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Biomedical Image Segmentation using Optimized Fuzzy C-mean Algorithm

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Abstract

Background/Objectives: Automatic segmentation of brain MRI has an important role in image research along with medical image processing. It has been investigated widely in recent research. It helps for patient diagnosis for different diseases its value concerns in diagnostics through various biomedical images such as PET, CT, MRI and X-ray. In this paper, we analyzed for different biomedical images using partition method. The objective is to detect patch in the biomedical images that may lead to tumors. **Methods/Statistical Analysis**: The objective of segmentation is to divide the complete image into informative regions and respective specific application. Segmentation separates the image from the background, read the contents and isolating it. Both the concept of clustering by fuzzy technique with edge based segmentation method where standard methods like Sobel, Prewitt edge detectors are applied. Further it is optimized using evolutionary algorithm for efficient minimization of the objective function to improve classification accuracy. **Findings**: To find the smooth image Gaussian filter is used. Successive segmentation has been performed to detect the patch of desired region. It is observed for different images and compared. **Improvements/Applications**: It will be helpful for clinical analysis and observe the quality of images for diagnosis of diseases.

Keywords: Clustering, Fuzzy C-mean Algorithm, Genetic Algorithm, Optimization, PSO, Thresholding

1. Introduction

Segmentation of biomedical images plays a vital role in the field of medicine and clinical analysis. Its purpose is noticed that little research have been exercised in the field of automatic image segmentation and processing. We enrich the field of medical research by using optimization technique for different biomedical images.

The clustering algorithm is used because the same featured patterns will be put into the same cluster and patterns from different clusters differ as far as possible.

Biomedical signal and image processing occupies a special position in both academia and research of biomedical engineering. The concepts of signal and image processing have been extensively used for extracting the physiological information in implementing many clinical procedures for sophisticated medical practices and applications.

Biological and medical information processing is a dynamic field of natural science[1]. The biomedical signals have been used by the architects for designing the bioelectrical and biomechanical systems. The physicians and human services experts introduced the diagnosing procedures of medical issues. The biomedical signal has been handled earlier to focus on design or diagnosis. The existing signal processing tools/programs is more suitable for engineers functioning in biomedical applications[2].

Over a few decades image analysis as well as bio-signal analysis occupied an important space in research. It is a preprocessing task for computer vision like medical imaging, location of objects in satellite images, machine vision, biometrics recognition etc. The accuracy level

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would have a great impact on the effectiveness. This problem has been studied by many researchers since several years. Due to the characteristics of the images such as their different modal histograms, the problem of image segmentation is still an open research issue and can be further explored.Segmentation subdivides an image into its constituent regions or objects[1–3].

The level to which the separation is carried depends on the problem being solved. These algorithms are based on the discontinuity and similarity of image intensity values. Discontinuity is to divide the image for on abrupt changes in intensity whereas similarity is based on partitioning into similar regions according to a set of predefined criteria. Thus, the choice of image segmentation technique is specific problem dependent.

To identify desired organs/features in medical images requires an expertise concerning the shapes and locations of human anatomy. It is performed manually by physicians for treatment and diagnosis. Due to the huge data and feature complexity of interest, it becomes a necessity of automated segmentation methods. Medical imaging is performed in various modalities, such as Magnetic Resonance Imaging (MRI), Computed Tomography (CT), ultrasound, etc. Many methods have been explored to process the different images and identify the desired portion, including intensity-based methods, region-growing methods and deformable contour models.

Various methods have been proposed by the researchers[4–10]. Some are hybridized the fuzzy C-means algorithm using methods like watershed, ant colony optimization and grown region method for segmentation of images[11–19]. A comparative analysis has been done for fuzzy logic using K-means and C-means algorithm. It is found from the literature that the C-means us better than K-means algorithm in terms of speed and accuracy. Based on the literature, C-means clustering algorithm is chosen in this case[11–14]. The generalized segmentation approach using morphology is provided[19–21].

In this paper, authors have considered an approach for segmentation of image using FCM algorithm. Further, the fitness function of Genetic Algorithm is modified and used for optimization. The proposed method minimizes as per the fitness function and obtains better quality as compared to the previous methods[22–25].

The paper is organized as follows. Section 2 depicts the methods for image segmentation. The result is discussed in Section 3 and finally in Section 4 concludes the work.

2. Materials and Methods

In image processing, different stages are there. However segmentation is an important stage and used for pre-processing stage. Based on biomedical application, specific entities are to be identified from pathological images. From these images, the desired section can be segmented by pattern recognition techniques. A set of feature patterns are to be generated and partitioned through similar clusters using clustering techniques. In this piece of work monochromatic images are considered to study their gray level properties to observe discontinuing and similarity for segmentation.

2.1 Clustering for Segmentation

The techniques attempt is based on clustering and optimization of clusters. These methods are described as follows. The clustering task is of pattern representation, distance measures, grouping, data abstractions and assessment of outputs. Initially the K-means algorithm is applied to verify the literature. Next-to it the efficient fuzzy C-means algorithm is used. Finally, has been optimized using evolutionary algorithm as Genetic Algorithm (GA)[22–25].

For our work two different images of patients as brain image of two samples and breast images of two samples are considered. The proposed algorithm is mentioned step-wise as follows.

- From the input images as described, the region of interest (ROI)
- The images are de-noised with the help of Gaussian filter described as:

$$G(u,v) = e - 2(u,v)/2\sigma^2$$

- The obtained images are converted into intensity matrix that ranges between 0 and 1. It can prepare for important clusters, where the clustering algorithms are applied as described in Appendix-I.
- The clusters are optimized using GA (described in subsection 2.2). Keeping those values as the initial value of C-means algorithm, step (iii) is repeated until the optimized result is obtained.
- From the obtained result, the threshold is fixed using binarization technique and unwanted edges are removed.

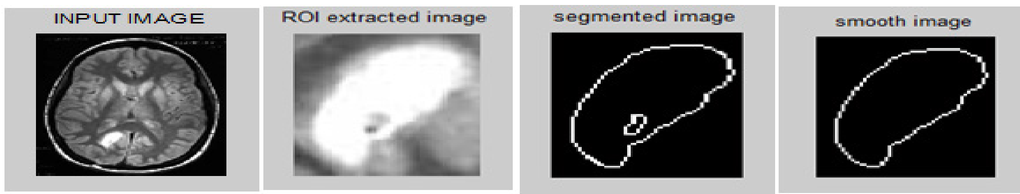

Figure 1. Brain Image-1 with the patch (a) Original, (b) ROI of Image, (c) Segmental and (d) Smoothed Image.

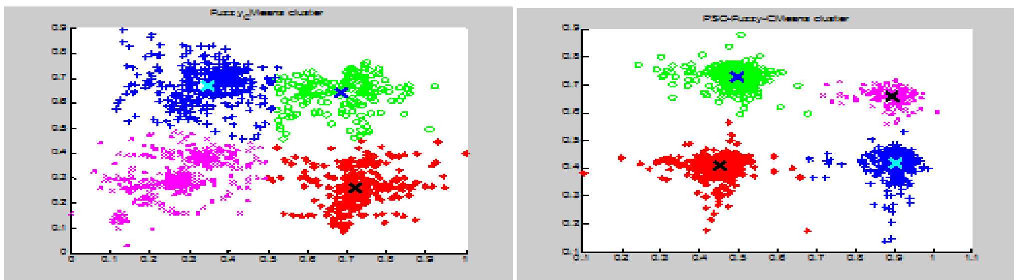

Figure 2. (a) Clustering without optimization and (b) Optimized clusters.
Number of Iteration = 16, Objective function = 11.70 Number of Iteration = 14, Objective function = 3.83.

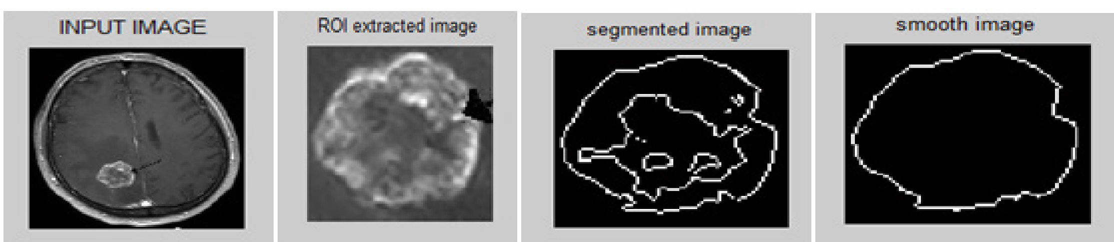

Figure 3. Brain Image-2 with patch (a) Input Image, (b) ROI extracted Image, (c) Segmented Image and (d) Smooth Image.

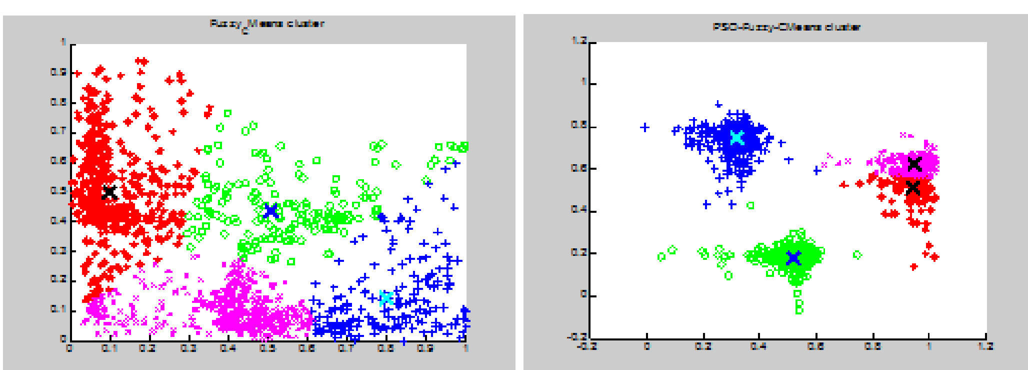

Figure 4. (a) Clustering without optimization and (b) Optimized clusters.
Number of Iteration = 67, Objective function = 22.21, Number of Iteration = 23, Objective function = 5.98.

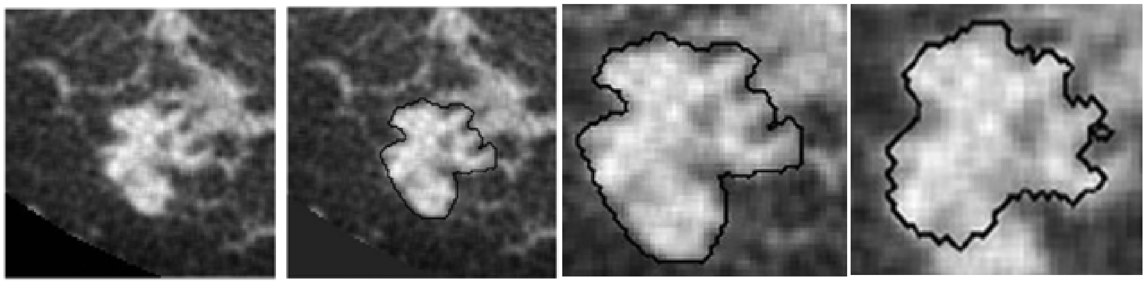

Figure 5. Breast Image-1 with patch (a) Input Image, (b) ROI extracted Image, (c) Segmented Image and (d) Smooth Image.

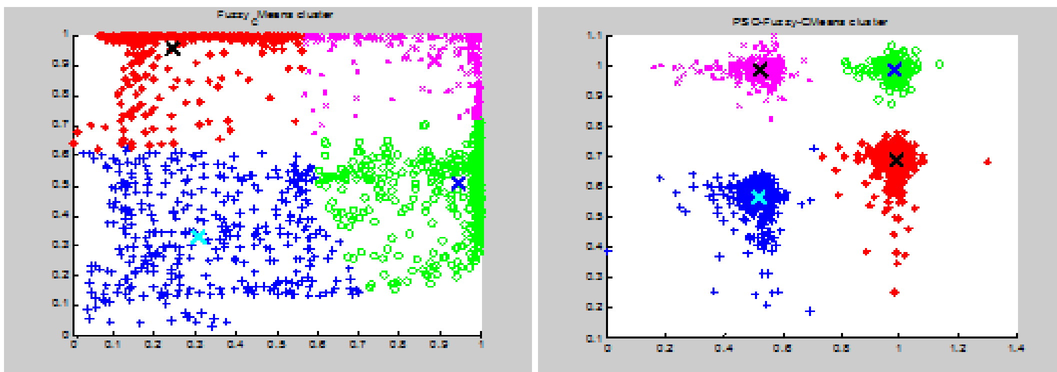

Figure 6. (a) Clustering without optimization and (b) Optimized clusters.
Number of Iteration = 30, Objective function = 33.55, Number of Iteration = 13, Objective function = 6.43.

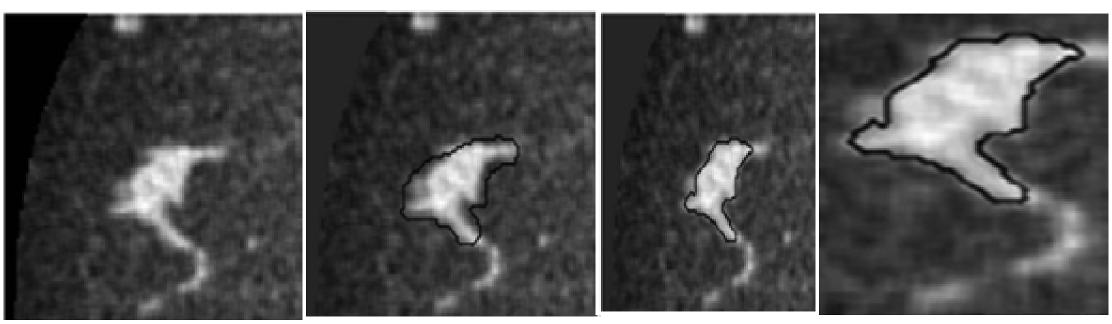

Figure 7. Breast Image-2 (a) Original Image, (b) ROI extracted Image, (c) Segmented Image and (d) Smooth Image.

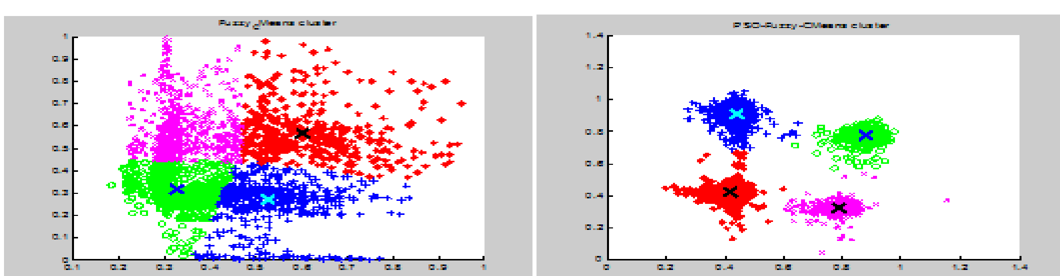

Figure 8. (a) Clustering without optimization and (b) Optimized clusters.
Number of Iteration = 55, Objective function = 22.45, Number of Iteration = 13, Objective function = 8.62.

Table 1. Comparison of brain and breast images for optimized and unoptimized methods

Images	MSE		PSNR		SSIM		V	
	un optimized	optimized	unoptimized	optimized	unoptimized	optimized	unoptimized	optimized
Brain-1	0.04981	0.04539	29.9940	30.954	0.9765	0.98999	77.2447	73.2654
Brain-2	0.046382	0.039269	30.708	32.896	0.9984	0.99795	73.8851	67.9370
Breast-1	0.04539	0.036369	30.9940	31.796	0.9881	0.99105	74.8951	66.9490
Breast-2	0.04758	0.035269	31.9940	33.846	0.9787	0.98795	73.8851	68.9380

- Smoothening of the results is done using morphological method of boundary detection[19-21].

2.2 Cluster Optimization using Evolutionary Algorithm

Out of many evolutionary algorithms, Genetic Algorithm is an efficient global optimization technique[22–25]. It is a random search iterative technique as well as adaptive one. It can improve the performance of entire population instead of individual. Each individual is encoded into binary bit string and named as chromosome of fixed length.

It has a promising solution based on fitness function are objective function for particular problem. The fitness value is associated with individual chromosome. It is used for both maximization and minimization problem depending on the type of problem. Different operators like selection, crossover and mutation provide a better solution. GA begins with randomized set of chromosomes called as population. Like the theory of evolution, the chromosomes are processed interactively to match the fitness value and create the optimized solution. Hence the objective function/fitness function has a major role to find the solution of the specific problem.

The fitness of each individual can be evaluated. In this case it considers the covered and uncovered points of the clusters.

Let x be the covered points, if $x \in P_{j,\,Pj}$ is the region that contains the connected points around the center cj. It is uncovered if $x \in P_{j,} P_{j}$ [10]. The fitness value is considered as:

$$F.V. = \alpha \sum_{i=1}^{n} \sum_{j=1}^{k} \left\| C_j - R_j\left(X_i, y_i\right) \right\|^2 + NCR$$

Where NCR can be evaluated as:

$$NCR = \alpha \sum_{i=1}^{m} \left\| Med - R\left(x_i, y_i\right) \right\|^2, \; m = \text{uncovered points}$$

The . norm term represents the Euclidian distance from the centroid. If $dist_{ij} < dist_{euclid}$, then x_j belongs to covered value, otherwise uncovered. The optimization technique is applied to fuzzy C-means data points for optimal solution and obtained.

3. Results and Discussion

Two different brain images along with two different breast images have been considered for this work. The segmented results are shown for all these images in following figures pictorially. The clusters for unoptimized and optimized are shown in Figures. Finally this table provides the different measuring values to compare among the methods.

4. Conclusion

Biomedical signal and image processing constitutes different interests in the educational and research field in biomedical engineering. With the enhanced physiological knowledge, a wide assortment of innovative works in clinical methods makes use of this concept in the medical applications. The objective of this work is use the GFCM method to optimize the image segmentation. We have analysed the work using the popular fuzzy based clustering approach. The Genetic Algorithm (GA) has been used as an evolutionary computing platform for the discussed optimization. The discussed segmentation method emphasized on the clustering approach including optimization of the clustering scheme. A visually relevant segmentation has been manifested using the algorithm as observed from our results. The method proposed has been found reliable in bio-medical image analysis. Although, the automated segmentation approaches may not replace the doctors completely, however, these can serve as the important tools in interpretation of medical images. It creates numerous challenges so as to advance in the field of clinical diagnosis and decision making. The automated processes may help engineers, physicists, mathematicians and physicians working in this area for concrete decision making based on the optimized results.

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