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Brain MRI Segmentation: A Comparative analysis

Kavita A. Ugale
M.Tech. Student Department of computer Engineering,
Vishwakarma Institute of Technology,
Pune, Maharashtra, India

Prof. Dr. S. T. Patil
Professor, Department of computer Engineering,
Vishwakarma Institute of Technology,
Pune, Maharashtra, India

Abstract— Image segmentation is an important step in medical image processing. The segmentation technology aims at partitioning the image into its constituent objects. MRI is an important diagnosis tool in medical field. MRI of brain is used to evaluate the internal structure of the brain. In this paper segmentation is performed on brain MR images using region growing and fuzzy c means algorithm. Also segmentation results of these two algorithms are compared based on various performance matrices MSE, PSNR, elapsed time, kappa index. This analysis gives an overview that on which performance parameter different algorithm can be evaluated at best. The key results shown are segmented MRI by region growing and segmented MRI using FCM algorithm with two threshold values

Keywords— MRI, region growing, FCM, image segmentation, MSE, PSNR.

I. INTRODUCTION

Image segmentation is fundamental step in Image processing. With the help of segmentation one can differentiate between the various objects or part present in that image. Segmentation technique partitions the image based on various features such as shape, color, intensity etc. Brain MRI scans frequently use to evaluate internal structure of brain. Brain MRI are not only use to discover tumor, infection and chronic diseases but also are now increasingly used to acute setting to look for bleed and stroke. The segmentation of Brain MR Images help in detecting and diagnosis of various brain diseases. Image segmentation algorithms based on gray level values, changes in gray level values and similarity between two pixels are the basis for image segmentation. Different algorithms have been proposed for segmentation of an image.

This paper covers two image segmentation algorithms that are region growing segmentation and fuzzy c-means segmentation. The comparative analysis is done on the basis of results of each methodology. The phenomenon of magnetic resonance imaging which works by finding hydrogen protons in water is also explained. The paper successfully highlights the above mentioned segmentation techniques and its results analysis .In medical imaging, automated methods for segmentation have gained importance due to its accuracy in identification. but the fact is , some of the traditional approached are still not acceptable among pathologist due to not having standardized procedures. Therefore, these approaches need to be compared to address problems of segmentation with best suitable approaches. Brain MRI dataset is used as input to these image segmentation algorithms. A comparison between seeded region growing and fuzzy c-means based on MRI segmentation is taken into account. This comparison is done based on various performance parameters such as mean square error, PSNR, Kappa index and elapsed time to figure out best method among this two. The outline of the paper is as follows. Section II explains phenomenon of magnetic resonance imaging. Section III presents Image segmentation methodology, Section IV explains region growing segmentation algorithm. Further, Section V explains fuzzy c-means segmentation technique; Section VI presents various performance parameters and comparison of segmentation algorithms based on these parameters. Finally section IX concludes the paper.

II. MAGNETIC RESONANCE IMAGING

An MRI is a safe and painless test that uses magnetic field and radio waves to produce detailed image of bain.MRI provide much greater contrast between soft tissues of body than other imaging techniques.MR image is local transverse magnetization of hydrogen nuclei which in turn depends on intrinsic properties of tissue. The Magnetic Resonance phenomenon relies on the fundamental property that protons and neutrons that make up a nucleus possess an intrinsic angular momentum called spin. When protons and neutrons combine to form nucleus, they combine with oppositely oriented spins. Thus, nuclei with an even number of protons and neutrons have no net spin, whereas nuclei with an odd number of protons or neutrons possess a net spin. Hydrogen nuclei are made up of only a single proton and thus possess a net spin. The human body is primarily fat and water, which have many hydrogen atoms. Medical MRI primarily images the magnetic Resonance signal from the hydrogen nuclei in the body tissues. The net spin of the nucleus around its axis gives it an angular moment. Since the proton is a positive charge, a current loop perpendicular to the rotation axis is also created, and as a result the proton generates a magnetic field. The joint effect of the angular moment and the self-generated magnetic field gives the proton a magnetic dipole moment parallel to the rotation axis. Under normal condition, one will not experience any net magnetic field from the volume since the magnetic dipole moments are oriented randomly and on average equalize one another. When placed in a magnetic field, a proton with its magnetic dipole moment processes around the field axis. MRI scans frequently use to evaluate internal structure of brain. Brain MRI are not only use to discover tumor, infection and chronic diseases but also are now increasingly used to acute setting to look for bleed and stroke. An MRI of the brain will evaluate Sinuses, Orbits, Bones, Brain matter, Ventricles**.**

III. IMAGE SEGMENTATION

Image segmentation is a process of subdividing an image into its constituent parts or objects in the image. The main motive of subdividing an image into its constituent objects is that we can further analyze each of these objects or our region of interest in the image once they are identified or we have subdivided them. So, each of this constituents can be analyzed to extract some information so that those information are useful for high level machine vision applications. Generally the level of segmentation is application dependent.

There are two approached on which segmentation of an image is carried out. First approach is based on discontinuity and second based on similarity. In discontinuity based approach partition of an image is carried out on the basis of some abrupt changes in intensity levels in an image. Here, main focus is identification of points, lines, edges etc. In similarity based approach pixels are grouped together according to homogeneity criterion. Image segmentation groups the homogeneous region based on pixel characteristics like gray level, color, texture, intensity and other features. Image data has a practical importance in medical field. In medical image analysis image segmentation identifies the boundaries of objects such as organs or abnormal regions (e.g. tumors).segmentation results make it possible for shape analysis, detecting volume changes, making precise radiation therapy treatment plan. In case of brain structure accurate classification of MRI according to tissue type at voxel level is needed. As brain structure is defined by boundaries of constituent tissues, thus accurate segmentation is important step in qualitative study. In this paper we review two segmentation algorithms that are Region growing segmentation and Fuzzy c-means segmentation.

IV. REGION GROWING SEGMENTATION

Region growing segmentation is the procedure which groups the pixels or sub-regions into a larger region based on some predefined criterion. Region growing works on principal of homogeneity. The main objective is to produce homogeneous regions. Algorithms assume that region must be connected with some predefined criteria. A seed point is collected or selected based n user criterion (pixel in certain grayscale ranges). Regions are then grown from seed point to adjacent points depending on region membership criteria for example pixel intensity. Algorithm start from single pixel(also called seed point)and try to find other pixels. Every pixel is compared with its neighbor for similarity check Such as gray level, texture, color, shape. If the result is positive, then that particular pixel is "added" to the pixel set and a region is "grown" in this manner. The growing is stopped when the similarity test fails.

If R represents an image, then the image segmentation is simply division of R into sub regions R1,R2…..Rn , such that

$$R = \bigcup_{i=1}^{n} R_i$$

and is governed by following set of rules:

a) Ri is a connected set, i=1,2,…..n.
b) Ri ∩ Rj = Ø for all i and j, i ≠ j
c) Q(Ri) = True for i= 1,2,…n.
d) Q(Ri U Rj) = False for adjoint regions, Ri and Rj .

Where Q(Rk) is a logical predicate**.** The rules described above mentions about continuity, one-to-one relationship, homogeneity and non-repeatability of the pixels after segmentation respectively.

The steps in RG algorithm can be as follows:

1. Determine seeds to start the segmentation process.
2. Determine the criteria to grow the region. In case of multiple regions, clearly the characteristic of regions should be mentioned. So that no ambiguity exists to place the pixel in particular region.
3. The candidate pixels to include in the region it should be 8-connected to at least` one of the pixel in the region.
4. Cross-check is to be done to ensure all the pixels are tested for allocation and then label has to be given to all regions.
5. If two different regions get same label then they have to be merged.

V. FUZZY C-MEANS SEGMENTATION

Fuzzy clustering is a unsupervised method for the analysis of data. Fuzzy clustering is more natural than hard clustering. Objects on the boundaries between several classes are not forced to fully belong to one of the classes, but rather are assigned membership degrees between 0 and 1 indicating their partial membership [1, 2]. Fuzzy c-means algorithm is most widely used in case of hard dataset. The FCM employs fuzzy partitioning such that a data point can belong to all groups with different membership grades between 0 and 1. This algorithm works by assigning membership to each data point corresponding to each cluster center on the basis of distance between the cluster center and the data point. More the data is near to the cluster center more is its membership towards the particular cluster center. Clearly, summation of membership of each data point should be equal to one. After each iteration membership and cluster centers are updated according to the formula.

Fuzzy c-means Algorithm:

1. Initialize $U = [i, j]$ matrix, $U^{(0)}$

2. At k-step: calculate center vectors $c^k = \lfloor c_j \rfloor$ with $U^{(k)}$ $c_{ij} = \frac{\sum_{j=1}^{n} u_{ij}^m x_j}{\sum_{j=1}^{n} u_{ij}^m}$
3. Update $U^{(k)}, U^{(k+1)}$
4. $d_{ij} = \sqrt{\sum_{i=1}^{n}(x_i - c_i)}$

$$u_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{d_{ij}}{d_{kj}}\right)^{2/(m-1)}}$$

5. If $\|U(k+1) - U(k)\| < \varepsilon$ then STOP; otherwise return step 2.

VI. RESULTS

The above segmentation algorithm works as follows. Result of region growing segmentation shown in fig.1 and Two results are shown for fuzzy c-means segmentation with two different threshold levels.

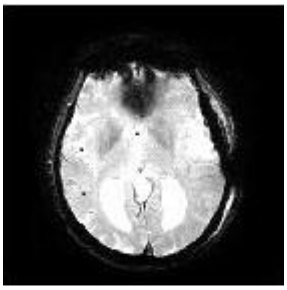

Fig. 1 Input MR image of brain

Fig.1 segmented MRI image using Region growing segmentation

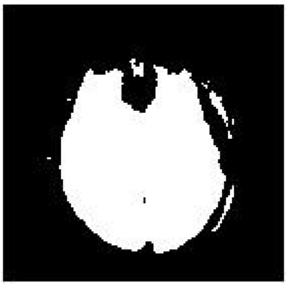

Fig. 3 segmented MRI image using fuzzy c-means segmentation with threshold level=0.224426

Fig. 4 segmented MRI image using fuzzy c-means segmentation with threshold level=0.606472

VII. PERFORMANCE PARAMETER

In order to know the efficiency of the above methods we use parameters like Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Root Mean Square (RMS), Elapsed time, Kappa index.

A. MSE:

For an m*n image the MSE can be calculated as:

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]^2$$

Where I (i, j) is input image and K (i, j) is output image. The value of MSE should always be less than PSNR. Lower the value of MSE of an image means less error and high quality of the image. PSNR and MSE are inversely proportional to each other.

B. PSNR is defined

$$PSNR = 10.\log_{10}\left(\frac{MAX_1^2}{MSE}\right)$$
$$= 20.\log_{10}\left(\frac{MAX_1}{\sqrt{MSE}}\right)$$
$$= 20.\log_{10}(MAX_1) - 10.\log_{10}(MSE)$$

Higher the PSNR values, better the quality of image. If PSNR value is above 30, that means the output has hundred per cent image clarity. The unit of PSNR is dB (decibel). It takes from 0 to infinity.

C. Elapsed time

Elapsed time is time taken to retrieve the segmented area from the input image. This method is calculated by tic and toc methods in mat lab.

E. Kappa index

For an image the kappa coefficient can be calculated as:

$$\kappa = \frac{Pr(a) - Pr(e)}{1 - Pr(e)}$$

VIII. COMPARISON

The below section shows the outputs of segmentation methods applied on different MR images. To show the efficiency of each methods we will use six parameters like peak signal to noise ratio, mean square error, elapsed time, kappa index, root mean square and accuracy. The comparison tables are shown below.

A. Test Results 1

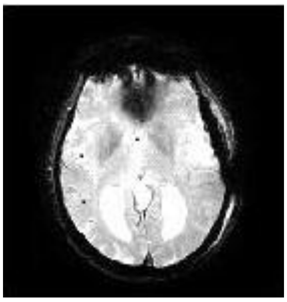

Fig. 5 Input MR image of brain

TABLE I COMPARISON TABLE OF SEGMENTATION METHODS FOR INPUT IMAGE IN FIG.5

Segmentation	***PSNR***	***MSE***	***Elapsed Time***	***Kappa index***
Region Growing	19.8252	682.2731	131.5502	2.9909e-04
Fuzzy c-means	6.7232	1.3937e+04	4.4317	0.0403

B. *Test Results 2*

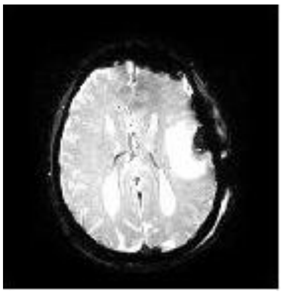

Fig. 6 Input MR Image of brain

TABLE III COMPARISON TABLE OF SEGMENTATION METHODS FOR INPUT IMAGE IN FIG.6

Segmentation	*PSNR*	*MSE*	*Elapsed Time*	*Kappa index*
Region Growing	22.6861	353.0790	133.5842	4.2762e-05
Fuzzy c-means	6.7364	1.3894e+04	5.2794	0.0394

C. Test results 3:

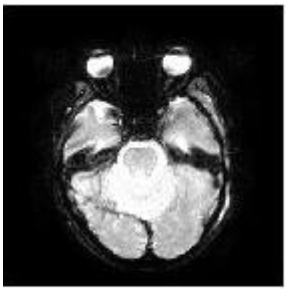

Fig. 7 Input MR image of brain

TABLE IIIII COMPARISON TABLE OF SEGMENTATION METHODS FOR INPUT IMAGE IN FIG.7

Segmentation	**PSNR**	**MSE**	**Elapsed Time**	**Kappa index**
Region Growing	24.3941	238.2687	131.1926	-4.1875e-04
Fuzzy c-means	8.2577	9.7883e+03	6.5570	0.0657

The above comparisons show the qualitative result parameters when compared to these methods. When the PSNR values are high and MSE values are less than the segmentation process gives good results. Elapsed time gives us how much time it takes for a segmentation method to generate the output. Less elapsed time gives us good result. Kappa coefficient parameter gives another efficient method for segmentation process. Kappa Coefficient values should lie between 0 to 1.

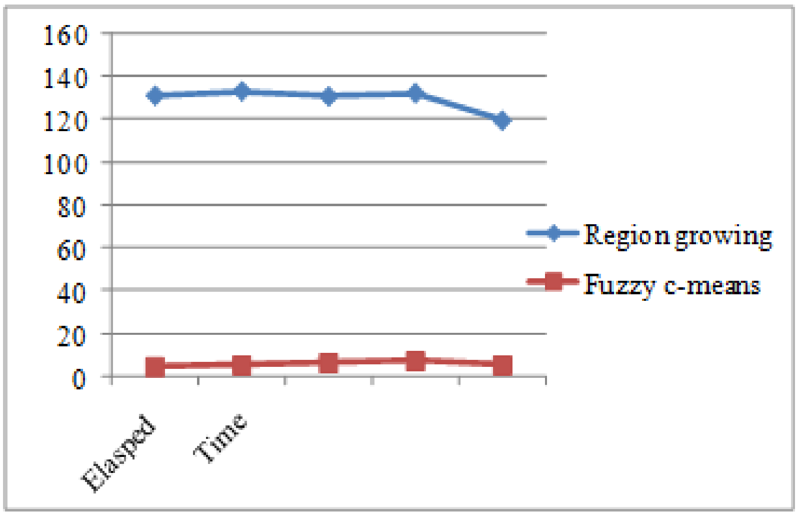

Fig. 8 Elapsed Time comparison between region growing and FCM

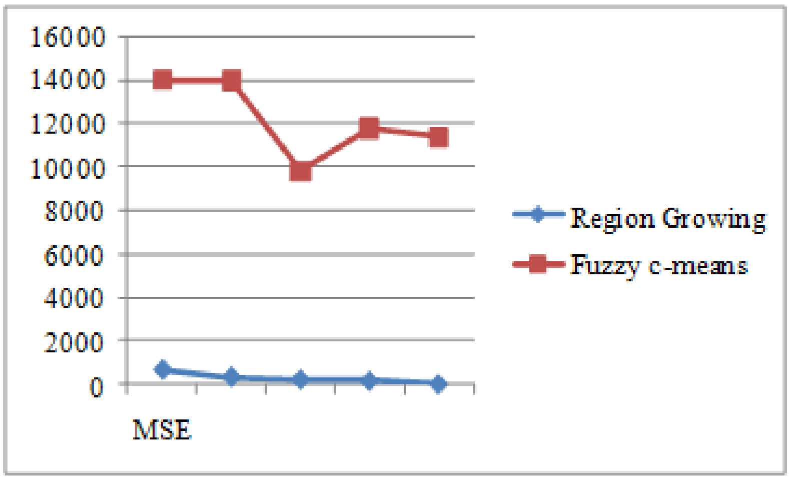

fig.9 MSE comparison between region growing and FCM

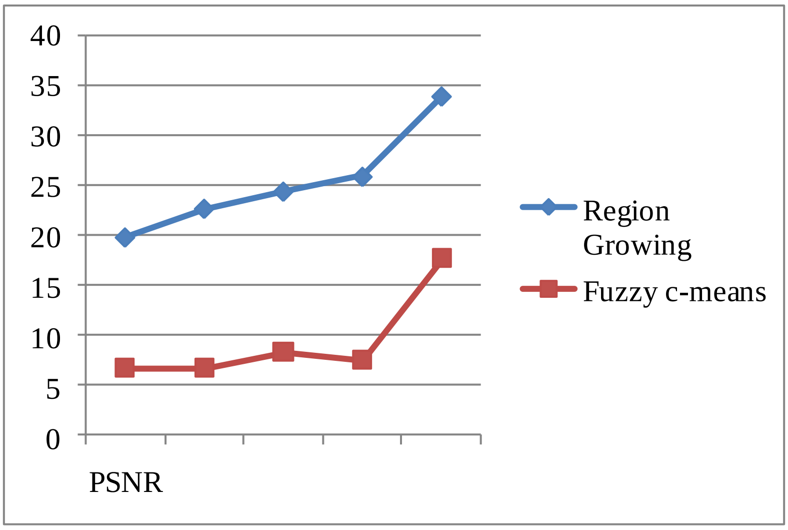

Fig.10 PSNR comparison between region growing and FCM

IX. CONCLUSIONS

Image segmentation has crucial role in medical image analysis. Region growing and FCM is used for image processing in various fields. Segmentation is used as per the convenience of application. Region growing and FCM are used for Brain MRI scanning and are well known for their own advantages. Comparison between them shows the advantages and disadvantages according to various performance parameters on which these algorithms are evaluated. From this comparison, FCM is the fastest algorithm as compared to the region growing but region growing gives the better clear results than FCM. FCM is best in MSE parameter where as Region growing is best in PSNR parameter.

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