3D segmentation in medical images

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Abstract—Medical imaging modalities like CT, MRI provide good image of bones, hard tissue, soft tissues and tumors etc. Researcher will process and analyze these images to extract meaningful information like shape, growth of tumor, motion of organs and any kind of abnormalities in the patient body. This paper presents thresholding and clustering techniques like k-means and FCM with three dimension visualization by using volume rendering method. Experiments on Sheep-Logan phantom data sets are conducted to demonstrate the effectiveness of segmentation methods with performance measure.

Keywords—Medical Imaging; CT, MRI, PET

I. INTRODUCTION

Image segmentation technique has been applied in various types of images such as medical image, satellite image, topographic image, color or gray scale image, natural images. Image segmentation technique is capable of partitioning an image into homogeneous region of interest based on their features such as intensity, shape, color, texture and contrast.

In medical imaging modalities, segmentation techniques can be used for diagnosing a tumor or any abnormalities inside patient body from CT scan, MRI scan or PET scan. There is various segmentation techniques has been proposed in the last decades. These techniques can be broadly classified into five categories like thresholding, region growing method, clustering method, deformable surfaces and level-set methods and graph-cut method. From these categories histogram based thresholding is a very popular technique due to its simplicity and efficiency. In the Literature Sezgin discuss about 40 different thresholding algorithm which classified into six groups according to the exploited information. They mainly classified into clustering, histogram shape based, entropy based, object attribute based method, spatial and local method. Lloyd [1], uses clustering method by using Gaussian density function to calculate the optimum threshold. Otsu[2] calculates threshold by maximizes the between-class variance of foreground and background pixels. Ridler and caluvard[3] also use Gaussian distribution of gray level of the image with iterative scheme to calculate optimum threshold value. Ramesh[4], apply histogram shape based method to calculate the optimal threshold by using error function which defined as the sum of squares between each possible bilevel function and the original gray-level histogram. Kapur[4] use Shannon entropy for image foreground and background as a measure of the uncertainty of pixel distribution in entropy based method. Sahoo[1] combine the result of three threshold from different definition of entropy like Shannon and Renyi entropies of order $\rho=2$ and $\rho=1/2$.

There have been many works have been done in the clustering methods. This method used to classify the pixels of an image correctly in a decision oriented application. One of the simple and most used clustering algorithms is k-means clustering. There are many methods implemented so far with in k-means to initialize the centre. Allan Jose, S Ravi and M. Sambath proposed brain tumor segmentation using k-means clustering with FCM clustering for area calculation[6]. In the clustering category, fuzzy c-means (FCM) clustering is also most popular for medical image segmentation. Wells et a1 reported a new segmentation method called adaptive segmentation **[9].** Traditional FCM was employed for brain segmentation by Li et a1 [8]. Despite the discussion of various thresholding techniques, this article uses above traditional segmentation techniques and it also applies volume rendering method for 3-D visualization.

The rest of the paper is structured as follows: section II describes thresholding techniques; in section III, clustering techniques like k_means and fuzzy c-means, section IV experimental results and analysis and finally conclusions are drawn in section V.

II. THRESHOLDING

In this paper, we use 3D volume image like Sheep-Logan Phantom dataset for thresholding. The thresholding process divides pixel of the image into two classes like foreground and background in binary image. Generally, threshold T is a function of the form T=T[x,y , f(x,y),g(x,y)], where f(x,y) is the gray intensity level of point positioned at (x,y), and g(x,y) denotes some local properties of this point. There are various large number of gray-level based segmentation methods either global or local thresholding method. Here some global thresholding methods like OTSU, ISO-DATA are implemented in Sheep-Logan phantom dataset.

2.1 Otsu

This method is widely used in the literature[2], it analyze the distribution of gray value of an image histogram. It selects value of Θ to choose minimum value of two peaks of the histogram Otsu defines this choice of Θ as the minimizing the value of weighted sum of within-class variance and maximizing the inter-class scatter. The result by using this method is stable and advantage is it is robust to noise and it holds for both bi-level and multi-level thresholding cases. For an image taking on discrete pixel(2 D image) values k, the optimal threshold value Θ is

$$\theta otsu = argmax\theta \{\sum_{k<\theta} p(k)(\mu 0 - \mu)^2 + \sum_{k \gg \theta} p(k)\ (\mu 1 - \mu)^2\} \quad (1)$$

Where p : normalized histogram
μ : Mean { f(x)}
μ_1 : Mean { f(x) | f(x) >= Θ }
μ_0 : Mean { f(x) | f(x) < Θ }
In case of 256 gray values, threshold T can be determined by calculating the term for each gray value and selects the global minimum, while in the discrete case, it can be entirely evaluated from the histogram by summing over the appropriate value range. This method is proven to be a robust tool for threshold selection in many cases.

2.2 Isodata Method

This is an automatic thresholding selection method which is the iterative isodata method. This method is initially proposed by Ridler and Calvard[3] for object-background discrimination, which is actually an application of the more general isodata clustering algorithm to the gray values of an image. In an image, the distribution of gray levels is given by histogram h, where h(0), h(1), …h(L) are the numbers of points with gray levels 0,1,…..L. Let [LO,UP] be the smallest interval containing all non-zero histogram values. Algorithm with mathematical equation is described as follows:

1. Select some initial values for the mean values such that LO<= < < …..<
2. Loop : Calculate thresholds $T_1, T_2, \ldots T_{c-1}$ by the formula : T_i = (+) / 2 ; Assign to class i, all gray levels in the interval Ii = [Ti-1 +1 , Ti] ; where, T0= LO -1 and Tc= UP,
3. Recompute the means : for every i make the nearest gray level to ($\sum_{j \in I_i} j * h(j)) / \sum_{j \in I_i} h(j))$) , 1 ;
4. If any mean has changed value , go to Loop otherwise , stop the algorithm

In this method foreground and background methods can be characterized by different means and . This method is widely used in medical application.

III. CLUSTERING TECHNIQUES[14]

Clustering is an approach in which pixels are grouped to form a cluster, which is closest among all clusters. A cluster is a collection of objects which are "similar" between them and are "dissimilar" to the objects belonging to other clusters. Pixels having homogenous characteristics belong to the same cluster and pixels must follow the homogeneity criteria in the same cluster. Clustering provides us an exact and subtle analysis tool from the mathematic view. Clustering techniques provide better results for exact shapes, range and area of tumors or any sort of abnormal growth. The segmentation techniques used in this paper are discussed below.

3.1 K-Means Clustering[11]

K-Means clustering is a type of hard clustering algorithm. It belongs to unsupervised cluster analysis algorithm and achieves partitioned clustering method. It is a key technique in pixel-based methods. By using pixel based K-means clustering, approach is simple and also the computational complexity is relatively low compared with other segmentation methods like region-based or edge-based Algorithm with mathematical equation is described as follows:

1. Initialization of no. of clusters with value as k.
2. Select k cluster center randomly
3. Compute mean M or center of the cluster by eq(2)

$$M = \frac{\sum_{i.c(i)=k}}{N_k} \text{ k= 1,2,……, k} \quad (2)$$

4. Calculate the distance between each pixel to each cluster center

$$D(i) = \arg\min \|x_i - M_k\| \text{ , i= 1,2,……, k 1,2..N} \quad (3)$$

5. If the distance is close to to the center then move to that cluster else move to other cluster.

6. Calculate or Re-estimate the center.
7. Repeat the steps until the center doesn't move.

This algorithm minimizes the total distance of data points to the cluster center, of the cluster they are assigned to. K-means has the advantage of being faster and easier to implement, but the no. of clusters need to be predefined.
The quality of the final clustering results depends on random selection of initial center. Because of random selection of center it may give unexpected results. In this technique, if we carefully chosen initial center value then we obtain our desire segmentation results [10].

3.2 Fuzzy C-Means Clustering
Fuzzy C-Means is a method of clustering which allows one pixel to belong to two or more clusters. It is a soft clustering technique and unsupervised clustering algorithm that has been applied to a wide range of problems involving feature analysis[9], clustering and classifier design. Fuzzy logic is a form of probabilistic logic which contains only approximate values. The fuzzy logic is a way to process the data by giving a partial membership value to each pixel in the image. A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) and it lies between 0 and 1 for fuzzy sets. The sum of all membership degrees for any given data point is equal to 1. The membership function defines the fuzziness of an image and also to define the information contained in the image. There are three main basic features involved in this concept characterized by membership function. They are support, boundary and the core. The core is a full member of the fuzzy set. The support is non-membership value of the set and boundary is the intermediate or partial membership with value between 0 and 1 [12]. Mathematical step along with algorithm is described as follows:

1.) Initialize U = [u_{ij}] matrix, $U^{(0)}$

2.) At iteration, calculate center vectors $C^{(k)} =$ with ι

$$= \frac{\sum_{i=1}^{N} uij.^{m}}{\sum_{i=1}^{N} u_i^{n}} \tag{4}$$

3.) Update the membership matrix u for the step and.

$$u_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{||x_i - c_j||}{||x_i - c_k||}\right)} \tag{5}$$

4.) If $\|U^{k+1} - U^{k}\| <$ then STOP, otherwise return to step 2.[2]

Here, δ is a termination criterion between 0 and 1.
Fuzzy C-means (FCM) algorithm is proved to be superior over the other clustering approaches in terms of segmentation efficiency. But the major drawback of the FCM algorithm is the huge computational time required for convergence.

IV. EXPERIMENT RESULT

As we apply above thresholding and clustering techniques[12][13] on Sheep logan 3D phantom dataset[5]. To represent the medical modalities like CT,MRI ,PET we can use 3D sheep logan matrix and test our algorithm. In above mentioned medical image modalities , no. of slices are vary as per the thickness given by the operator by the guidance of radiologist. Here we took 128 slices for Sheep Logan Phantom dataset. In this dataset we explicitly insert tumor which can be one of the research area like tumor detection from medial image where this segmentation techniques can be used. We experiment by adding different types of noise [15] like salt and pepper, Gaussian, poisson noise and speckle noise to compare the efficiency of different segmentation techniques.
In below Table I, after adding above mentioned noise in sheep logan phantom dataset, we use average ray casting method[16] to visualize 3D phantom dataset and first hit ray casting method for tumor detection by implementing different segmentation techniques. Here viewing angle we had given $\alpha = 50$. $\beta=40$ and $\gamma=10$. This technique helps doctor to know growth of tumor. We can view from any point to see tumor and its depth also.

V. PERFORMANCE EVALUATION

To evaluate performance two measures such as peak signal to noise ratio and mean square error are used. The comparison of techniques using these measures is shown in Table 2.

VI CONCLUSION

In this research, various segmentation techniques applied on Sheep Logan phantom data set which is 3 D matrix for tumor detection where tumor is explicitly inserted in it. The results which are mentioned in Table II, shows that otsu thresholding technique gives better result compare to other clustering techniques. When we increase the noise

parameter like density in Salt and Pepper noise and mean(M), variance(V) in case of Gaussian noise the PSNR decreases and MSE closer to 1, While in the case of Poisson and speckle noise, algorithm gives better result in terms of performance measures . Here 3D visualization will help doctor to view the growth of tumor very well.
In future work, we can use various soft computing techniques to decrease error and improve the result. We can also apply same technique to MRI,CT or PET dataset.

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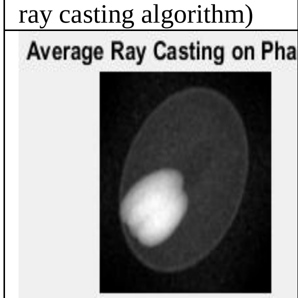
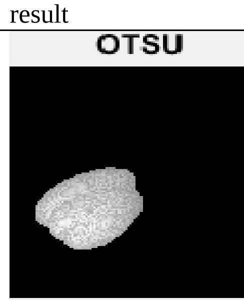
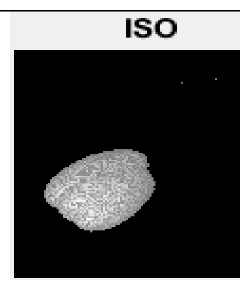
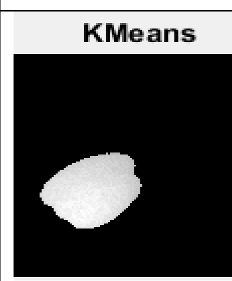
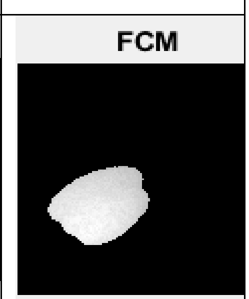
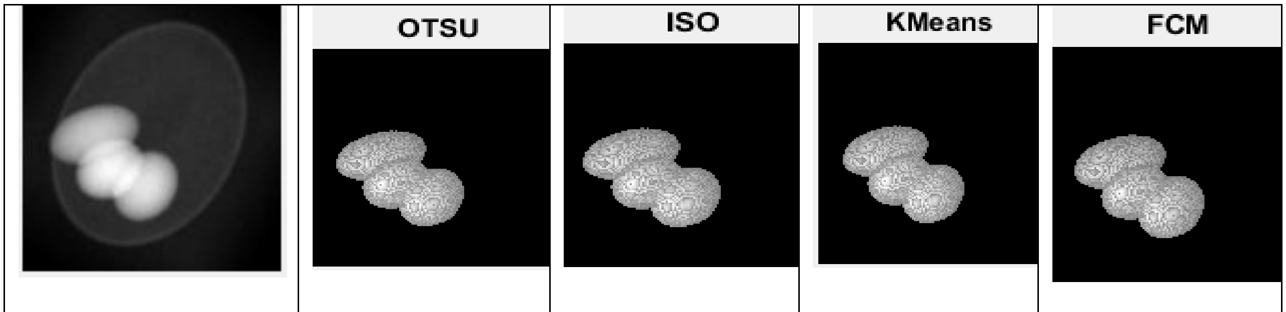
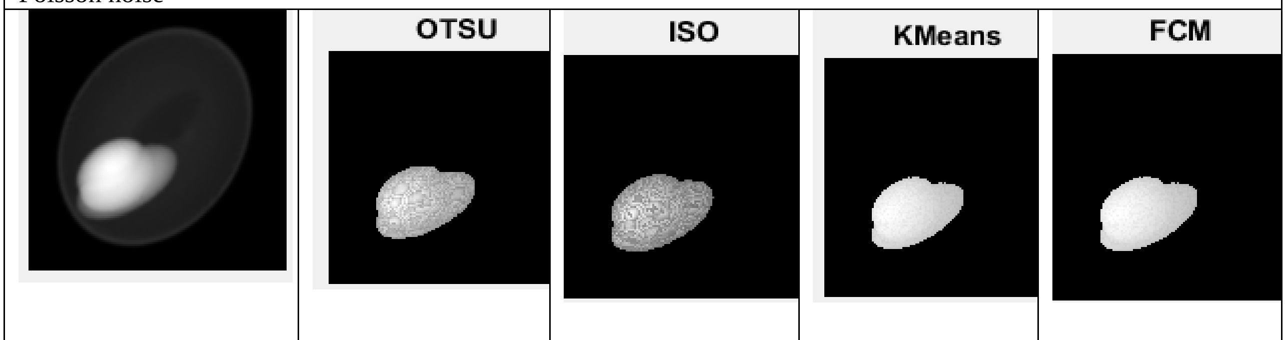
Table I Tumor Detection With Various Segmentation Techniques

Salt and Pepper Noise				
Phantom with Average ray casting algorithm)	Otsu Thresholding result	ISO DATA	K-Means cluster	FCM cluster
				
Gaussian Noise				



Poisson noise



Speckle Noise

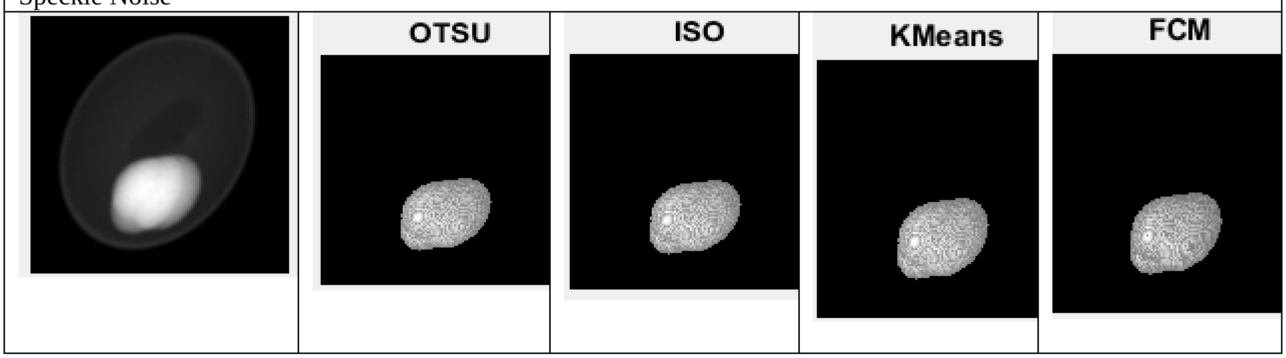


Table ii. Comparision of Segmentation Technique in terms of measures

NOISE		OTSU		ISODATA		KMEANS		FCM	
SALT & PEPPER		PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE
0.2		27.37	0.007	27.08	0.002	16.80	0.02	16.80	0.02
0.4		21.87	0.9	16.32	0.02	15.5	0.02	15.5	0.02
0.6		16.47	0.02	9.46	0.11	15.15	0.03	15.16	0.03
0.8		10.83	0.08	5.4	0.28	14.27	0.03	14.27	0.03
POISSON NOISE		32.33	5.8E-04	48.30	1.47E-05	23.80	0.004	23.80	0.004
SPECLE NOISE		45.97	2.52 E-05	46.22	2.38 E-05	46.31	2.32 E-05	43.67	4.29 E-05
GAUSSIAN NOISE									
MEAN	VARIANCE								
0	0.01	48.03	1.5 E-05	48.16	1.52 E-05	46.16	1.52E-05	46.78	2.07 E-05
0.2	1.2	5.26	0.29	5.36	0.29	5.36	0.29	5.45	0.28