

Intuitionistic Fuzzy Clustering Based Segmentation of Spine MR Images

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Abstract - In medical field segmentation of image is very difficult because of poor resolution and limited contrast. Traditional segmentation techniques and thresholding methods which are commonly used suffers from drawbacks due to heavy dependence on user interaction. These techniques cannot show the uncertainties present in an image. The degradation of results takes place when the images are effected by noise, outliers and artifacts. The main motive is to overcome the drawbacks of traditional Fuzzy C Mean, the objective functions of traditional Fuzzy C Mean approaches has been modified and the spatial information has been introduced in the objective function of the traditional Fuzzy C Means. An automated technique has been proposed to regulate the initial values of the centroid of the cluster using intuitionistic fuzzy clustering. A new complement function of intuitionistic Fuzzy Clustering is mentioned for intuitionistic fuzzy image representation which takes the inhomogeneity of intensity and spine Magnetic Resonance image noise into consideration. The evaluation of which is done using Dice Coefficient, Jaccard coefficient, Recall and Precision.

Key Words: Intuitionistic fuzzy clustering, labelling, MRI, Pre-processing, Vertebra segmentation.

1. INTRODUCTION

The basic building block of image analysis tool kit is the image segmentation. Image segmentation in medical field is tedious as the images are mostly affected by the noise. Automation of the segmentation process of medical images is a difficult task which is complex and does not contain any of the simple linear characteristics features. Moreover the results obtained by segmentation algorithm is severely affected by the inhomogeneity of the intensity and the volume effect especially when the MRI (magnetic resonance images) is considered. Most complex bony structure in entire human body is spine which bears the load of entire body and consists of 26 irregular bones which are connected so as to provide a curved and flexible structure. The backbone or the vertebral column has 5 major divisions and is 70cm long. The first 7 vertebrae which is present in the neck make the cervical vertebrae, the next 12 form the thoracic vertebrae and the lumbar vertebrae are 5 in number and are the one supporting the lower back. Sacrum is portion inferior to the lumbar which articulates with hipbones of the pelvis. The termination of entire vertebral column is done by the tiny coccyx. The extension of spine is done by the help of

intervertebral disc whose function is that of a shock absorber. These discs are thickest in the cervical and lumbar region making these regions more flexible. Due to wear and tear with age degeneration of disc is a common phenomenon which results in back pain. Few types of disc wear tear are Herniate disc, degenerated disc and spinal stenosis. The spine Magnetic Resonance imaging is identified by T1 and T2 weighted images. The water contents appears bright in T2 weighted image (in medical terms its hyper Intense which can be clearly seen in the spinal canal) and vice versa (i.e. hypo Intense) in that of T1 weighted images.

The signs degeneration of bone marrow can be clearly detected by a MR with high spatial resolution where water protons and fat are found in abundance. Even though degenerative changes occurring in the spine which are imaged using a radiological equipment are biological phenomena, certain irrelevant processes are also captured. These are the artifacts which are produced by the intensity inhomogeneity. The process of segmentation is highly affected by the MR image complexities. As a result of which accurate diagnosis remains a challenge without manual interference in segmenting the vertebral features. Diagnosis using a computer therefore requires a Robust automated segmentation of vertebrae from MR images.

There are many automated segmentation techniques among which clustering techniques are more predominantly used. Clustering techniques are classified into two types first one is hard clustering i.e. k means and second one is soft clustering i.e. Fuzzy C-Means Clustering. Various segmentation techniques of MR image of vertebrae using fuzzy c mean (FCM) clustering are used to identify and label the individual vertebral structures. But FCM clustering fails to deal with local spatial property of images which results in strong noise sensibility. As it's considered that the uncertainty and unknown noise are always included in medical images, this leads to degradation in segmentation quality generally. [1]

The approaches of Intuitionistic fuzzy set (IFS) is also used for segmentation of image. IFS takes non- membership and hesitancy values into account along with membership value and these sets serve useful to deal with uncertainty and vagueness in the image pixel intensities .FCM based clustering methods are mostly dependent on selection of parameter, noise sensitivity and their convergence mainly depends on cluster centroid initialization . Due to the

limitations there can be stucking of the algorithm in a local optimum which in turn reduces the accuracy of segmentation. In this work, an intuitionistic fuzzy clustering (IFC) algorithm (which is rough set based) is proposed for the segmentation of spine MR images. The main contributions of present work is: To achieve best possible result than the existing system by applying Intuitionistic Fuzzy C Mean algorithm and help the medical specialists to diagnose deformities.

The work in this paper is divided in two parts. 1) Pre-processing 2) Segmentation and post-processing. Pre-processing is done by applying filters i.e. anisotropic diffusion filter which helps to remove the acquisition noise which is present in MRI image. Thereafter, the segmentation is been done using intuitionistic Fuzzy C Means clustering algorithm on the pre-processed mages followed by morphological processing of erosion and dilation. Then, components are labelled and a coloured vertebrae is got. The paper organisation is as follows. Section 2 shows the previous work done in this field. The steps of the algorithm and the flow diagram is described in section 3 and section 4 presents experimental results showing results of tested mages. Finally, Section 5 shows the conclusion part.

2. RELATED WORK

Global thresholding, thresholding at multilevel and supervised techniques of clustering are the commonly used segmentation methods. The intensity level is resolved from the grey scale image histogram in intensity thresholding. In medical images the intensity distributions are random especially in MRI images which results in failure of global thresholding methods due to absence of resolving the optimal threshold. Disadvantage of spatial uncertainty takes place in intensity thresholding methods as the information of pixel location is overseen [3]. For identifying the contour boundaries of the ROI, an edge detection technique can be implemented. The probability of these lines being continues is minimum. And these methods usually need expensive post processing to obtain objects without any holes.

Segmentation of MRI vertebral body using a graph based approach is proposed in [4]. A Nystrom approximation is used here to decrease the processing speed of Ncut (normalized cut) method. Above methods maximize the dissimilarity between two subsets and similarity within a subset in an image. This problem as proposed by Malik and Shi, minimizes to solve the generalized Eigen vector which requires a diagonal matrix and a weighted matrix that is initiated using the feature image strength. Nystrom approximation simplifies the computationally intensive calculation of the Eigen vectors which uses few random samples to calculate the diagonal matrix and the solution is extended to the complete set. Here anisotropic diffusion is used for the pre-processing which gives a coil corrected output. A semiautomatic classification of spine disorders disc

degeneration, spinal stenosis and disc herniation is given in [5]. The authors have represented MRI response in T2 weighted images for classification of disc degeneration. The level of degeneration s denoted by reduction in mean intensity and Pfirmann scale is used to classify it. Segmentation of disc is done using gradient vector flow (GVF) on an image after pre-processing which is followed by skeletonization. The length is marked by drawing a vertical axis from the mid-point. The abnormalities in disc is classified by changes in intensity and length. About 90% of herniation [6] happen in Lumbar region, which leads to the processing of discs located in the lumbosacral area. Evaluation for disc herniation, is done by extracting the contour from the axial slice. The herniated discs can be either classified as focal based (extrusion) or broad based (protrusion). An automatic segmentation method (quasi) for intervertebral disc (IVD) is given in [7].

The only involvement for selection of initial point is to be deformed by snakes for evolving an elliptical contours. FCM is used for further refinement of the ROI (Region of interest). An equation is evolved using a new energy term called geometric energy, which is included with active contour that shapes the disc and controls it to a certain limit. In this case, since IVD appears to have an elliptical structure, so evolution of contour is reduced when it goes beyond the mentioned shape. Here the Adaboost classifier is used for classification of discs and the root of mean square error (RMSE) and Dice similarity coefficient is used for performing validation between the segmented disc and the ground truth. The thresholding is extended by region growing methods by integrating it with the connectivity by an intensity similarity measure. An initial origin position is assumed in these methods and the intensity column is expanded using connected neighborhood, over the neighboring region.

However, these are highly affected by the initial origin points and noise. Among all others FCM algorithm is found out to be more effective and efficient with significant benefits for classification-based segmentation method [8]. FCM algorithm allows pixels dependencies with different membership degrees with multiple clusters, unlike the hard clustering methods, like K-means algorithm, that exclusively assign pixels to only one cluster and is found out to be more worthy in real applications. Introduction of non-membership is done along with its values in segmentation of MR images of brain using intuitionistic fuzzy clustering (IFC) [9] along with that of membership (MF). The degree of hesitation for each pixel is a significant part in heuristic based segmentation. Several general grey scale images are presented in [10] where the merging of membership functions takes place using IFC, to show the uncertainty in selecting the best MF. Detection of Modic changes (MC) can remarkably present the lesion detection on the bone marrow. Disc herniation [2] can also be associated with it. It is seen that higher the severity of Modic changes, higher is the level of herniation. The burden of manual differentiation

of Modic Changes levels for a radiologist can be decreased by automating the process of classification and detection. It also provides an accurate percentage of degeneration based on intensity change in signal contrasts to the normal level. Though there are articles on MR segmentation of vertebral bodies [11][12][13], due to the complexities involved in delineating VB's, the paper focuses on utilizing the intuitionistic fuzzy concept for perfectly isolating them. The paper focuses on implementation of IFC based method for segmentation of vertebrae with further post-processing. The vertebrae are also labelled to reduce the burden of radiologists to classify the degenerations involved.

3. SYSTEM ARCHITECTURE

The proposed system is schematically shown in figure 1. The MR Spine images of patients have been collected. Total 14 MRI images of spine is been used with a dimension of 512 x 512 from Samarth diagnostics centre. The T1 weighted images, are used as the initial dataset for the proposed algorithm. Firstly, the image is smoothed using the edge preserving anisotropic diffusion filter. The MRI images are prone to various types of noise among which acquisition noise is common, to remove this noise anisotropic diffusion filter has been used. This pre-processing serves both the purpose of removing inhomogeneity and as contrast enhancer as well. After pre-processing the pre-processed images are segmented using Intuitionistic Fuzzy clustering algorithm followed by some of the morphological operations which are executed for extracting the vertebral bodies (VB) from the clustered output. The hole filling is the preliminary step followed by removing islands using an erosion. Finally the vertebrae are got which are completely devoid of inter-vertebral discs in between them and other muscles present near the vertebrae. After which the colour code is been obtained by using an area metric for labelling of the vertebrae.

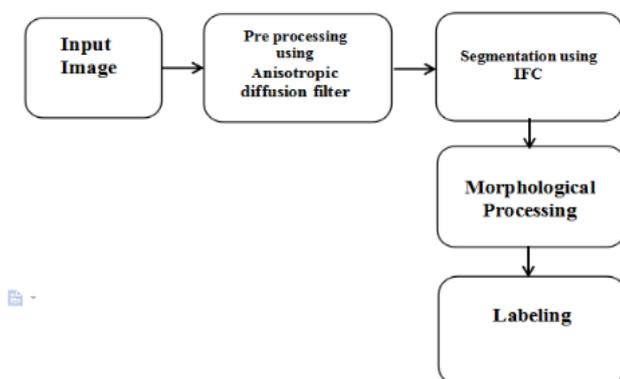


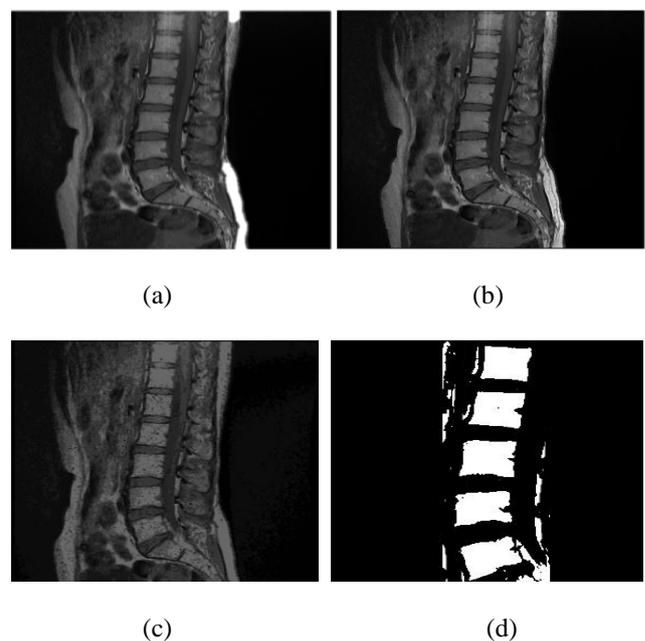
Fig 1. : System Architecture Diagram

In the existing system after pre-processing segmentation is done by using Fuzzy C Mean clustering. Fuzzy C Mean Clustering (FCM) is the most successful algorithm for data clustering but the main drawback of FCM for segmentation

of image is that its objective function does not take into consideration any spatial dependence among pixels of image. Secondly, the membership function of FCM is mostly decided by the Euclidean distance which measures the pixel intensity similarity and the center of the cluster. Closer intensity values to the cluster center is defined by the higher membership. Hence the sensitivity to noise of a membership function is high. In MR image with noise and intensity inhomogeneity, the performance of FCM methods decreases and results in improper segmentation. To overcome these issues we have used Euclidean distance based on intuitionistic fuzzy set, using this intuitionistic fuzzy distance measure, partition matrix and cluster centroid are updated. While updating membership, membership function, non-membership and hesitation of pixel value are considered which results into compensation for the inhomogeneity in the intensity and noise in spine MR images and results in more appropriate tissue segmentation. This provide us better results when compared with the existing system.

4. EXPERIMENTAL RESULTS

Figures shows the results of pre-processing of the sagittal view of the Spine MRI image and segmentation using Intuitionistic Fuzzy C Mean Clustering algorithm. Figs. 2 (a) shows the original MRI Spine image. (b) is the image obtained by applying Pre-processing. Image shown in fig 2 (c) is the image obtained by Fuzzy C Means algorithm (d) is the lumbar portion of the spine vertebra obtained after morphological processing (e) is the image of lumbar portion of the vertebrae obtained by applying Intuitionistic Fuzzy C Mean Clustering algorithm. Graphical representation of the result of image P9 of Dice coefficient, Jaccard Coefficient, Precision and Recall is shown in fig 3(a),(b) and (c) respectively. The results of the proposed system is found to be more efficient than the existing system.



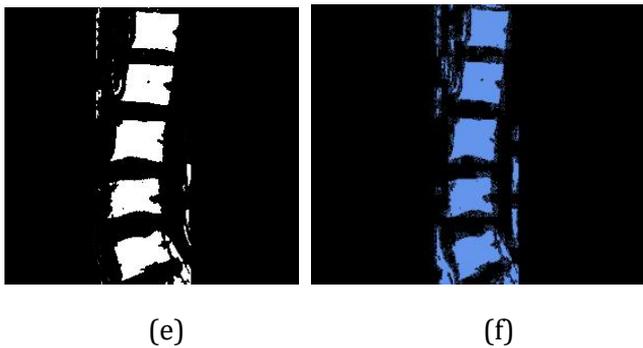


Fig. 2. Pre-processing and segmentation of P9 (a) Original image (b) Image after applying pre-processing (c) Image after applying FCM clustering (d) Image of vertebrae after applying FCM (e) Image of vertebrae after applying IFC (f) Coloured vertebrae or labelled vertebrae.

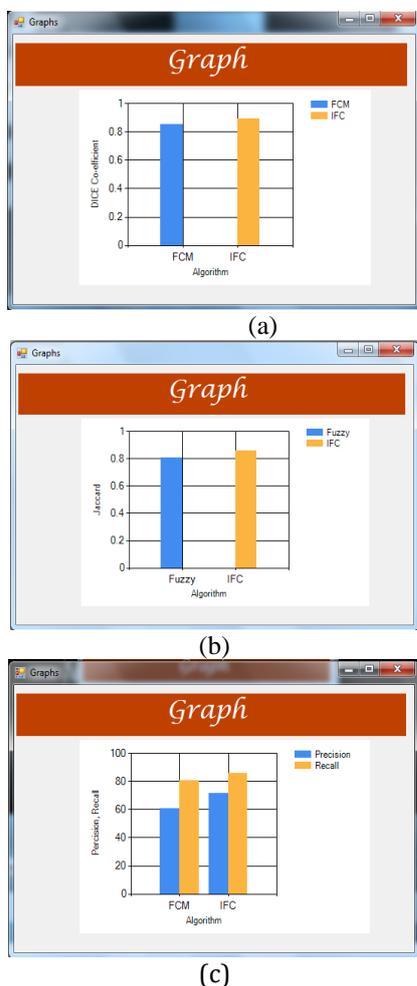


Fig. 3. Graphical representation of P9 (a) Dice Coefficient (b) Jaccard coefficient (c) Precision and Recall

In the proposed system we have used the dataset of a clinical centre named Samarth diagnostic centre for Image segmentation and since the existing system and the proposed system both deals finding out the deformities in

the lumbar part of spine so the modality that is been chosen is Magnetic Resonance Imaging or MRI. T1 weighted MRI images are considered as the best images to find out diseases related to bones. The results of both the existing system and proposed system are been compared by using Dice Coefficients, Jaccard Coefficient, Recall and Precision as metrics for evaluation. The results of which are been shown below in table 1.

Table -1: Comparative Results of FCM and IFC

Image	Comparative Results for IFC and FCM							
	Dice Coefficient		Jaccard Coefficient		Recall		Precision	
	FCM	IFC	FCM	IFC	FCM	IFC	FCM	IFC
T1_sag_P 1	0.91	0.95	0.91	0.93	90.9	93.1	55.6	63.4
T1_sag_P 2	0.81	0.85	0.71	0.77	70.8	77.4	71.8	88.1
T1_sag_P 3	0.86	0.90	0.81	0.85	81.2	85.4	60.0	71.8
T1_sag_P 4	0.86	0.92	0.83	0.87	82.8	86.7	59.9	68.2
T1_sag_P 5	0.75	0.82	0.63	0.75	63.1	75.1	62.6	70.1
T1_sag_P 6	0.85	0.89	0.76	0.81	76.3	80.7	65.7	73.2
T1_sag_P 7	0.84	0.87	0.74	0.79	73.8	79.0	61.4	74.6
T1_sag_P 8	0.84	0.90	0.78	0.82	78.0	81.7	57.8	63.4
T1_sag_P 9	0.85	0.89	0.81	0.86	80.5	85.8	60.6	71.3
T1_sag_P 10	0.68	0.71	0.51	0.70	51.0	69.6	58.1	66.5
T1_sag_P 11	0.81	0.82	0.63	0.78	63.2	77.7	80.2	87.7
T1_sag_P 12	0.63	0.69	0.46	0.66	46.0	65.5	70.5	77.7
T1_sag_P 13	0.87	0.92	0.78	0.80	78.4	80.0	57.2	62.5
T1_sag_P 14	0.71	0.79	0.53	0.77	53.0	77.2	59.1	68.8

5. CONCLUSIONS

In this paper an IFC algorithm followed by morphological operations and labeling has been presented for segmentation of vertebra from spine MR images, which is compared to the simple FCM clustering. The study includes a dataset of 14 patients of age 29 to 65 of T1-weighted MR images of spine. It is seen that the proposed system proved to be more efficient than the existing system and provides improved segmentation results as compared to the existing system.

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