

Integrated approach of brain segmentation using neuro fuzzy k-means

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ABSTRACT

A proposed method using neuro-fuzzy k-means for the segmentation process of brain has been developed successfully, simulated and assessed. The proposed method has been assessed by using clinical brain images of magnetic resonance imaging (MRI) technology, to segment the three main tissues of the brain. The proposed system is able to segment the three important regions of the brain, which are white matter, grey matter and cerebrospinal fluid (CSF) more accurately, as compared to the benchmarked algorithms. Furthermore, the developed method's misclassification rate (MR) has been significantly minimized by 88%, 27%, 88%; 82%, 71%, 84%; and 82%, 29%, 83%, as compared to k-means, fuzzy logic, and radial basis function (RBF) for white matter, grey matter and CSF, respectively. Also, from the visual interpretation, it is observed that the brain's edges are well preserved and the tissues are clearly segmented. From these measures, the proposed integrated approach is shown to be accurate in segmenting the MRI brain tissue with reduced misclassified pixels.

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1. INTRODUCTION

Ahirwar [1] have written a review paper that discusses the segmentation methods of magnetic resonance imaging (MRI) images for brain tumour [2]. The process of Image segmentation plays a vital role in feature extraction, image analysis and understanding of the many scientific applications. K-means method [3], [4] is the key technique in pixel based segmentation. The k-means algorithm, although simple and efficient, might not be able to provide an optimum value even after with sets of big data and iterations [5]. If the quantity of selected clusters equals the number of the actual number of clusters, then it might result in right segmentation, otherwise, it may lead to wrong results [6]-[11].

Saneipour and Mohammadpoor [12] have shed light on an automatic image segmentation method by using images of MRI machine through greedy snake model and optimization of fuzzy c means method. According to them, brain segmentation process can be grouped into four categories or groups: Threshold based segmentation technique, Region based segmentation, edge based segmentation technique and clustering based segmentation [13], [14]. The proposed method for the segmentation of brain can be archived using following steps, namely, i) pre-processing, ii) detection of snake contour, iii) applying of greedy snake algorithm, and iv) fuzzy c-means clustering optimization, and v) accurate region selection [15], [16].

Artificial neural networks (ANN) is yet another technique that is widely used in the medical imaging field. The supervised learning model is highly suitable for applications that do not require any assumptions based on prior distribution [17]. ANN plays a significant role in reducing the computation time and false

recognition rate [18]. Within ANN, radial basis function (RBF) networks have gained popularity due to its advantages over other ANN types in terms of simpler structure, faster learning based algorithm, easy design, easier training, better tolerance to noise input, and better approximation capabilities [19], [20]. This has led to the development of the proposed methodology to partition and segment MRI brain images.

Automated brain tumour segmentation is a challenge and an essential task as well in various medical imaging applications, since it involves a significant amount of data. Moreover, Tomasila and Emanuel [21] have implemented support vector machine (SVM) method by using MRI images but it did not perform well when data has more noise. So the removal of noisy data is a challenging task as well so the output data could be more enhanced and the misclassification rate (MR) could be as low as possible, while the tumour that has been formed in the brain region causes the human body functions to be malformed. It is quite difficult to address and treat the tumour due to its complex location and spreading ability [22]. Medical image segmentation may vary significantly from a case to case. The data set which are used in the process of segmentation is not big enough and the resultant resolution is quite low. The results of segmentation procedure are not able to link up with the actual clinical requirements [23]. Furthermore, going forward, the static nature of filters lead to constraint the filtering process in the MR images to some specified regions only which has to be resolved [24]. Finally, the intensity variation of the MRI data further increases the complexity of accurate segmentation [25].

The new integrated approach of neuro-fuzzy k-means integrates the advantages of the k-means, fuzzy logic and neural network. k-means is applied for segmentation, fuzzy logic to extract the features and the neural network to classify the grey matter (GM), white matter (WM) and cerebral spinal fluid (CSF). In this method as a contribution, partial contrast stretching is used for image enhancement which helps to rectify the weakness found in an image, followed by subtractive clustering to obtain the optimal data points for segmentation using k-means. Further, only two features are extracted using fuzzy logic namely, mean and standard deviation.

2. METHOD

The proposed methodology for the brain segmentation is an integration of k-means, fuzzy and neural network to overcome the drawbacks of these individual algorithms. The k-means, fuzzy and neural network are used for segmentation, feature extraction and classification purposes respectively. The median filter has been used for image filtering and to remove the noise. The proposed integrated approach undergoes four different stages as shown in Figure 1 and described below.

Step 1: pre-processing stage. Firstly, the MRI image (which is the input) is being converted into a grayscale image, then resized, undergoes image enhancement and a filtering technique is applied (specifically, median filtering is used to filter the noise). The MRI images used for this research work have been taken from various sources which means the quality of the images are of not the same. Hence, if the images have to be normalized prior to being segmented and for other processing to be done. A contrast enhancement known as partial contrast stretching (PCS) helps to rectify the weakness found on an image. Weaknesses include low contrast and blurred images which are common especially if captured under low lighting or without image stabilizer.

Step 2: k-means Segmentation. We need to define and allocate centroids; each cluster will be having one centroid. These centroids should be positioned strategically and in the right manner because different and various locations could lead and result in to different and undesirable results. For good coverage, the best way is to position these centroids away from each other. Next, we need to consider each point which belongs to a given data set and link it to the nearest centroid, until there are no more remaining points in the process. Hence, the first step is completed. At this stage, re-calculate and evaluate the K latest centroids as Barycenters of the resultant clusters which have been produced from the previous step. With these K new centroids, a new link has to be done between the same points of the data set and the coldest new centroid. The K centroids may be considered to change their location step by step at each iteration until no changes occur. Finally, the method minimizes an objective function, in this particular point a function of squared error. The k-means algorithm is given as follows:

Step a: select K arbitrary initial centers: $Z_1(1), Z_2(2), \dots, Z_j(K)$.

Step b: at the K^{th} iterative step, scatter the sample $\{X\}$ among the K Cluster area, by choosing the relation $X \in S_j(k)$, if $\|X - z_j(k)\| < \|X - z_i(k)\|$ where, $S_j(k)$ is the collection of samples whose centre of cluster is $z_j(k)$.

Step c: compute the new clusters: $z_j(k+1)$, where $j = 1, 2, \dots, k$, $z_j(k+1) = 1/n_j \sum X, X \in S_j(k)$ where, n_j is the quantity of samples in $S_j(k)$ and the centers of the clusters are updated sequentially.

Step d: if $z_j(k+1) = z_j(k)$, then the algorithm is converged successfully and the process is stopped, otherwise go to step 2.

Step 3: fuzzy logic feature extraction. The input of the fuzzy logic system takes the output data of the k-means algorithm and at this stage, the functions of the membership are defined and fuzziness used to create

and form the clusters. A specific form of attraction called neighborhood attraction occur between pixels of neighbor, which is considered eventually as a feature for extraction in this process. During the process, each and every pixel attracts its neighboring pixel towards its own cluster. This kind of attraction is dependent on two factors; distance attraction or spatial position (which depends on the structure of neighborhood), and the second factor is feature attraction or pixel intensities. The noise is greatly controlled by the factor of neighboring pixels. The rules of developed fuzzy system are:

- If the mean value is low and the standard deviation value is also low, then the result is not an edge pixel.
- If the mean value becomes medium and the standard deviation value is low, then the result is an edge pixel.
- If the mean value becomes high and the standard deviation value is low, then the result is not an edge pixel.
- If the mean value becomes low and the standard deviation value is high, then the result is not an edge pixel.

Step 4: neural network classification and detection. The extracted features are considered as input to the neural network. The radial basis transfer function is used for the neural network, in which the radial basis output layer computes the Euclidean distance weight function between clusters (input and target vector) based on the net input. The net input computes the net of the corresponding layer input by combining its weighted inputs and biases. This process is repeated until the cost function is minimized.

This algorithm minimizes an objective function, which is in this case a function of squared error. The segmented output image is then produced. From this, the tissues in the brain are detected. Each image is resized to 256×256 pixels. The proposed integrated method is applied on the processor of Intel Core i5, using software of MATLAB. A graphical user interface (GUI) feature is created with two push buttons - one to browse the MRI image and the other to segment and partition by using the existing or proposed algorithms to analyze their impact.

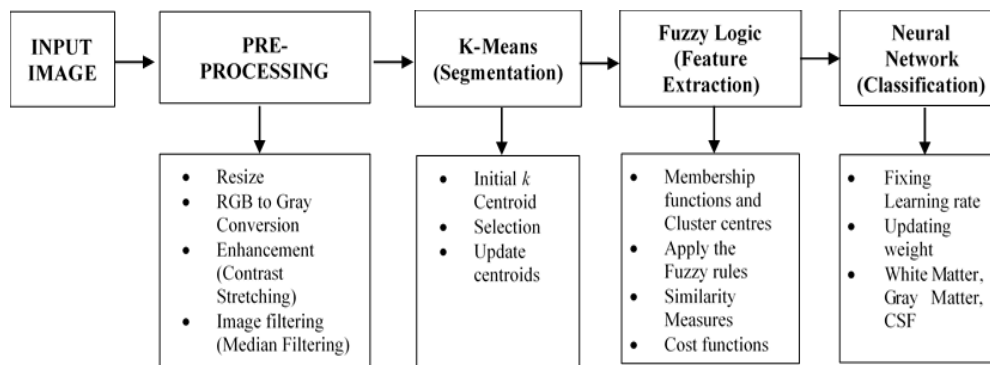


Figure 1. Proposed intergrated approach of brain segmentation using neuro-fuzzy-k-means

3. RESULTS AND DISCUSSION

3.1. Database

For this research work, the data images have been collected from a private hospital of kingdom of Saudi Arabia for MRI imaging modalities. The proposed integrated algorithm was tested on the 500 real images acquired from 22 patients, which are MRI images. Each image is resized to 256x256 pixels.

3.2. Simulated GUI results

The proposed integrated algorithm is implemented on the processor of Intel Core i5, using the software of MATLAB software. A GUI feature was created with two push buttons-one to browse the input image of MRI and the other to segment using the existing or proposed algorithms to analyze their impact. Figure 2 shows the developed GUI with the MRI input image chosen for the segmentation process of brain and the method/algorithm selected for the analysis purpose. Firstly, the existing k-means algorithm is being selected to partition and segment the given input MRI brain image. The output image is segmented into the following regions: white matter, gray matter and CSF accordingly.

Next, the existing fuzzy logic method is chosen to segment the given input MRI image, as shown in Figure 3. Then, the existing RBF method is selected to segment the image, with the output shown in Figure 4. Finally, the proposed integrated improved fuzzy k-means RBF algorithm is selected, with the output images shown in Figure 5.

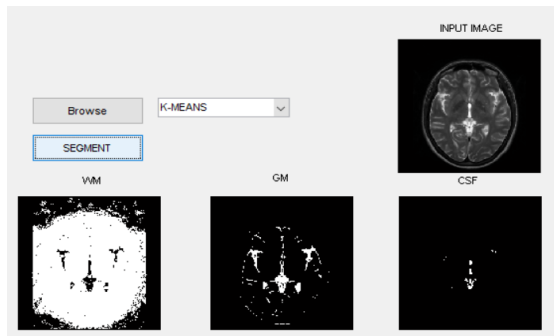


Figure 2. GUI for brain segmentation process using k-means algorithm

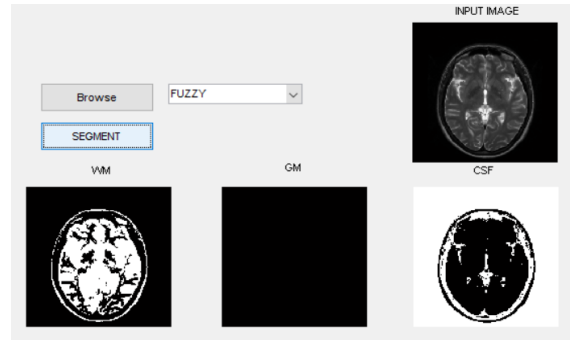


Figure 3. GUI for segmentation of brain using fuzzy

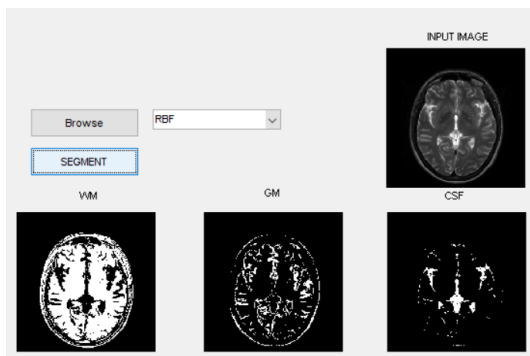


Figure 4. GUI for segmentation of brain using RBF

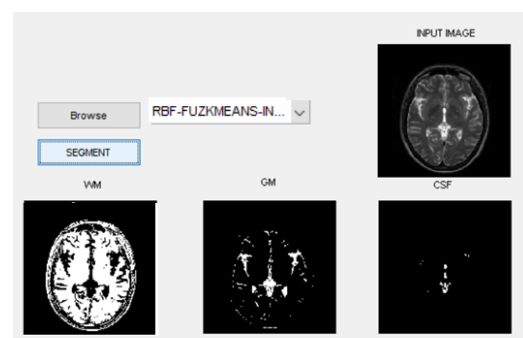


Figure 5. GUI for segmentation of brain using improved fuzzy k-means RBF

3.3. Analysis of results

Figure 6 exhibits the segmentation results of k-means, fuzzy algorithm, RBF and the proposed method for the white matter region. It can be observed from the first image (Figure 6(a)) that the white matter is not identified clearly by using K means algorithm and it also carries more white pixels and the edges of the region are not detected clearly. If we observe the second image; Figure 6 (b), there are many misclassified pixels in the center bottom portion of the image although the white matter is highlighted well and it performed better than Figure 6 (a). Figure 6(c) and Figure 6(d) exhibits well identified and detected edges of the white matter, and the noise is highly minimized inside the segmented brain image. The brain edges of the region are also better detected in Figure 6(d) as compared to the Figure 6(c) of RBF. Thus, this demonstrates and proves that the proposed method has segmented the white matter more precisely and performed well by preserving the edges of the brain region and minimizing the noise and misclassification rate.

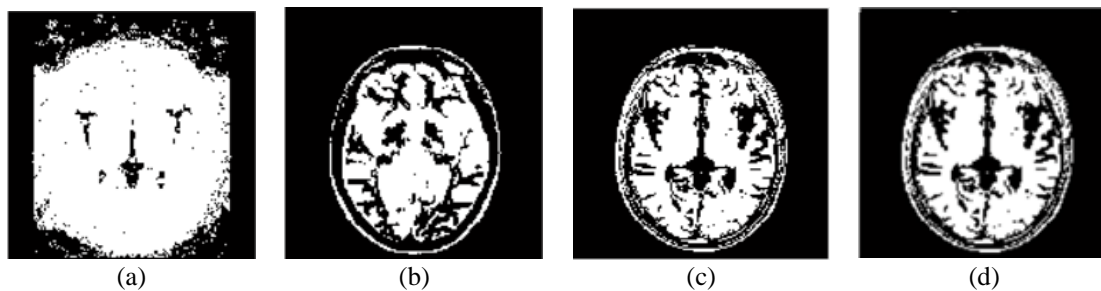


Figure 6. White matter region segmented by: (a) k-means, (b) fuzzy logic, (c) RBF and (d) proposed algorithm

Figure 7 shows the results for the three benchmarked and proposed algorithms for the analysis of grey matter. It can be observed from the first image that the grey matter is visibly present using K-means algorithm in Figure 7(a), but some edges of the region are not clearly identified. While in Figure 7(b), the fuzzy logic fails to detect the grey matter. Also, from Figure 7(c), it can be seen that the gray matter is not correctly detected but rather the white pixels are misclassified as grey matter. However, the proposed method in Figure 7(d) shows better results as the edges of the grey matter region are well detected, which is highly preserved as compared to other three benchmarked algorithms in the Figure 7. Thus, the proposed algorithm (Figure 7(d)) is able to segment the grey matter more accurately and perform better, preserving the edges of the region, and minimizing the noise and misclassification rate, as compared to other three algorithms.

The segmented CSF is shown in Figure 8 for the benchmarked and proposed algorithms. In Figure 8(a) and Figure 8(d), the k-means and proposed algorithms were able to segment the CSF with edges detected clearly. However, in Figure 8(b) and Figure 8(c), the fuzzy logic and RBF failed to segment the CSF clearly, rather have resulted in misclassified pixels. Thus, the proposed algorithm has successfully presented the best visual results in detecting and identifying the CSF edges while minimizing the misclassifications.

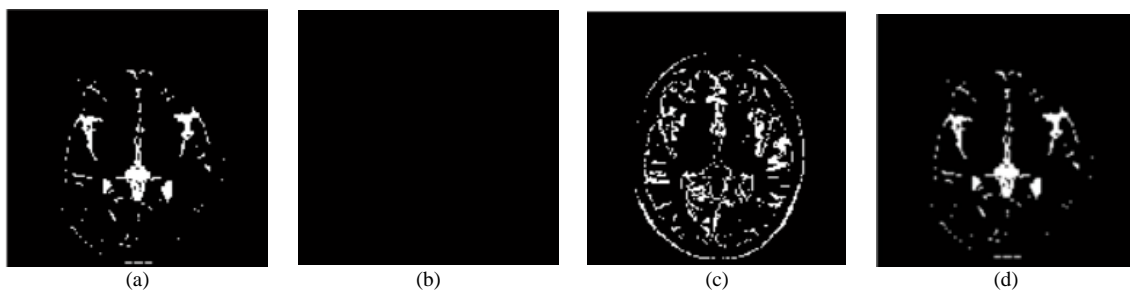


Figure 7. Gray matter region segmented by: (a) k-means, (b) fuzzy logic, (c) RBF and (d) proposed algorithm

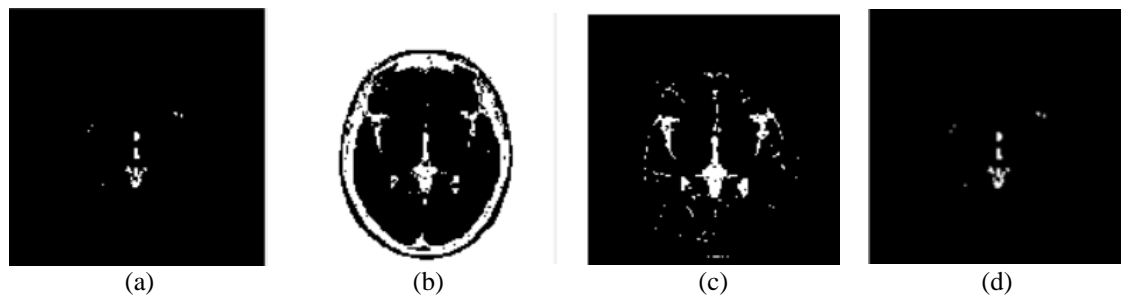


Figure 8. CSF segmented by: (a) k-means, (b) fuzzy logic, (c) RBF and (d) proposed algorithm

3.4. Performance measures

The performance of the proposed hybrid algorithm is assessed based on the following parameters: misclassification rate (MR): it calculates the rate at which the algorithms wrongly classified the brain tissues. It can be observed from the Table 1 that the MR for white matter, grey matter and CSF are 47, 26, and 48 using K-means algorithm, is 31, 65, and 35 using fuzzy logic, are 32, 27, and 33 using RBF, and 5.66, 19.05, and 5.66 using the proposed Fuzzy K-means RBF algorithm. As lower MR is better, the proposed algorithm performed the best for all 3 types of brain tissues segmentation. Percentage of clustering: it can be seen and concluded from the Table 2 that the clustering percentage for white matter, grey matter and CSF are 53, 74, and 52 using K-means algorithm, are 69, 35, and 69 using fuzzy logic algorithm, 68, 73 and 67, using RBF, and 94, 81 and 94 using the proposed improved fuzzy k-means RBF algorithm. As larger percentage of clustering is desired, the proposed algorithm was found to perform the best. Thus, it is concluded that the performance of the proposed algorithm in classifying the white, grey and CSF was better than other three benchmarked algorithms, for the given data of MRI images.

Table 1. Misclassification rate

Algorithms tested	Misclassification rate		
	White matter	Gray matter	CSF
K-means	47	26	48
Fuzzy logic	31	65	35
RBF	32	27	33
Fuzzy K-means RBF	5.66	19.05	5.66

Table 2. Percentage of clustering

Tested algorithms	Clustering percentage		
	White Matter	Grey Matter	CSF
K-means	53	74	52
Fuzzy logic	69	35	69
RBF	68	73	67
Fuzzy K-means RBF	94	81	94

4. CONCLUSION

The research paper proposes an improved method using an integrated fuzzy k-means RBF method, which is developed, simulated and evaluated. The segmentation process of brain is simulated by using the clinical MRI brain images, and the system classified the segments into three brain regions, which are: white matter, grey matter and CSF accordingly. The method was assessed and evaluated in terms of the MR and percentage of clustering. The MR was significantly minimized by the proposed system as compared to the existing algorithms; k-means, fuzzy logic, fuzzy k-means and RBF. The clustering percentage was also enhanced by the proposed integrated system as compared to the benchmarked algorithms.





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