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IVUS Image Segmentation By Using Expectation-Maximization Approach

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Abstract: Now a day's heart attack is one of the cause of human deaths. It mainly comes from the atherosclerotic plaques. Segmentation of coronary arteries of atherosclerosis is one important process prior to many analyses and visualization tasks for intravascular ultrasound (IVUS) images. The algorithm used in this project includes K-means clustering, Fuzzy C Means (FCM) clustering, and Expectation-Maximization (EM). K-means uses standard Euclidean distance metric, which is usually insufficient for image clustering. Instead in FCM, weighted distance metric utilizing pixel co-ordinates, RGB pixel color and/or intensity and image texture is commonly used. As the datasets scale increases rapidly it is difficult to use K-means and FCM to deal with massive data and Sensitive to noise. This noise could lead to serious inaccuracies in the segmentation result. To overcome this limitation, this project gives a new Expectation-Maximization called Gaussian Mixture Model using Expectation-Maximization (GMM-EM). GMM-EM is implemented through probabilistic approach for smoothening and clustering. Experiment results show that the new algorithm yields better segmentation results.

Keywords: Medical imaging; Segmentation; Intravascular ultrasound (IVUS); Gaussian mixture model using expectation-maximization (GMM-EM).

I. INTRODUCTION

Image segmentation is an effort to classify similar colors of image in the same group. It clusters colors into several groups based on the closeness of color intensities inside an image. The objective of the image segmentation is to extract the dominant colors. The image segmentation is very important to simplify an information extraction from images, such as color, texture, shape, and structure.

The applications of image segmentation are diversely in many fields such as image compression, image retrieval, object detection, image enhancement, and medical image processing. Several approaches have been already introduced for image segmentation. Here we used different algorithms based on Expectation Maximization. Image segmentation can also use for analysis of the image and further pre-processing of the image. After a segmentation process each phase of image treated differently. Now we are going through about medical images like Ultrasound Images (US) which is widely used today.

Atherosclerosis (or arteriosclerotic vascular disease) is a condition where the arteries become narrowed and hardened due to an excessive build up of plaque around the artery wall. The disease disrupts the flow of blood around the body, posing serious cardiovascular complications like heart attack or stroke. Coronary arteries mainly consist of three layers.

The inner layer is intima, middle layer is media and the outer one is adventitia. Atherosclerosis can also occur in the arteries of the neck, kidneys, thighs, and arms, causing kidney failure or gangrene and amputation. The disease occurs due to High cholesterol, High blood pressure, Smoking, Obesity, Diabetes, Mental stress, Lack of physical activity.

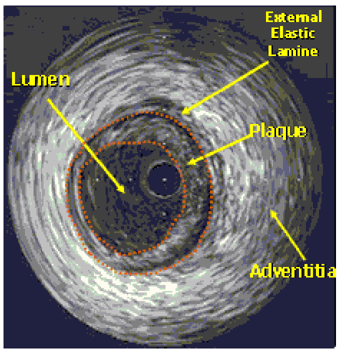

Fig 1. Example of IVUS imaging segmentation and its major elements

Intravascular US (IVUS) is an imaging technique that allows to clearly assess the arterial wall internal echomorphology. The technical procedure of acquiring IVUS data consists in introducing a catheter, carrying a rotating US emitter inside the vessel. During rotation, a piezoelectric transducer transmits US waves and collects the reflected components that are afterward converted into electrical signals (A-lines) and sampled by an analog to digital converter. Thus, IVUS is considered a suitable technique for characterization of the coronary plaques composition. This paper intends to model the atherosclerotic plaque through the analysis of the envelope backscattered IVUS data.

II. ALGORITHMS

This section aims at providing the mathematical description for estimating the mixture coefficients (weights) and the Gaussian parameters associated with each mixture component (distribution) using the EM method applied to US data.

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A. Expectation Maximization (EM)

The EM (expectation-maximization) algorithm is an iterative approach to compute maximum-likelihood estimates when the observations are incomplete. Expectation Maximization (EM) is one of the most common algorithms used for density estimation of data points in an unsupervised setting. The expectation maximization (EM) algorithm introduced by Dempster (1977) for maximization likelihood functions with missing data. This algorithm is a popular tool for simplifying difficult maximum likelihood problems. It has two steps; in E-step we compute the expectation and in M-step the maximization of the last step is done and iteration EM-steps continue until convergence occur. The EM algorithm is used for the research of the parameter achieving the maximum likelihood. The criteria of stop of the algorithm, is either a maximum number of iterations to limit the time of calculation, either a lower mistake. It is put easily in application because it leans on the calculation of the complete data. The drawback of EM is, it does not directly incorporate spatial modeling and can therefore be sensitive to noise and intensity inhomogeneities.

B. Gaussian Mixture Model (GMM)

The application of standard GMM (using a grey level as a single feature of pixel) yields a good segmentation of pixels inside regions and pixels of contours. Image is a matrix within which each element is a pixel. The value of the pixel is a number that shows intensity or color of the image. Let X be a random variable that takes these values. For a probability model determination, we can suppose to have mixture of Gaussian distribution as the following form:

$$f(x) = \sum_{i=1}^{k} p_i N(x \mid \mu_i, \sigma_i^2)$$

Where k is the number of components or regions and $p_i > 0$ are weights such that $\sum_{i=1}^{k} p_i = 1$,

$$N(\mu_i, \sigma_i^2) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(\frac{-(x-\mu_i)^2}{2\sigma^2}\right)$$

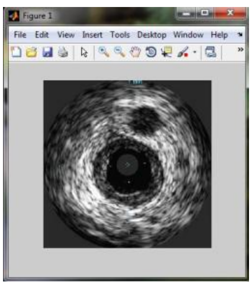
Where μ_i, σ_i^2 are mean and standard deviation of class i.

For a given image X, the lattice data are the values of pixels. However, the parameters are

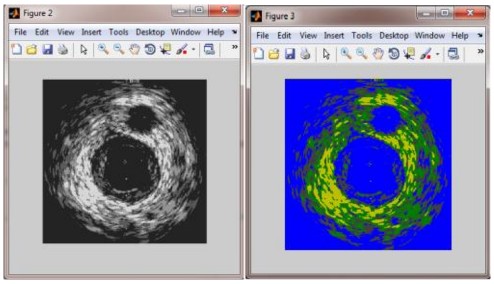
$$\theta = (p_1, \ldots, p_k, \mu_1, \ldots, \mu_k, \sigma_1^2, \ldots, \sigma_k^2)$$

The application of the GMM segmentation algorithm can generate a good classification of the internal pixels to the regions as well as the noisy pixels, but produces a deterioration of the contours between the two regions. Of this study the advantage and the inconvenient of the use of the grey level and the spatial feature for the noise and the contours classification.

III. EXPERIMENTAL RESULTS

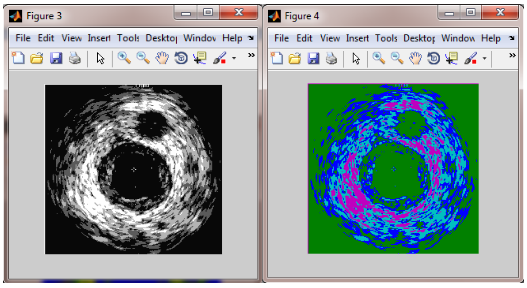


(a)



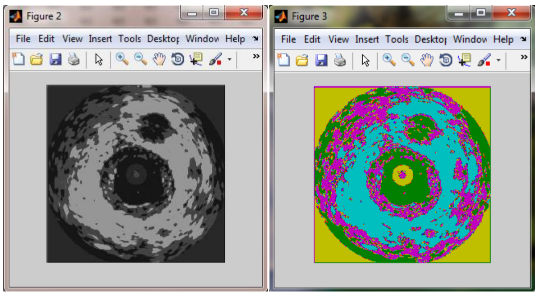
(b) (c)

Since Kmeans Clustering Algorithm is based on crisp set theory, it doesn't cares whether a pixel belongs to single region or multiple no of regions. Hence in the above result (Kmeans Clustering Algorithm) some amounts of desired regions are not properly segmented.



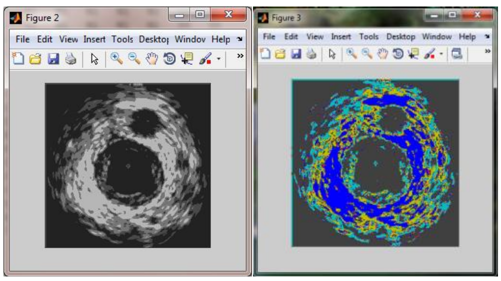
(d) (e)

The problem with crisp logic can be overcome by giving much importance for a pixel's degree of membership in a multi region image. The drawback of FCM is sensitive to noise. Hence in the above results it can be observed that the result seems to be affected with noise.



(f) (g)

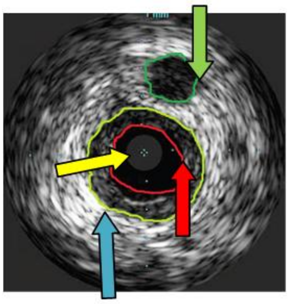
In FCM the segmentation is truly concentrated on updating new centroids and then the membership function. It is necessary to include the significance of mean and variance of the individual regions for attaining optimum results. This is possible in the Expectation maximization approach. From the above result it can be observed that this method is giving good results, but it is sensitive to noise.



(h) (i)

Problem with the above methods are sensitivity towards noise. This can be reduced using filter at the pre-processing stage. Hence Gaussian Mixture model using expectation maximization has given optimum results.

Fig 2.: a) Original IVUS image b) Kmeans segmented output image c) Kmeans Segmented Colormap output image d) Fuzzy C Means segmented output image e) Fuzzy C Means segmented colormap output image f) Expectation-Maximization output Image g) Expectation-Maximization Colormap output Image h) Gaussian Expectation Maximization Output Image i) Gaussian Expectation Maximization Colormap Output Image



In the above figure we observe that

- Side branch shadow
- Fibrous cap
- Lumen
- Calcium

In this work, a comparative analysis is performed on the techniques based on the performance measures. The output reveals the same detection of the plaque for both techniques. Significant improvement is achieved GMM-EM over EM in terms of convergence rate.

Comparison table

	MSE VALUE	PSNR VALUE
K-Means clustering	71.9333	29.5615
FCM clustering	27.7542	33.6975
Expectation-Maximization	0.0127	67.0889
Gaussian Mixture Model using Expectation - Maximization	0.0080	69.1090

From the above table, it can be observed that Quality parameters Mean square error (MSE) gives the occurrence of noise and Peak signal to noise ratio (PSNR) gives signal quantity. Thus from the table Gaussian Expectation-Maximization gives the better segmentation result.

IV. CONCLUSION

The results show that EM and GMM-EM methods can successively segment a IVUS image. The visualization results of the segmentation show the success of the approaches. The Gaussian Mixture Model using Expectation Maximization yields superior convergence rate. . The segmented results obtained from Gaussian Mixture Model using expectation maximization methods gives clear identification of plaque developed inside of artery vessels. Thus from output results we conclude that Gaussian Mixture Model using Expectation-Maximization gives more information rather than previous methods. In this project the quality parameters, Mean square error (MSE) and Peak signal to noise ratio (PSNR) gives the occurrence of noise and signal quantity.

V. FUTURE SCOPE

The Gaussian Mixture Model Using Expectation-Maximization performs the smoothing, at that time some desired data neglected. By using the Edge Preserving Smoothing method we will achieve the optimum results.

VI. ACKNOWLEDGEMENT

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BIOGRAPHIES

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