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# Medical Image Segmentation Based on Penalized Fuzzy Clustering

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***Abstract— Medical image segmentation plays vital role in providing health care assistant for diagnosis and treatment. Fuzzy clustering is proved superior technique for medical image segmentation over other clustering methods. Fuzzy c-means (FCM) is the most popular fuzzy clustering algorithm used for image segmentation. But FCM has drawbacks of noise sensitivity and huge computational time. This paper presents enhanced fuzzy c-means algorithm with local adaptive thresholding to penalize fuzzy clustering. The aim is to make fuzzy c-means noise efficient and reduces its complexity.***

***Keywords— Image segmentation, Medical images, Clustering, FCM, Penalized fuzzy clustering.***

## I. INTRODUCTION

Medical imaging is the process of creating images of the human body (parts or functions) for clinical purposes such as diagnosis, examining disease, treatment planning or medical science [3]. It is performed in various modalities such as magnetic resonance imaging (MRI), computed topography (CT), ultrasound etc. This paper presents primarily the segmentation techniques for the medical images. In recent years, efforts have been made in computerizing medical image analysis and processing

Segmentation is the key process for the representation, characterization and the visualization of anatomical structures and regions of interest (ROI) in medical imaging [9]. It is the process of partitioning the image into multiple segments to simplify and/or change the representation of an image into something that is more meaningful and easier to understand. Image segmentation is the process of dividing image into distinct regions by grouping together pixels that have similar attributes such as gray levels, color, texture, brightness, contrast etc. Its purposes are the detection, recognition and the measurement of objects in an image. Some application areas include: object identification and recognition, biometrics, criminal investigation, industrial inspection and medical image processing. The increasing influence of the segmentation in medical image processing requires a great need to develop efficient and robust image segmentation algorithm. The basic image segmentation techniques can be divided into four categories [3]:

*Threshold based segmentation:* In this approach the objects and the background is separated based on the image-space region.

*Edge based segmentation:* With this technique, detected edges in an image represent object boundaries and help in detection and segmentation of objects in an image.

*Region based segmentation:* Where an edge based technique may attempt to find the object boundaries and then locate the object itself by filling them in, a region based technique takes the opposite approach, by starting in the middle of an object and then "growing" outward until it meets the object boundaries.

*Clustering techniques:* Clustering is the process of dividing the dataset into classes or clusters so that data elements in the same class are as similar as possible and data elements in the different class are as dissimilar as possible.

In image segmentation, Clustering is regarded as an unsupervised learning task to identify a finite set of clusters to classify pixels by grouping together them on similarity metric such as intensity, distance or connectivity [10]. Based on whether the clusters are crisp or fuzzy, clustering methods can be classified as: hard or crisp clustering and fuzzy or soft clustering. These algorithms are based on objective functions J, which are mathematical criteria that quantify the goodness of cluster. Objective functions serve as cost functions that have to be minimized to obtain optimal cluster solutions [4].

Hard clustering methods are based on the classical set theory, where each data element belongs to exactly one cluster. K-means clustering is the example of hard clustering scheme. It considers that a pixel can belong to a single cluster and also that there exist sharp boundaries between clusters [11].

To overcome these limitations, fuzzy set theory is applied which give rise to fuzzy clustering technique. A fuzzy concept is where the boundaries of application can vary considerably according to context or conditions, instead of being fixed once and for all [4]. Fuzzy sets were proposed by Lofti A.Zadeh in 1965 as: Let X be a space of points, with a generic element of X denoted by x. Thus X={x}. A fuzzy set [A] in X is characterized by a membership function f(x) which associates with each point in X a real number in the interval [0, 1] with the values of f(x) at x representing the grade of membership of x in [A]. Thus, near the value of f(x) to unity, high the grade of membership of x in [A].

In fuzzy clustering, data elements can belong to one or more cluster and associated with each element is a set of membership levels. These membership levels indicate the strength of the association between that data element and a particular cluster [10]. Fuzzy clustering is a process of assigning these membership levels and then using them to assign data elements to one or more clusters. Fuzzy clustering has been widely studied and successfully applied in image segmentation. Fuzzy c-means is the most popular used fuzzy clustering algorithm.

FCM is a method of clustering which allows one piece of data to belong to two or more clusters. This method (developed by Dunn in 1973 and improved by Bezdek in 1981) is frequently used in image segmentation [7]. It is based on minimization of the following objective function:

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} \left\| x_i - c_j \right\|^2$$

where $m$ is any real number greater than 1, $u_{ij}$ is the degree of membership of $x_i$ in the cluster $j$, $x_i$ is the $I$ th of d-dimensional measured data, $c_j$ is the d-dimension center of the cluster, and ||*|| is any norm expressing the are There are huge amount of work proposed to enhance the conventional FCM algorithm. Though many approaches existed, people are still very interested in developing the algorithms that can quickly and correctly segment an image.

## II. REVIEW OF RELATED WORK

Fuzzy c-means (FCM) clustering algorithm is a soft segmentation method which retains more information from input image than hard segmentation methods and provides more flexibility. Various FCM based algorithms for medical image segmentation have been presented in literature. Possibilistic C-Means Means (PCM) is proposed by Krishnapuram and keller in 1993 to add possibility to FCM [12]. Fuzzy-Possibilistic C- Means (FPCM) is proposed by Boudouda in 2005 which combines the objective functions of FCM and PCM [9].

Many algorithms are introduced to make FCM computation fast. Fast FCM is introduced by Yong et al. in 2004 [13] and by Balafar et al. in 2010 [5]. To speed up FCM these methods instead of using pixels used different gray-levels as input. Many researchers proposed algorithms to make FCM noise efficient. Acton and mukherjee in 2000, dave in 1991, Hall et al. in 1992 [6].

FCM does not incorporate spatial information in clustering process. Many researchers introduced spatial information into the FCM process. Tolias and Panas in 1998 proposed spatial constraint rule-based system to enhance the results of FCM [15]. This method spends more time in smoothing. Pham in 2002 introduced modified objective function by incorporating spatial penalty and called it robust FCM (RFCM) [12]. However, modified objective function increases complexity. Zhang and Chen in 2004 proposed spatially constrained kernelized FCM (SKFCM) to modify objective function with kernel-induced distance metric [14]. All these methods that modified objective function leads to computation issues. Also, these methods can not employ FCM functions well-realized in tools like MATLAB. Thus, most of these algorithms need to be improved for more efficient and robust results.

## III. PROPOSED METHODOLOGY

### *A. Traditional FCM algorithm*

Fuzzy c-means (FCM) is the most popularly used fuzzy clustering algorithm for medical image segmentation. FCM was developed by Dunn in 1973 and improved by Bezdek in 1981 based on fuzzy set theory [2]. It is a soft (fuzzy) segmentation method that retains much more information than hard segmentation methods. It provides flexibility through fuzzy classification of pixels where pixels are allowed to belong to multiple clusters with a membership degree between 0 and 1. The algorithm is an iterative optimization that minimizes the objective function. Objective functions serve as cost functions that have to be minimized to obtain optimal cluster solutions that can be defined as follows [7]:

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} \left\| x_i - c_j \right\|^2$$

where *uij* represents the membership of pixel *xi* in the *i*th cluster, *cj* is the *i*th cluster center, is a norm metric, and *m* is a constant. The parameter *m* controls the fuzziness of the resulting partition, and *m*=2 is used in this study. The objective function is minimized when pixels close to the centers of their clusters are assigned high membership values, and low membership values are assigned to pixels with far away from the centers of their clusters. The membership function represents the probability that a pixel belongs to a specific cluster. In the FCM algorithm, the probability is dependent on the distance between the pixel and each individual cluster center. The algorithm is composed of the following steps [9]:

1. *Initialize* $U=[u_{ij}]$ *matrix,* $U^{(0)}$
2. *At k-step:calculate the centers vectors* $C^{(k)}=[c_j]$ *with* $U^{(k)}$

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} \left\| x_i - c_j \right\|^2$$

3. *Update*$U^{(k)}$ *,*$U^{(k+1)}$

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} \left\| x_i - c_j \right\|^2$$

 

4. *If* $|| U^{(k+1)} - U^{(k)} || < \mathcal{E}$
5. *Then STOP; otherwise return to step 2.*

Starting with an initial guess for each cluster center, the FCM converges to a solution for *cj* representing the local minimum point of the objective function. FCM technique is time consuming and noise sensitive. The drawback of the FCM is improved by the enhanced FCM algorithm.

### *B. Enhanced FCM*

The enhanced FCM algorithm is based on the concept of penalizing the traditional algorithm by using local adaptive thresholding to add the spatial information to the algorithm. The algorithm follows the steps of the conventional FCM for the initialization of the cluster centers and assignment of the membership degree to the pixels for each cluster centres according to the membership functions. The step for updation of cluster center and membership function is penalized by using threshold value for comparison. The threshold value taking into account the pixels coordinate values update the cluster center and membership function. Thresholding is the simplest segmentation method. The pixels are partitioned depending on their intensity value.The thresholding algorithm uses the following criteria for the segmentation of the images:

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

It composed of following steps:

1. Initial estimate of *T* depending upon the neighboring pixels coordinate values of each cluster.
2. Segmentation using *T*:
   - *G1*, pixels brighter than *T*;
   - *G2*, pixels darker than (or equal to) *T*.
3. Computation of the average intensities *m1* and *m2* of *G1* and *G2*.
4. New threshold value:
   $Tnew = m1 + m2/2$.
5. If $|T - Tnew| > \_T$, back to step 2, otherwise stop.

In local adaptive thresholding the local properties are used to adapt the thresholding. The local adaptive thresholding uses the following criteria for the selection of the cluster center and membership function:

$$Txy = a\sigma xy + bm\sigma xy$$

$$Txy = a\sigma xy + bmG$$

where *T* is the threshold value that is the function of the *(x, y)* and *T* depends upon the neighborhood of *(x, y)*.The segmentation is operated using a suitable predicate, *Qxy*:

$$g(x, y) = \begin{cases} 1, \text{ if } Qxy \\ 0, \text{ otherwise} \end{cases}$$

where Qxy is:

$f(x, y) > Txy$

$f(x, y) > a\sigma xy$ *and*

$f(x, y) > bm\sigma xy$.

The threshold value thus adds the spatial information to the traditional algorithm to make it noise efficient. The enhanced algorithm does not change the objective function and control the rate of iterations thus does not increase the complexity of the proposed algorithm.

## IV. EXPERIMENTAL RESULTS

In this section, the results of the penalized fuzzy c-means (PFC) algorithm are presented through [figures 1, 2]. The proposed enhanced fuzzy c-mean algorithm is implemented using MATLAB and tested on medical images to explore the segmentation accuracy of the proposed approach. The proposed approach of medical image segmentation using enhanced fuzzy c-means algorithm reduces the effect of noise and increased the segmentation accuracy of the proposed medical image segmentation technique by reducing the complexity.

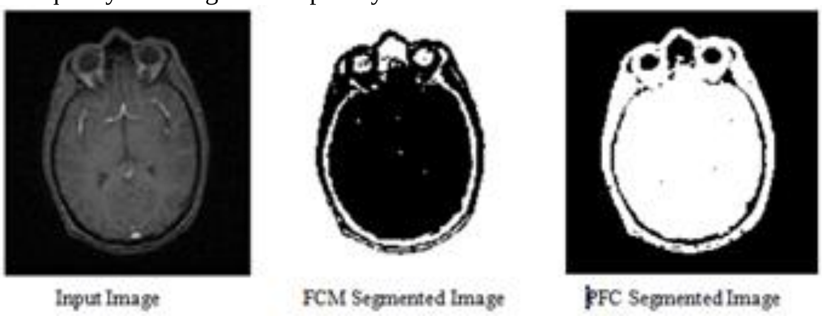


Fig. 1 Result of segmentation for the proposed work on medical image.


Fig. 2 Result of segmentation for the proposed work on medical image.

## V. CONCLUSION

Medical image segmentation has a promising future as the universal segmentation algorithm and has become the focus of contemporary research. Image segmentation depends upon nature of the application. Thus, medical image segmentation is a challenging task in image processing and still a pending problem in the literature. FCM clustering algorithm is the commonly used segmentation method in medical image segmentation. FCM technique is time consuming and noise sensitive. The drawback of the FCM is improved by the enhanced FCM algorithm. The enhanced FCM algorithm is based on the concept of penalizing the traditional algorithm by using local adaptive thresholding to add the spatial information to the algorithm.

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