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Fuzzy C- Means Clustering Based Segmentation of Vertebrae in T1-Weighted Spinal MR Images

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Abstract:The spinal cord is anorgan that is the sole communication link between the brain and also the numerous components of the body. It is susceptible totraumatic spinal cord injury and numerous diseases such as tumors, infections, inflammatory diseases and chronic diseases. The exact segmentation and localization of the spinal cord are essential to effective clinical management of such conditions. In recent years, because of the advances in imaging technology, the structure of internal organs and tissues can be capturedaccurately, and various abnormalities are diagnosed based on scanned images. This paper presents fuzzy clustering based approach for segmentation of vertebrae in T1- Weighted spinal MR Images. The objective of this paper is to segment spinal MR image using Fuzzy C-Means clustering algorithm. Implementation of the algorithm is done on both kinds of images – noiseless and corrupted with noise. Gaussian noise is introduced and the image consists of two clusters.

Keys: Segmentation, Fuzzy C- Means, Morphology, MR images.

I. INTRODUCTION

In Computer Vision, image segmentation plays a very important role in the exploration of an image. Image segmentation is having a wide variety of applications such as medical segmentation, object recognition etc. Image segmentation helps in separating an image to numerous parts. A portion of an image which is having a same set of datasets would form a group and another dataset belonging to dissimilar group. The grouping of the similar dataset can help us to extract different regions
of texture, intensity, color etc. This technique of image partitioning into groups (clusters) having similar datasets is considered as Clustering. Image segmentation can be divided basically in four types: region extraction, clustering, edge detection, thresholding. There are many clustering algorithms having their own unique features. They can be categorized basically in two groups: "Hard" clustering algorithm or "Soft" clustering algorithm. K-mean clustering, is a 'hard' clustering algorithm. In this algorithm, every dataset of an image has its place to one cluster only. Hard segmentation becomes a difficult task in the situations where images are having poor contrast, noise, overlying intensities etc. The most widespread method of soft clustering is Fuzzy C-means (FCM) algorithm which is widely used in image segmentation because of its strong features which give more data information than the hard-segmenting methods. In FCM, task of membership function is linked with each element of data set and these elements can fit to more than one cluster. Membership function gives the possibility that pixel belongs to a certain cluster. This possibility depends on the distance amongst individual cluster center and the pixel. When a new locality of new cluster is restructured degree of membership shows how each pattern contribute in adjusting the new location of cluster center. Low membership values are allotted to minimize the cost function for FCM. FCM uses the Euclidean distance measurement technique to measure the distance between cluster center and data elements. Although FCM algorithm works fine, it has some limits. This algorithm is not succeeded to segment corrupted images owed to noise, outliers. In [1] FCM failed to outline some region of interest of several images as well as in the complex topologies like spinous process and transverse process it failed to give the quality results when segmented.

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II. METHODOLOGY

The proposed method is shown in figure 1. Proposed algorithm consists of preprocessing as a first stage.

Preprocessing:
Denoising, unwanted artifacts removal is the work of preprocessing stage. Denoising can be done by using adaptive median filter and unwanted artifacts can be removed by using some morphological processing [3].

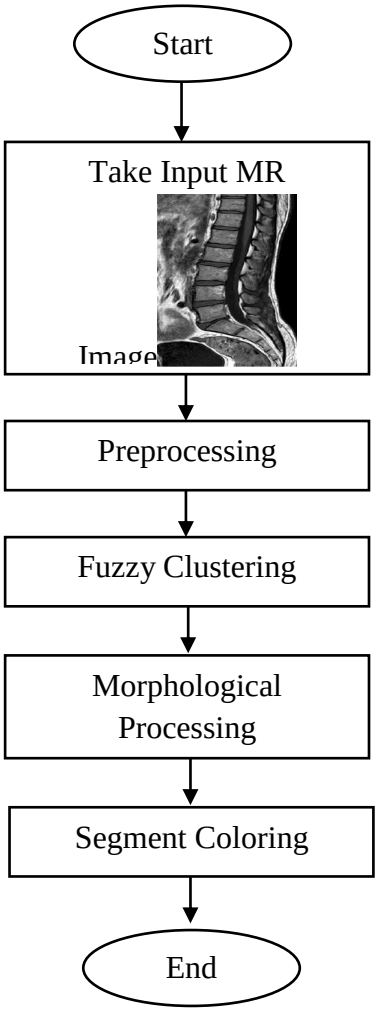

Fig 1. Proposed algorithm

Preprocessing also works as an enhancer.

Fuzzy C – Means Clustering:
FCM widely used for segmentation. Fuzzy c-means (FCM) is a process of clustering that permits one piece of information to belong to two or more clusters. The clustering of a dataset can be obtained by minimizing anobjective function J for a known number of clusters [2]:

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$$J = \sum_{i=1}^{N} \sum_{j=1}^{M} u_{ij}^{k} \left\| x_i - v_j \right\|^2 \quad whr\ 1 \le k < \infty \qquad \ldots. (1)$$

Where, k is any real number known as the weighting factor, u_{ij}^{k} is degree of membership of x_i in the cluster j. x_i is the ith P – Dimensional measured intensity data. v_j is the P – dimensional center of the jth cluster.

$$u_{ij} = \frac{1}{\sum_{l=1}^{M} \left\| \left(\frac{x_i - v_j}{x_i - v_l} \right) \right\|^{\frac{2}{(k-1)}}} \qquad \ldots. (2)$$

$$v_j = \frac{\sum_{i=1}^{N} u_{ij}^{k} x_i}{\sum_{i=1}^{N} u_{ij}^{k}} \qquad \ldots. (3)$$

Morphological Processing:
Morphology is a collection of non-linear operations related to the shape or morphology of features in an image. Morphological operations depend only on the relative order of pixel values, not on their numerical values, and thus are particularly suited to the process of binary images. Morphological operations may also be useful to greyscale images such that their light transfer functions are unfamiliar andso their complete pixel values are of no or minor interest. Morphological techniques probe afigure with a small form or pattern called a structuring element. The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of pixels. Mainly opening and closing used to remove unwanted part after segmentation. Opening is so called because it can open up a gap between objects connected by a thin bridge of pixels [4].

$$f \circ s = (f \ominus s) \oplus s \qquad \ldots. (4)$$

Closing is so called because it can fill holes in the regions while keeping the initial region sizes [4].

$$f \bullet s = (f \oplus s_{rot}) \ominus s_{rot} \ldots. (5)$$

Segment Coloring:
Segmented part is then colored using some standard functions in MATALB.

III. RESULTS AND DISCUSSION

The results are taken for sagittal cross section of T1-weighted MR images of spine. MR Image is taken for segmentation, preprocessing is the first stage using 3*3 adaptive median filter noise is removed. Unwanted artifacts are removed using morphological operation like opening and closing.

(a)

(b)

(c)

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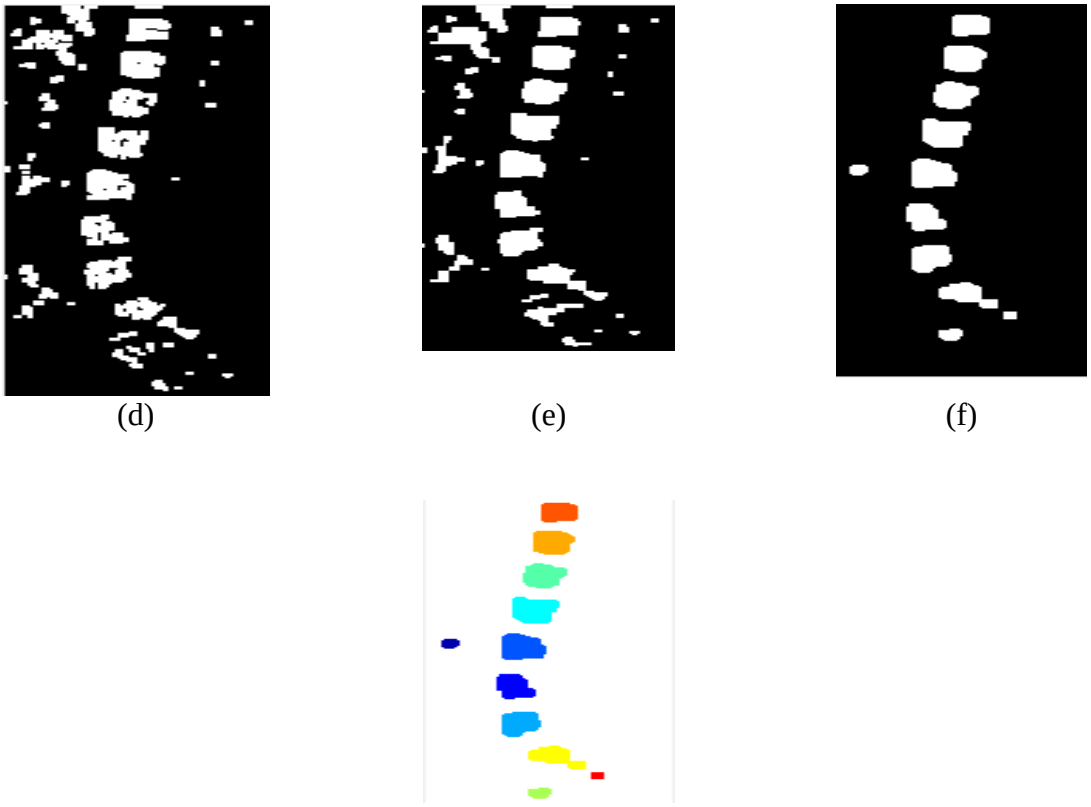

(d) (e) (f)

(g)

Figure 2. (a) Original MR image (b) Clustering (c) Thresholding (d) Opening e) Closing (f) Segmented Image (g) Color Code

5. Quality Parameters:

The following quality parameters are used for evaluation of this algorithm.

Mean: the mean pixel value of the image can be calculated using this measuring parameter.

$$Mean = \frac{1}{rc}\sum_{i=1}^{r}\sum_{j=1}^{c} x(i,j) \quad \ldots. (5)$$

Standard Deviation: It is a most commonly used measure of inconsistency or diversity used in statistics. In terms of image processing it shows how much variation or "dispersion" exists from the average (mean, or expected value). Standard deviation with low value indicates that the data pointtends to be very close to the mean, whereas high standard deviation indicates that the data points are spread out over a large range of values.

$$\sigma^2 = \frac{1}{N-1}\sum_{i=0}^{N-1}(x_i - \mu)^2 \ldots. (6)$$

The table of Mean, Standard Deviation and total time elapsed for Spine MR Image is given below

Table: Output parameters

Sr. No	Mean	Standard Deviation	Time Elapsed
1	0.8697	0.02817	10.25 sec

Graphical User Interface:

Algorithm is implemented with the MATLAB and graphical user interface of the same is as shown below. To run this code any version above MATLAB 7.8 is required.

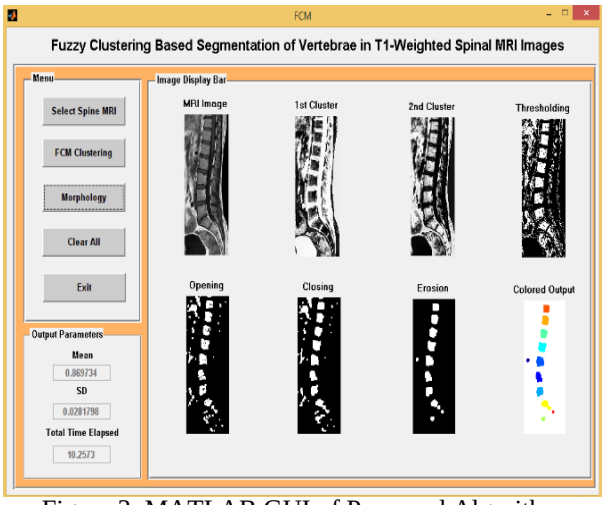

Figure 3. MATLAB GUI of Proposed Algorithm

IV. CONCLUSION

In this paper FCM clustering is proposed and tested over various spine MR Images. Paper included clustering followed by morphological operations. It is observed that FCM gives much more information than other hard segmentation methods and has robust characteristics for ambiguity.FCM algorithm worked well on noise free image of vertebrae in T1- Weighted spinal MR Image. Time complexity of this method is also presented.

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