International Journal of Electronics Engineering (ISSN: 0973-7383)
Volume 11 • Issue 2 June - Dec 2019 pp. 81-85 www.csjournals.com

Medical Image Segmentation using Fuzzy C-Means Algorithm

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Abstract: This paper reviews and compares the performance of different segmentation algorithms. Segmentation plays crucial role in analyzing medical images in medicine. The performance of the existing and proposed segmentation algorithms are compared with respect to performance evaluation measures such as Sensitivity, Precision, Accuracy, Peak Signal to Noise Ratio(PSNR), Root Mean Square Error (RMSE) and Mean Absolute Error (MAE). Adaptive Histogram Equalization (AHE) is used as pre-processing technique and Fuzzy C-Means Algorithm is used as segmentation algorithm. The proposed method were used to study the 500 CT images of neck and head to identify the disease.
Keywords: Sensitivity, Precision, Accuracy, Peak Signal to Noise Ratio(PSNR), Root Mean Square Error (RMSE) and Mean Absolute Error (MAE),Adaptive Histogram Equalization (AHE), and Fuzzy C-Means Algorithm

Introduction

Image segmentation is first step in image analysis and it divides digital image in to multiple segments. Medical Image segmentation plays very crucial role in medicine, diagnosis, and treatment. Accurate segmentation of medical images is a key step in contouring during radiotherapy planning. Computed topography (CT) and Magnetic resonance (MR) imaging are the most widely used radiographic techniques in diagnosis, clinical studies and treatment planning. The techniques available for segmentation of medical images are specific to application, imaging modality and type of body part to be studied. There is no universal algorithm for segmentation of every medical image.

Different approaches of image segmentation are broadly classified based on two properties of image.

i) Detecting Discontinuities: It includes division of image on the basis of discontinuous intensity values of pixels like in edge detection algorithm of image segmentation.

ii) Detecting Similarities: It includes partition an image on the basis of some already stated similarity criteria into set of homogeneous regions using image segmentation algorithms such as thresholding and region splitting and merging. There are many approaches to segment an image;some of these are described in the following section.

A. Intensity based approach:

This is the simplest method of image segmentation and also called as Threshold based approach. Thresholding based techniques divide the image into two parts based on discontinuity of pixels values. Thresholding can be implemented locally or globally. Other techniques used to implement thresholding are based on histogram, clustering and local adaptive segmentation. Many methods are used for thresholding e.g. maximum entropy method, Otsu's method (maximum Variance) and K-means clustering, and Fuzzy logic.There are two types of thresholding algorithmsi.eGlobal thresholding algorithms and Local or adaptive thresholding algorithms

B. Discontinuity based approach: This approach is based on the variations in the intensity value of pixels near edges and boundaries of image thus follow edge detection approach. Edge detection segmentation is done using two methodsi.eGray Histogram Technique and Gradient based method

Spatial masks can be used to detect all the three types ofdiscontinuities in an image. All the edge detection operators are grouped under two groups i.eFirst order Derivative (Prewitt operator, Sobel operator, and Canny operator) and Second order derivative (Laplacian operator and Zero-crossings).

C. Similarity based approach: This is also calledRegion Based Segmentation. These methods divide theimage into different parts based on similarity criteria.In comparison to edge detection methods these are simpleand more effective in removal of noise. Watershedtransformations related to region based similarities. Alsohistogram based segmentation works well when pixelsvalues are similar in nature throughout the image. Regionbased methods are divided into two parts i.eRegion growing method and Region split and merges method.

Literature Survey

Balpreet Kaur and Prabhpreet Kaur et.al have studied different Image segmentation techniques in both spatial and frequency domains[1]. All segmentation techniques are compared with respect to different performance evaluation measures (Structural Similarity Index (SSI), Peak Signal to Noise Ratio (PSNR) etc.,), Algorithms used, benefits and limitations.Gaps in different algorithms have been identified.

Manoj Kumar V &Sumithra M G et. alhave studied current segmentation approachesin medical image segmentation and then reviewed with an emphasis on the advantages and disadvantages of these methodsand showing the implemented outcomes of the thresholding, clustering, region growing segmentation algorithm for the brain MRI and also explained the edge detection of retinal image[2].

D. Anithadevi and K. Perusalet.al [3]haveproposed hybrid approach based imagesegmentation using the combined features of region growing and threshold segmentation technique. It isfollowed by pre-processing stage to provide an accurate brain tumor extraction by the help of MagneticResonance Imaging (MRI). If the tumor has holes in it, the region growing segmentation algorithm can'treveal but the proposed hybrid segmentation technique can be achieved and the result as well improved.Hence the result used to made assessment with the various performance measures as DICE, Jaccardsimilarity, accuracy, sensitivity and specificity. These similarity measures have been extensively used forevaluation with the ground truth of each processed image and its results are compared and analyzed.

Adegoke, B. O, Olawale, B. O, Olabisiet.al [4] have reviewed the segmentation of medical images. They examined fundamental medical image processing flow of actions, reviews available segmentation methods in literatures, their applications and brief performance. It conclusively highlight the need for development of a robust medical image segmentation method which will be able to recognize malignant growths in human body before it gets out of hand. The problem of cancerous growth as a threat to human existence is emphasized.

DeepaliAneja and Tarun Kumar Rawatet.al[5] have used fuzzy clustering algorithm for medical image segmentation. It uses only intensity values for clustering which makes it highly sensitive to noise. This algorithm executed in two scenarios– both in the absence and in the presence of noise and on two kinds of images– Bacteria and CT scan brain image. In the bacteria image, clustering differentiates the bacteria from the background and in the brain CT scan image, clustering is used to identify the abnormality region. Performance is analyzed on the basis cluster validity functions, execution time and convergence rate. Misclassification error is also calculated for brain image analysis.

Deeparani M, Kalamani M, and Krishnamoorthi M et.al have reviewed the all recent image segmentation algorithms for medical images [6]. From the recent survey, the various methods and applications of medical image segmentation are discussed [7]&[9]. The narrative of this paper is focused on different image segmentation algorithms used for computer aided diagnosis of female pelvic masses for ultrasound.

ChandniPanchasara and AmolJoglekaret.al have usedOtsu's Method, Anny edge detection algorithm, Region growing algorithm to obtain the resulting segmented image.The proposed method identified the correct image, on defective images features are already available, by comparing with segmented images [8].

AnamikaAhirwaret.alexplored the possibility of applying techniques for segmenting the regions of medical image. Region classification is an essential process in the visualization of brain tissues of MRI[10-13]. Brain image is basically classified into three regions; WM, GM and CSF. The forth region can be called as the tumor region, if the image is not normal. In the paper; Segmentation and characterization of Brain MR image regions is done using SOM and neuro fuzzy techniques. Images were tested on axial view images to classify the regions of brain MRI and compare the results from the Keith„s database. Performance of the segmentation algorithm were evaluated based on accuracy, precision, sensitivity, specificity, positive predictive value, negative predictive value, false positive rate, false negative rate, likelihood ratio positive, likelihood ratio negative and prevalence.

Proposed Method

The proposed method is implemented in three phases i.e 1) Pre-processing (Adaptive Histogram Equalization 2) Segmentation (Fuzzy C-Means Algorithm) and 3) Performance Evaluation measures.

Adaptive Histogram Equalization

It is spatial domain enhancement technique used to enhance the image so that it improves the appearance of the image based of histogram.The probability density function of the image is called histogram. The following steps are used

1. Calculate a grid size based on the maximum dimension of the image. The minimum grid size is 32 pixels square.
2. If a window size is not specified chose the grid size as the default window size.
3. Identify grid points on the image, starting from top-left corner. Each grid point is separated by grid size pixels.
4. For each grid point calculate the CDF of the region around it, having area equal to window size and centered at the grid point.
5. After calculating the mappings for each grid point, repeat steps 6 to 8 for each pixel in the input image.
6. For each pixel find the four closest neighboring grid points that surround that pixel.
7. Using the intensity value of the pixel as an index, find its mapping at the four grid points based on their CDFs.
8. Interpolate among these values to get the mapping at the current pixel location. Map this intensity to the range [min:max) and put it in the output image.

Fuzzy C-Means Algorithm

Fuzzy c-means is very important tool for image processing in clustering objects in an image and it is used to improve the accuracy of clustering under noise.Clustering is a statistical technique by which objects of similar nature are grouped together.The basic FCM algorithm is first explained for a set of data points and then the algorithm is extended to a gray-scale image. Let us assume we have a set of data points x = { x_1 , x_2, x_3, … x_m}where each point x_i = { x_1 , x_2, x_3,… x_n} is an 'n' dimensional vector. Mathematically, they form an '**n'**dimensional vector and so an **m * n** matrix. Let us assume that matrix is **A[m][n]**; Let us say, we have 'K' clusters. So the problem becomes dividing the data into **k** clusters such that the distance between the centroid and each point is minimum. Here again, the distance may be Euclidean distance (difference between the square of distances and the particular point) or the Manhattan distance (modulus of distance between the point and the centroid.)

The basic algorithm steps for FCM are,
1. Assign an initial random centroid to each cluster (Group).
2. Compute the distance between each point and the cluster centre using a simple algorithm.
3. Based on distance between each point and the cluster centre, re-compute the membership function.
4. Based on the new membership function, re-compute the centroid.
5. If the difference between the original centroid and the next one is below a certain threshold value say, €, then the algorithm stops, else it continues till this condition is true.

The steps for the FCM algorithm are illustrated as follows:

1. Initialize the fuzzy centroid(s) for the cluster(s), say c[0] = k_1, c[1]= k_2, c[2]= k_3 , …………., c[k] = k_n.

2. Calculate the distance between the respective cluster centres. Dist = | xi - Cj|
3. Update the fuzzy membership based on the distance between the cluster centre and each point in the image/ matrix. $U_{ij} = \frac{1}{\sum_{k=1}^{C}\left[\frac{\|x_i - C_j\|}{\|x_i - c_k\|}\right]^{\frac{2}{m-1}}}$
4. Calculate the centroid from the updated matrix $C_j = \frac{\sum_{i=1}^{N} U_{ij}^{m}}{\sum_{i=1}^{N} U_{ij}^{m}}$

Results and Discussion
In this research paper, 500 CT images has been studied, were provided by Head & Neck Surgery-Oncology Hospital. This paper images are enhanced using adaptive histogram equalization and segmentation is done using Fuzzy c-Means Clustering Algorithm. The performance the algorithm is compared with existing algorithms using Sensitivity, Accuracy, Precision, Peak Signal to Noise Ratio(PSNR), Root Mean Square Error(RMSE), and Mean Absolute Error (MAE).

Sensitivity: The ability of the segmentation algorithm to measure the portion of positives that are correctly identified. This is also called the true positive rate or recall. Sensitivity is measured using $\lambda_{SEN} = \frac{TP}{TP+FN}$.

Precision: The Precision or Positive Predictive Value of a segmentation algorithm is the probability that a positive outcome given that a positive classification result. The formula for PPV is given by Positive Predictive Value $\lambda_{PPV} = \frac{TP}{(TP+FP)}$.

Accuracy: Correct recognition of the segmentation algorithm is called 'accuracy'. It is also called as precision and accuracy is measured using $\lambda_{ACC} = \frac{TP+TN}{TP+TN+FP+FN}$.
Where TPs (True Positive) are the actual RBCs (Ground Truth) that have been fittingly marked. TNs(True Negative) are the non-RBCs that have been properly non marked. FPs(False Positive) are the number of non-RBCs imperfectly marked and FNs (False Negative) are the number of actual RBCs imperfectly marked.

Peak Signal to Noise Ratio (PSNR) is calculated using PNR(dB) = $10 \log_{10}(\frac{{Max_I}^2}{MSE})$

Mean Square Error (MSE) = $\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(I(i,j) - K(i,j))^2$

Root Mean Square Error (RMSE) = $\sqrt{\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(I(i,j) - K(i,j))^2}$

Mean Absolute Error (MAE) = $\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}|(I(i,j) - K(i,j)|$

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Figure 1.1: Inputimage

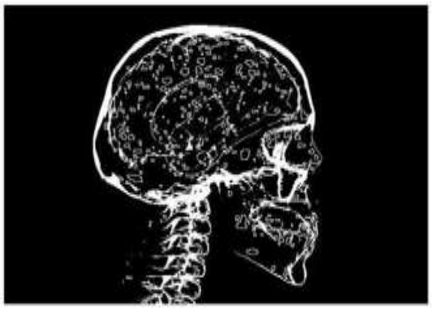

Figure 1.2: Fuzzy C-Means algorithmoutput

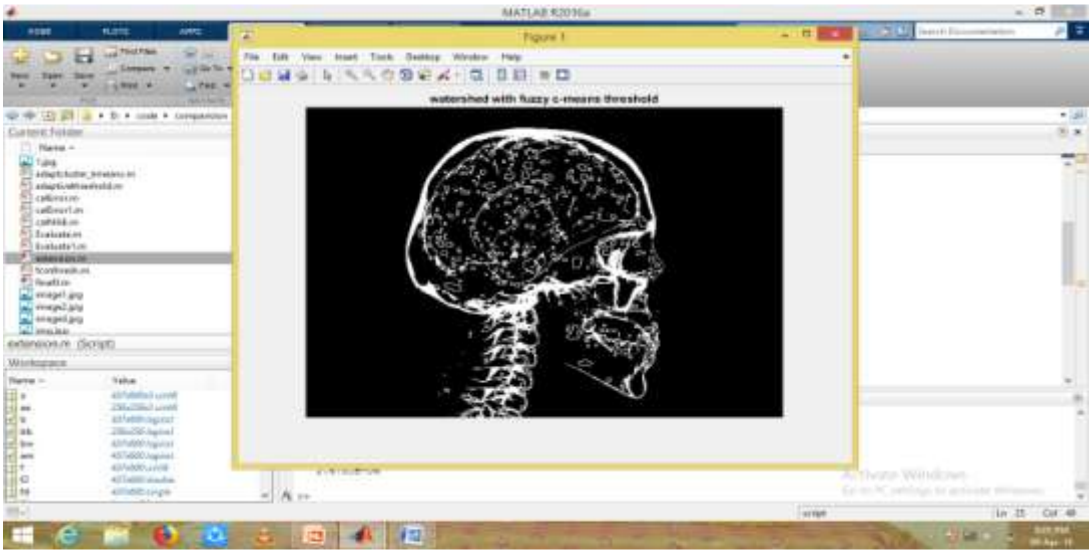

Figure 1.3: Output in MATLAB Window

The comparison between proposed method and existing methods are shown in the table 1.

S.No.	Technique	Sensitivity	Precision	Accuracy	PSNR(dB)	RMSE	MAE
1.	K-Means Clustering	89%	97.5%	87.5%	78.45	0.0413	0.0018
2.	Adaptive Thresholding	90.3%	98.3%	88.9%	78.46	0.0312	0.0019
3.	Seed based Region Growing Segmentation	76.83%	87.9%	88.8%	78.51	0.0311	0.0021
4.	Watershed Segmentation	79.67%	91.9%	87.9%	80.52	0.0211	0.0021
5.	Watershed Merge with Adaptive Color Conversion	87.97%	78.9%	98.7%	82.53	0.0156	0.0017
6.	Fuzzy C-Means Clustering (Proposed Method)	90.54%	78.9%	98.99%	85.63	0.0134	0.0016

The results of proposed method is compared with the existing method[14], Peak Signal to Noise Ratio (PSNR) increased, Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) are reduced because of pre-processing technique. And Performance evaluation measures Sensitivity, Precision &Accuracy are greatly improved by using Fuzzy C-Means algorithm.

Conclusion/Future Work

In this paper, different segmentation techniques are compared with proposed method. The performance of proposed method is improved with Adaptive histogram equalization enhancement technique and Fuzzy C-Means Threshold segmentation algorithm. The performance can be improved by using ANFIS Classifier with segmentation algorithms.

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