A Novel Method for Segmenting Magnetic Resonance Brain Images

Abirami.G
P.G Student
Velammal College of Engineering & Technology, Madurai

Veera Senthil Kumar. G
Assistant Professor,
Velammal College of Engineering & Technology, Madurai

ABSTRACT

Medical image segmentation is an important tool in viewing and analyzing Magnetic Resonance Images (MRI) and solving variousranges of problems in medical imaging. This paper focuses the new approach to segmentation by clustering the image by Genetic Algorithm based Fuzzy C-means clustering (FCM). First segmentation can be done with the help of FCM. Fuzzy C-means can be used to segment the image with fuzzy pixel classification. Then, Genetic Algorithm (GA) is applied to optimize the clustering result. It includes operations like Encoding, Population Initialization, Reproduction, Crossover, Mutation and Termination. It provides near optimal solution for objective function of an optimization problem.Hence GA based FCM is a novel method to segment the magnetic resonance brain images. Inspite of having more computational complexity, the accuracy is good for segmenting medical images.

Keywords
Segmentation, Clustering, Fuzzy C-means, Genetic Algorithm, MRI.

1. INTRODUCTION
Image segmentation plays a vital role in many medical imaging applications by automating or facilitating the marking out of anatomical structures and other regions of interest [3].Good segmentations of images will benefit doctors as well as patientsbecause it providesuseful information for three DimensionalVisualization, Planning for surgery and prior detection of disease. Magnetic Resonance Imaging uses magnetization and radio waves, rather than x-rays to provide very detailed, cross-sectional view of the brain [11], [16].MRI segmentation is used in Computer-guided surgery, locating the tumors [15], and to measure tissue volumes.

Segmentation is a process ofpartitioning an image into some homogeneous regions [3]. It is the initial step in image analysis which helps to separate the input image into meaningful regions [2]. Clustering is one among the type of Segmentation. It is a process of grouping unlabelled pattern into number of clusters such that similar patterns are assigned to a group which is defined as cluster [2][3]. Crisp and fuzzy clustering are the two types of clustering. Fuzzy clustering is also called soft clustering. If the boundary is clearly defined then crisp clustering is applied to solve the problem. But in many cases boundary can't be well defined. Hence fuzzy clustering is used there [9]. FCM is one of the types of fuzzy clustering.Fuzzy C-Means (FCM) is a method of clustering whichallows one piece of data to belong to two or more clusters.This method was first developed by Dunn in 1973 andimproved by Bezdek in 1981 [14], [15]. Hence each pixel is connected to many clusters with the help of membership function. It converges to the local optimum. To make the segmented output global optimum Genetic Algorithm is applied over this [1].

This paper is organized as follows. Section2is described about the proposed method for optimizing the image segmentation. In the Subsection 2.1 and 2.1.1 the basic concepts involved in FCM and its algorithm are presented.In Section 2.2overview of genetic Algorithm is described. The Steps involved and algorithm for GA are explained in Section 2.3 and 2.4 respectively. The Experimental results are discussedin Section 3.The Conclusion is depicted in the Section 4.Finally,future work for this paper is suggested in section 5.

2. PROPOSED METHOD
The below Figure No: 1 shows the block diagram for the proposed work.

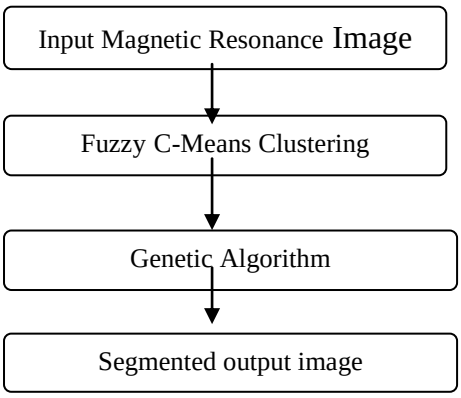

Figure No: 1

2.1 Fuzzy C-Means Algorithm
Fuzzy C-Means is a method of clustering which allows one pixel value belongs to two or more number of clusters and they are associated with membership functions [9], [11]. Segmentation can be highly improved by this method. Membership function denotes the strength of the association between that pixel and a particular cluster. Like the k-means algorithm, the FCM aims to minimize an objective function [4]. But the main difference when compared to the k-means is that, in the objective function has membership values u_{ij} and the fuzzifier m in addition. The fuzzifier m determines the level of cluster fuzziness [16]. If the value of m increases then the membership function u_{ij} decreases [12]. Assume the value of m as1,u_{ij} converge to 0 or 1 and it implies that it is crisp clustering.The value of m is commonly set to 2 in this paper. High u_{ij} is assigned when the pixel values are nearer to the centriod and low values are assigned if they are far away from the centriod [14].

2.1.1 Algorithm for FCM
Let $X = \{x_1, x_2, x_3 ..., x_n\}$ be the set of data points and

V = {v_1, v_2, v_3 ..., v_c} be the set of centers.

1) Randomly select *'c'* cluster centers.
2) Calculate the fuzzy membership 'μ_{ij}' using:

$$u_{ij} = \sum_{k=1}^{c} (d_{ij}/d_{jk}) \wedge (\frac{2}{m} - 1) \quad (1)$$

3) Compute the fuzzy centers 'vj' using:

$$v_j = (\sum_{i=1}^{n}(\mu_{ij}^{m} \; x_i)/(\sum_{i=1}^{n}(\mu_{ij}^{m})), \forall j \quad (2)$$

4) Repeat step 2) and 3) until the minimum 'J' value is achieved or $||U^{(k+1)} - U^{(k)}|| < \beta$.

$$j = \sum_{j=1}^{N}\sum_{i=1}^{c} \mu_{ij}^{m} \; ||x_j - z_i||^2 \quad (3)$$

where,
'k' is the iteration step.
'β' is the termination criterion between [0 1].
'U = $(\mu_{ij})_{n*c}$' is the fuzzy membership matrix.
J' is the objective function.
'*m*' is the Fuzzy parameter

2.2 Genetic Algorithm

The Genetic Algorithm is a randomized search and optimization technique guided by the principles of genetic systems [1]. The main advantage of GA is that fairly accurate results may be obtained using a very simple algorithm. Objective function determines how close they are to a better solution [6]. GA goes through the following cycle: Evaluate, Select, Crossover, and Mutate until some kind of stopping criterions are reached [7]. One criterion is to let the GA run for a certain number of cycles. A second one is to allow the GA to run until a reasonable solution is found. The solution obtained by this method is only a near global optimum solution.

2.3 Steps in Genetic Algorithm

Thebelow Figure No: 2 portraits the procedure involved in applying Genetic Algorithm. It has genetic operators like Reproduction, Crossover and Mutation.

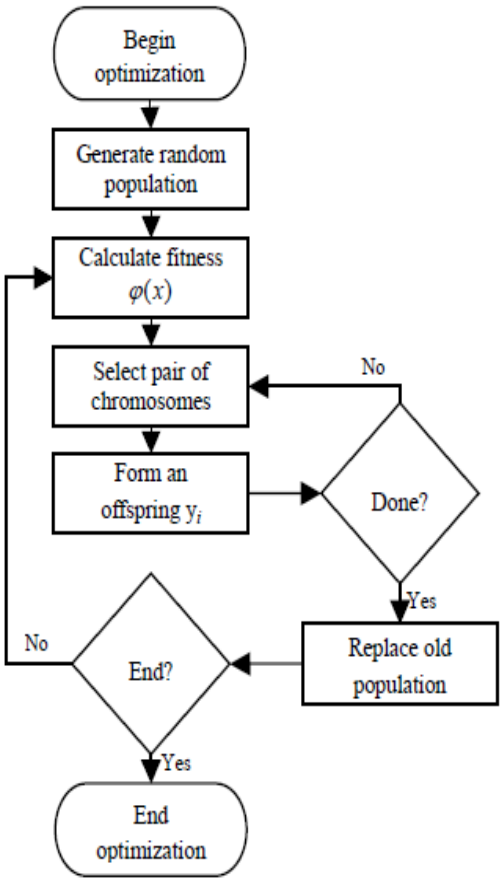

Figure No: 2

2.3.1 Encoding

It can be defined as the chromosomal representation of the problem. When GA was initially introduced, the binary string encoding technique was used. Two dimensional image data is considered in this paper. Here N number of consecutive genes in the chromosome is mapped with each cluster. For image data set, each gene is intensity value that is represented in integers.

2.3.2 Population Initialization

The N cluster centers encoded in every chromosome are initialized to N arbitrarily chosen points from the image data. This method is repeated for P chromosomes within the population, wherever P is the size of the population. After population initialization, further Genetic operations are performed over this.In thisproposed method, the FCM is run P times for generating the population.

2.3.3 Fitness Computation

There are two steps in computing the fitness function. Based on the centers the clustering can be done on data set so, that each pixel belongs to any of the clusters.

$$if \; ||x_i - z_j|| < ||x_i - z_p||, \forall p \; \& \; p \neq j \quad (4)$$

After this the second step is to form new cluster centre z_i^*. The previous cluster centers are replaced by taking the mean value of all the respective clusters.

$$z_i^* = \frac{1}{ni}\sum_{x_j \in C_i} xj, \quad \forall i = 1, 2, .. K \qquad (5)$$

The clustering metric can be calculated as the sum of Euclidean distance between the particular pixel and the center value. It is denoted by 'M'.

$$M = \sum_{x_j \in C_i} ||x_j - z_i|| \qquad (6)$$

and

$$M = \sum_{i=1}^{k} M_i, \quad \forall i = 1, 2.. K \qquad (7)$$

Thus, the fitness function is inversely proportional to cluster metric

$$f = \frac{1}{M} \qquad (8)$$

Hence the increase in the value of 'f' should decrease the value of 'm'. The main aim of this paper is to minimize the distance between the pixel and the cluster center and hence the fitness function is maximized.

2.3.4 Selection

It is also called reproduction and it is the first operator in Genetic algorithm that is applied on the population. Chromosomes are selected from the population to be parents to crossover and produce offspring [1], [7]. Various methods of selecting the chromosomes are Roulette – Wheel Selection, Tournament Selection, Rank Selection and Boltzmann Selection [7]. Out of these, Roulette-Wheel selection is commonly used operator. In this method a string is selected from a mating pool with the probability proportional to the fitness. Thus, i^{th} string in the population is selected with a probability proportional to the fitness function, f_i. The probability of ith string is given by the following

$$p_i = \frac{f_i}{\sum_{j=1}^{N} f_j} \qquad (9)$$

where 'N' is the number of chromosomes or individuals in the population.

2.3.5 Crossover

After completing the phase of reproduction, the population is containing better individuals. Hence, the crossover operator is applied over the newly created off springs. It is the recombination operator and it has three steps [6]. First reproduction selects two individual bit strings in a random fashion for mating, and then cross-site is selected along the string length. The position values are swapped between the two individuals (pixel values). Single point crossover is selected randomly along the length of the mated string and the bits next to the cross sites are exchanged [7]. The enhanced offspring is produced if the random selection is made in an appropriate manner.

The cross over rate is from 0 to 1. It is the ratio of number of pairs to be crossed to some fixed population. For the population size 30 to 200, the crossover rate is ranging from .5 to 1.

2.3.6 Mutation

After the crossover operation, the strings undergo mutation. Mutation of a bit involves flipping of a string which means changing the values of 0 to 1 and vice versa with a probability P_m.Mutation rate is the probability of mutation and it is used to calculate the number of bits to be mutated[5]. It preserves the diversity among the population which plays a vital role in the search. If the population size is 30 to 200 then the mutation rate is .001 to .5. If the value at the position of gene is v, after mutation it becomes

$$v \pm 2 * \delta * v, \quad v \neq 0$$

$$v \pm 2 * \delta, \qquad v = 0 (10)$$

This mutation operator introduces new genetic structures in the population by modification of bits [7]. It overcomes the problem of ending with local minimum since the modification is not related to previously create genetic structures of the population.

1.3.7 Termination

Genetic Operators are performed for a number of iterations. The process is repeated until the best string is obtained and it provides the solution to the problem.In this proposed method first, FCM segmentation can be done for MR images. In the next step, the segmented FCM is given as population Initialization to the Genetic Algorithm and optimized Clustering result is obtained.

2.4 Algorithm for GA

Step 1-[Start]
Generate the population of n chromosome (i.e. suitable for the problem) Fuzzy C-Means clustering is done.

Step 2-[Fitness]
Evaluate the fitness function for each chromosome in the population.

Step 3-[New population]
Create the new population by repeating the following steps until the new population is complete.
3a) Selection
3b) Crossover
3c) Mutation
3d) Accepting

Step-4 [Replace]
Use new generated population for further run of the algorithm.

Step-5[Test]
If the end condition is satisfied stop and return the best solution.

Step-6[Loop]
Else go to step 2 and continue.

3. EXPERIMENTAL RESULTS

The proposed method is applied to Magnetic Resonance Brain image. First Fuzzy C Means clustering is applied to MR image and it is followed by applying genetic operators. This proposed method is applied to a variety of Magnetic Resonance Brain image and the obtained output is shown in the following Figures.

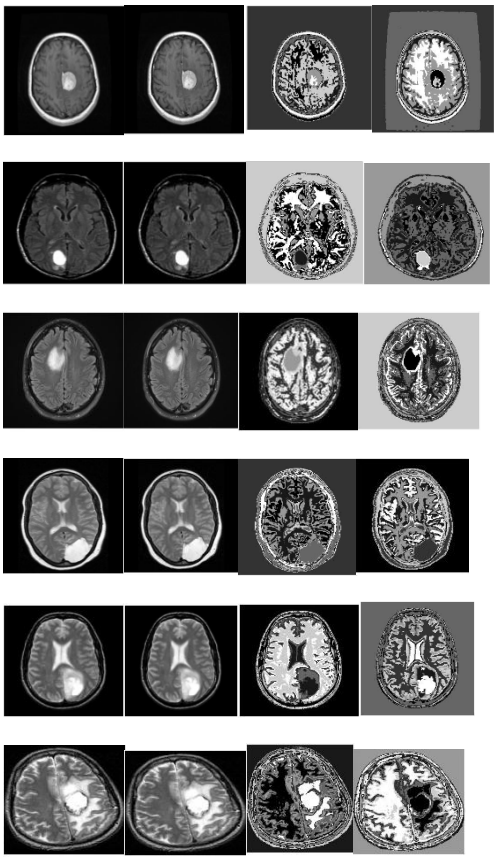

Fig 3(a) 3(b) 3(c) 3(d)

Figure No: 3(a) Original MRI brain images, 3(b)Gaussian filtered image, 3(c) FCM output Image, 3(d) Final output by applying GA with FCM Technique.

Performance can be evaluated with the help of error rate. It is calculated for various types of magnetic resonance brain images and it is tabulated. Comparison can be done for both FCM output and FCM with GA output.By analyzing the above graph it is given that the error rate value is less for all images of FCM with GA o/p when compared to FCM o/p.

Table No: 1 Performance Evaluation of various MR Images

Name of the Images	Error rate value for FCM	Error rate value for FCM with GA
MRI 1 Image	.9005	.7810
MRI 2 Image	.4181	.4102
MRI 3 Image	.7623	.3400
MRI 4 Image	.9894	.8938
MRI 5 Image	.8085	.7220
MRI 6 Image	.2712	.1451

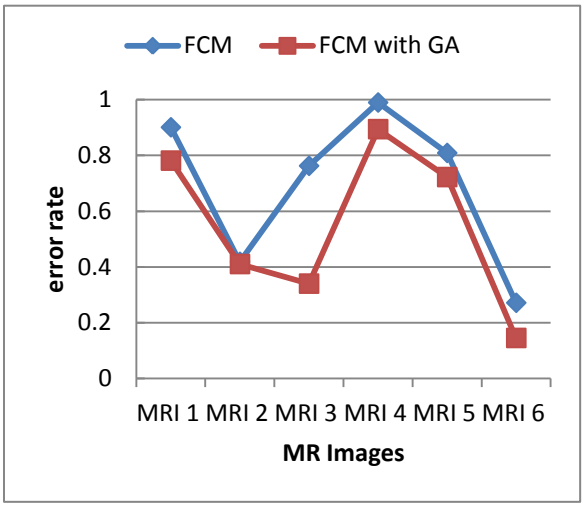

Figure 4: Experimental results on various MR images

4. CONCLUSION

This paper presented a novel approach to the segmentation of brain images using Fuzzy C means clustering with genetic algorithm. This helps to detect the tumor with minimum number of user interventions. Optimal results are obtained with help of this segmentation method. It produces accurate results even though it has the property of slow convergence.

5. FUTURE WORK

In future, it can be applied to anotherevolutionary algorithm particle swarm optimization for getting better results. Comparison of performance of proposed algorithm with the PSO can be done based on the cluster validity index to measure the number of components in that particular image. It can also be used to segment Satellite images for wide applicability.

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