUMBER OF ITERATIONS FOR TWO RANDOM INTEGER GENERATIONS

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Input medical Images</th>
<th>Iterations counts with Uniform Pseudo random Generator</th>
<th>Iterations counts with Normal Pseudo random Generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Skin_3</td>
<td>33</td>
<td>29</td>
</tr>
<tr>
<td>2</td>
<td>CT scan 1</td>
<td>31</td>
<td>23</td>
</tr>
<tr>
<td>3</td>
<td>MRI Brain Scan</td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>Bone ankle X ray</td>
<td>33</td>
<td>35</td>
</tr>
</tbody>
</table>

Therefore Figure 13 shows the comparison of iteration count for 10 individual simulations. It is observed from the both Figures that FCM with normal random generator reduces the iteration count.

The Table 3 shows the comparison of the segmentation with Euclidean distance and Chi square distances [19]. It is observed from Table 3, that FCM with Euclidean distance performs better in number of iterations except for Bone ankle X-ray image.

**TABLE 3**
COMPARISON OF THE ITERATION COUNT FOR FCM WITH DIFFERENT DISTANCE MEASURES

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Skin_3</th>
<th>CT scan 1</th>
<th>MRI Brain Scan</th>
<th>Bone ankle X ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Chi Square Distance</td>
<td>33</td>
<td>32</td>
<td>68</td>
<td>30</td>
</tr>
<tr>
<td>With Euclidean distance</td>
<td>21</td>
<td>32</td>
<td>22</td>
<td>61</td>
</tr>
</tbody>
</table>
V. CONCLUSION

Efficient method of medical image segmentation is proposed which uses the 3-Class FCM with thresholding for image segmentation. As a modification the normal pseudorandom generator is used, which improves threshold for most of the cases except for Born Ankle X-ray image with less numbers of gray levels. The colour segments are generated from the binary segments.

The performance of the proposed method is also compared with the FCM using Chi Square distance measure. It is observed that Chi square method is slower than the proposed Euclidean distance measure except for Born Ankle X-ray image. The proposed method improves the threshold level at the lesser computation cost. The colours of the segmented results are slightly shifted with respect to original image segment. In future the performance of the method can be improved for images with less colour variations such as X-ray images and optimization methods can be used for setting the exponent of partition adaptively.

Acknowledgment

I express my indebtedness and gratefulness to my guide Asst. Prof. R.R. Ahirwar and Dr. Yogendra Kumar Jain, Head – Department of Computer Science and Engineering for his continuous encouragement and guidance His intelligible conversations, patient listening and friendly behavior encouraged me to work with enthusiasm and honesty.

REFERENCES

AUTHORS

**Sunil Kumar** has done Diploma (First) in Computer Science & Engineering from SATI Vidisha (M.P) India in 2005. After receiving diploma I received my Bachelor Degree (First) in computer science & Engineering from JNCT Bhopal University RGPV Bhopal in 2009 and currently I am pursuing M. Tech from SATI Vidisha (M.P), India in Computer Science & Engineering.

**Mr. Ram Ratan Ahirwal** has received his B.E.(First) degree in Computer Science & Engineering from GEC Bhopal University RGPV Bhopal in 2002. During 2003, August he joined Samrat Ashok Technological Institute Vidisha (M. P.) as a lecturer in computer Science & engg. Dept. and complete his M.Tech Degree (with hons.) as sponsored candidate in CSE from SATI (Engg. College), Vidisha University RGPV Bhopal, (M.P) India in 2009.Currently he is working as assistant professor in CSE dept., SATI Vidisha. He has more than 12 publications in various referred international journal and in international conferences to his credit. His areas of interests are data mining, image processing, computer network, network security and natural language processing.

**Dr. Y. K. Jain**, Head CSE Deptt, SATI (Degree) Engg. College Vidisha, (M.P.), India. He has more than 30-40 publications in various referred International journal and in international conferences to his credit. His areas of interests are image processing, computer network.