Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IJCSMC, Vol. 2, Issue. 11, November 2013, pg.261 – 269

RESEARCH ARTICLE

Comparison Study of Segmentation Techniques for Brain Tumour Detection

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Abstract— Image segmentation plays an important role in diagnosis and treatment of diseases. Image segmentation locates objects and boundaries with in images and the segmentation process is stopped when region of interest is separated from the input image. Based on the application, region of interest may differ and hence none of the segmentation algorithm satisfies the global applications. Thus segmentation still remains a challenging area for researchers. This paper emphasis on comparison study of segmentation techniques for segmenting brain tumour from MRI images. The tumour area is identified by using different algorithms like seeded region growing and merging, K-Means, KNN, fuzzy C-Means and a comparative study of all this methods is presented here.

Keywords— Brain tumour; MRI images; Edge detection; Image segmentation; Fuzzy C-Mean; K-Means; KNN

I. INTRODUCTION

A brain tumour is an abnormal growth of tissue in the brain or central spine that can disrupt proper brain function. Doctors refer to a tumour based on where the tumour cells originated, and whether they are cancerous (malignant) or not (benign).There are various types of tumours such as **Benign**: The least aggressive type of brain tumour is often called a benign brain tumour. They originate from cells within or surrounding the brain, do not contain cancer cells, grow slowly, and typically have clear borders that do not spread into other tissue. **Malignant**: Malignant brain tumours contain cancer cells and often do not have clear borders. They are considered to be life threatening because they grow rapidly and invade surrounding brain tissue. **Primary**: Tumours that start in cells of the brain are called primary brain tumours. Primary brain tumours may spread to other parts of the brain or to the spine, but rarely to other organs. **Metastatic**: Metastatic or secondary brain tumours begin in another part of the body and then spread to the brain. These tumours are more common than primary brain tumours and are named by the location in which they begin.[2]

There are over 120 types of brain and central nervous system tumours. Brain and spinal cord tumours are different for everyone. They form in different areas, develop from different cell types, and may have different treatment options.

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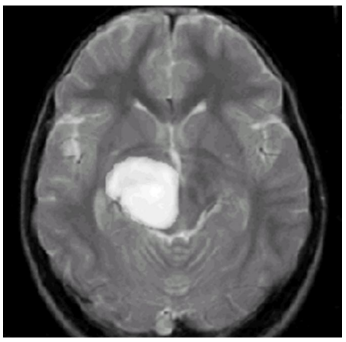

Fig. 1 Example of an MRI showing the presence of tumour in the brain

Radiologists examine the patient physically by using Computed Tomography (CT scan) and Magnetic Resonance Imaging (MRI). MRI images show the brain structures, tumour's size and location. From the MRI images the information such as tumours location provides radiologists, an easy way to diagnose the tumour and plan the surgical approach for its removal. The accurate estimation of tumour size is important for clinical reasons, e.g., for treatment planning and therapy evaluation.Edge-based method is by far the most common method of detecting boundaries, discontinuities in an image and segmentation. Here we present a comparative study (review) of different approaches used for medical image segmentation with their respective results. One way to obtain an estimate of tumour volume is via segmentation. Tumour segmentation can be done using several techniques such as Region growing ([8], [9], [10], [11], [29]), Fuzzy methods ([2], [4], [15]), K-Mean Clustering ([4], [7]) etc.

II. IMAGE SEGMENTATION TECHNIQUES

Several general-purpose algorithms and techniques have been developed for image segmentation, like region growing and merging algorithm, K-NN algorithm, K-Means algorithm, Fuzzy C-means algorithm. Segmentation is done using clustering technique, which separates the vessel structure from background. So the goal is to search for best algorithms that can be used to segment medical images. Brain tumour detection on MRI images is the main task. Tumour detection is done by various segmentation techniques as described in the following sections.

A. Seeded region growing approach for proposed method

For region growing start by choosing an arbitrary seed pixel and compare it with neighbouring pixels Region is grown from the seed pixel by adding in neighbouring pixels that are similar, increasing the size of the region. Seeds for different regions must be disconnected. Similarity of the pixel to its neighbours is calculated as follows

$$\sigma_x = \sqrt{\frac{1}{9}\sum_{i=1}^{9}(x_i - \overline{x})^2}$$

Two pixels can be grouped together if they have the same intensity characteristics or if they are close to each other [1].

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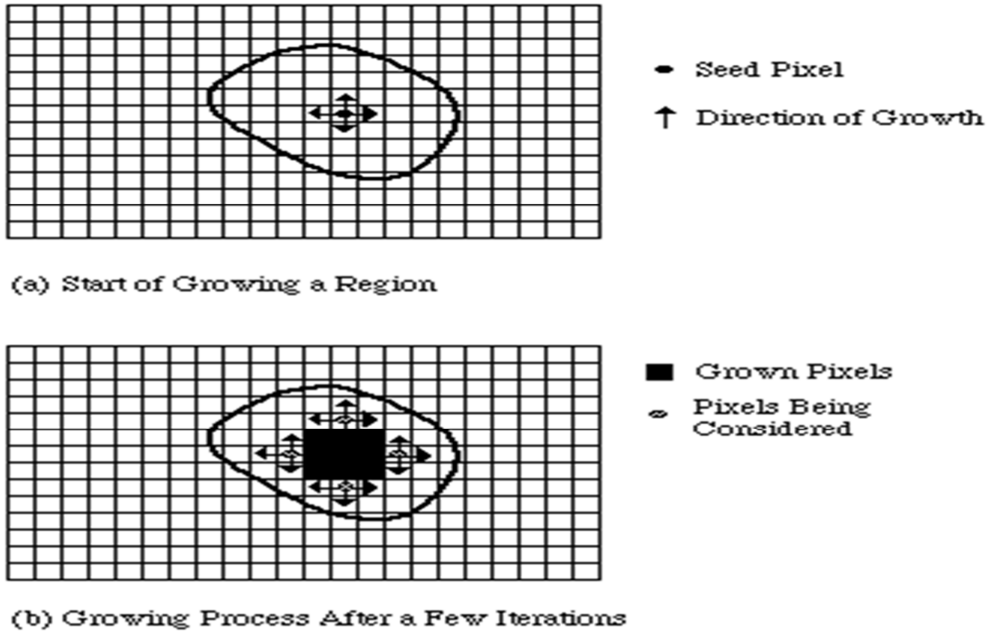

Fig. 2 Example of region growing

The main disadvantage of region growing approach is that it often requires a seed point as the starting point of the segmentation process. This requires user interaction. Due to the variations in image intensities and noise, region growing can result in holes and over segmentation. Thus, it sometimes requires post-processing of the segmentation result.

B. K-Means segmentation

In the K-Means algorithm initially define the number of clusters k. Then k-cluster center are chosen randomly. The distance between the each pixel to each cluster centers are calculated by using Euclidean function. Single pixel is compared to all cluster centers using the distance formula. The pixel is moved to particular cluster which has shortest distance among all. Then the centroid is re-estimated. Again each pixel is compared to all centroids. The process continues until the center converges **[4] [7]**.

C. Fuzzy c-means segmentation

Fuzzy c-means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters. FCM algorithm improves the accuracy under noise. It is based on minimization of the following objective function:

$$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^{m} \left\| x_i - c_j \right\|^2 , \quad 1 \le m < \infty$$

where m is any real number greater than 1, u_{ij} is the degree of membership of x_i in the cluster j, x_i is the i^{th} of d-dimensional measured data, c_j is the d-dimension center of the cluster, and ||*|| is any norm expressing the similarity between any measured data and the center.

Fuzzy partitioning is carried out through an iterative optimization of the objective function shown above, with the update of membership uij and the cluster centers c_j by:

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$$u_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right)^{\frac{2}{m-1}}}, \quad \max_{ij}\left\{\left|u_{ij}^{(k+1)} - u_{ij}^{(k)}\right|\right\} < \varepsilon$$

This iteration will stop when there is a termination criterion between 0 and 1, whereas *k* is the iteration steps. This procedure converges to a local minimum or a saddle point of *Jm[4]*.

D. KNN (Nearest Neighbour) segmentation

K-Nearest Neighbour (KNN) classification technique is the simplest technique that provides good classification accuracy. The KNN algorithm is based on a distance function and a voting function in K-Nearest Neighbour's, the metric employed is the Euclidean distance, Hamming distance, Minkowski distance. The KNN has higher accuracy and stability for MRI data than other common statistical classifiers, but has a slow running time.

Segmentation of brain tumor by KNN:

1) Euclidian distance: This is used as distance function due to its simplicity.

2) Hamming distance: This method detects edges in the image. The Hamming distance is a metric on the vector space of the words of length n, as it fulfils the conditions of non-negativity, identity of indiscernible and symmetry .It can be shown by complete induction that it satisfies the triangle inequality.

3) Minkowski distance: This is a metric on Euclidean space which can be considered as a generalization of both the Euclidean distance and the Manhattan distance.

4) Cosine similarity: This detects intense parts of the tumour.

III. RESULTS AND DISCUSSION

The above segmentation algorithms detects brain tumour in the following ways.

A. Seeded region growing approach

Fig. 3 shows the extracted tumour shape from the given image using the seeded region growing approach.

Start by choosing an arbitrary seed pixel and compare it with neighbouring pixels Region is grown from the seed pixel by adding in neighbouring pixels that are similar, increasing the size of the region.

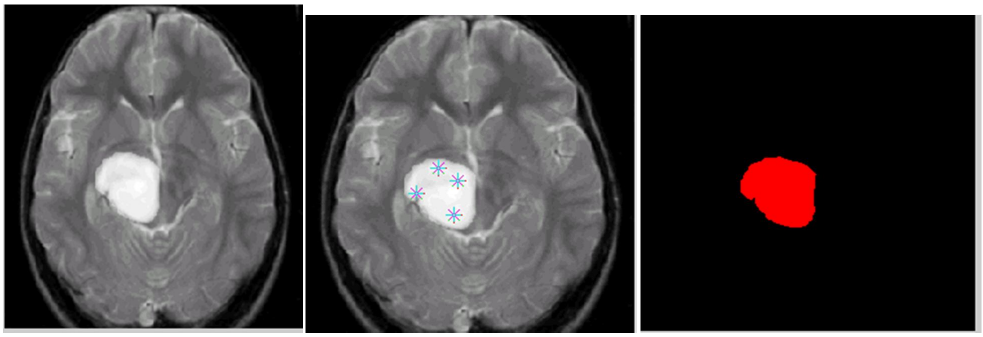

Fig. 3 Region growing segmentation on MRI image

When the growth of one region stops we simply choose another seed pixel which does not yet belong to any region and start again. This whole process is continued until all pixels belong to some region and the borders of regions found by region growing are perfectly thin and connected.

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B. K-Mean Clustering Algorithm [4]

Fig. 4 is the MRI image given as input to the pre-processing

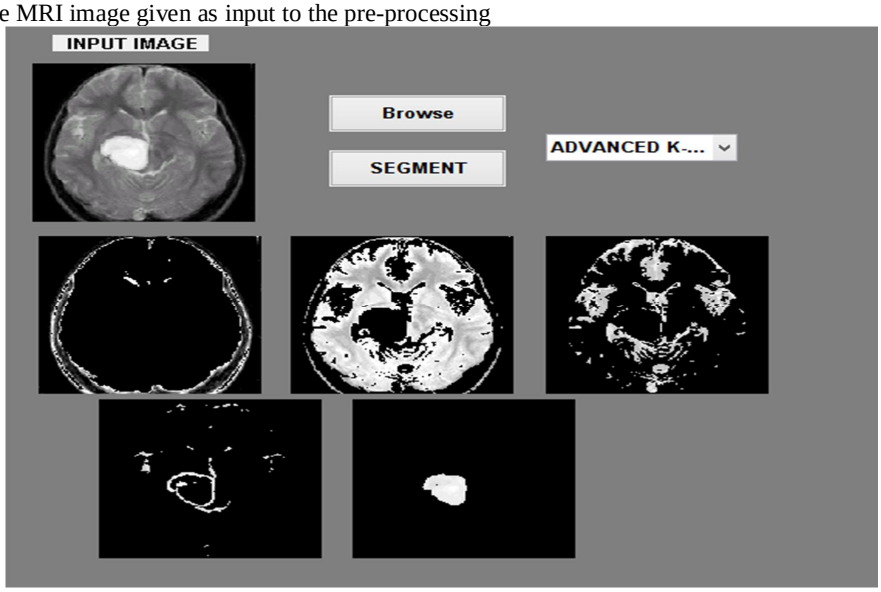

Fig. 4 Output for K-Means algorithm with five clusters. At the fifth cluster the tumor is extracted.

C. Fuzzy C-Means:

Fig. 5 is the output image for Fuzzy C-Means. It is developed for the accurate prediction of tumour cells which are not predicted by K-means algorithm. It gives the accurate result when compared to the K-Means.

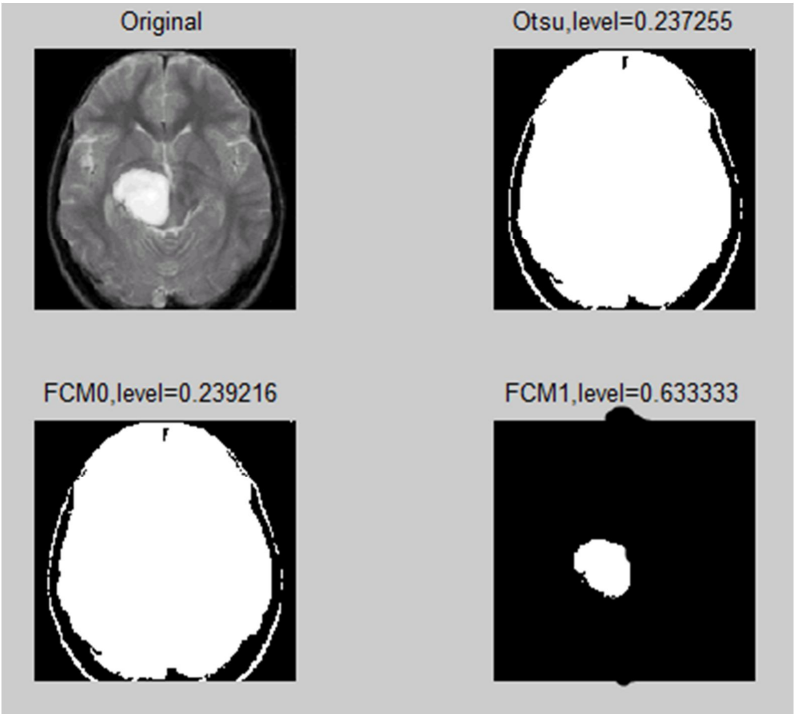

Fig. 5 Output for Fuzzy C-Means

D. KNN

Fig. 6 is the MRI image given as input. Here 0.02% of salt and pepper noise is added and that has been removed using the median filter. In this method the following parameters, Euclidian, hamming, Minkowski, cosine transformation are used in order to extract brain tumour.

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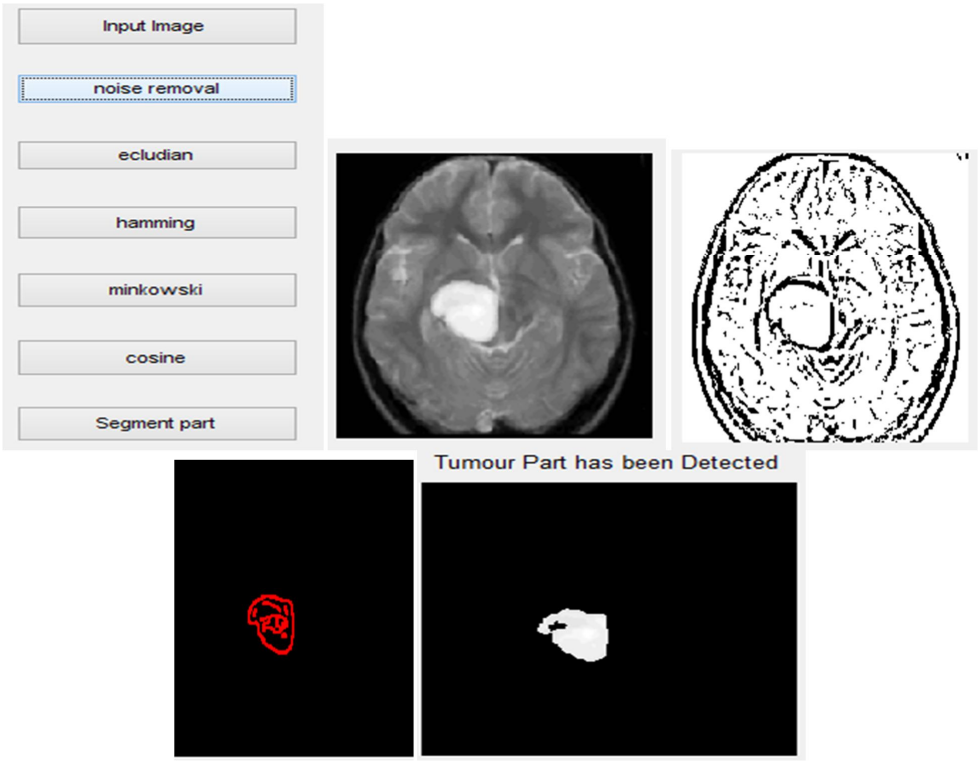

Fig. 6 Output for KNN

IV. PERFORMANCE ANALYSIS

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 and Accuracy.

A. MSE:

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

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

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

$$\begin{aligned} PSNR &= 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) \\ &= 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \\ &= 20 \cdot \log_{10}(MAX_I) - 10 \cdot \log_{10}(MSE) \end{aligned}$$

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.

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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.

D. Accuracy

In numerical analysis, accuracy is the nearness of a calculation to the true value; while precision is the resolution of the representation, typically defined by the number of decimal or binary digits.

$$\text{accuracy} = \frac{\text{number of true positives} + \text{number of true negatives}}{\text{number of true positives} + \text{false positives} + \text{false negatives} + \text{true negatives}}$$

An accuracy of 100% means that the measured values are exactly the same as the given values. Accuracy may be determined from Sensitivity and Specificity, provided Prevalence is known, using the equation:

Accuracy = (sensitivity)/(prevalence) + (Specificity)(1-prevalence)

$$O^c = \frac{\sum_{i=1}^{k} n_{ii}}{|T|}$$

Where |T|, being the number of pixels being tested.

E. Kappa index

For an image the kappa coefficient can be calculated as

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

V. EFFICIENCY

The below section shows the outputs of segmentation methods applied on different tumour images where the tumour has been detected. To show the efficiency of the methods we will use six parameters like peak signal to noise ratio, mean square error, elapsed time, kappa index, root mean square and accuracy.

A. Test Results 1

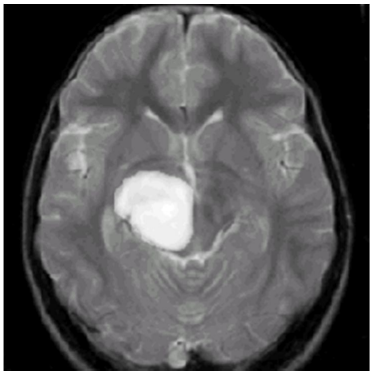

Fig. 7 MRI Input Image 1

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

Segmentation	PSNR	MSE	Elapsed time	Kapa value	Accuracy
k-means	33.27	30.59	3.58	0.305	3.0234e+004
Fuzzy C-means	34.13	1.5472e-004	7.25	0.625	0.0025
K-NN	41.908	1.357	2.980	0.805	3.262

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B. Test Results 2

Fig. 8 MRI Input Image 2

TABLE II
COMPARISON TABLE OF SEGMENTATION METHODS FOR INPUT IMAGE IN FIG. 8

Segmentation	PSNR	MSE	Elapsed time	Kapa value	Accuracy
k-means	27.21	123.41	3.41	1.023	1.318e+004
Fuzzy C-means	37.21	5.1317e-005	4.74	0.252	0.0020
K-NN	42.178	1.273	2.905	0.573	3.696

C. Test Results 3

Fig. 9 MRI Input Image 3

TABLE IIII
COMPARISON TABLE OF SEGMENTATION METHODS FOR INPUT IMAGE IN FIG.9

Segmentation	PSNR	MSE	Elapsed time	Kapa value	Accuracy
k-means	27.37	11.88	3.14	1.18	1.1945e+004
Fuzzy C-means	37.42	6.0509e-005	4.70	0.267	0.0023
K-NN	42.209	1.264	3.050	0.592	8.205

The above comparisons show the qualitative result parameters when compared to various 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.Greater the accuracy value more efficient the segmentation process.

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VI. CONCLUSION

From the comparative study it is observed that K-Nearest Neighbour segmentation method is an efficient method for brain tumour detection when compared to other methods. This K-NN method offers an automated and fully reproducible approach that accurate and applicable on standard clinical MRI images. The experiments and results show that our proposed method not only reduces the complexity of the K-NN, also it improves the classification accuracy.

In this study we observe some disadvantages with K-Means segmentation and Fuzzy C-Means segmentation. We can focus on future works for these disadvantages. We can implement an algorithm of K-Means with more clusters in order to improve efficiency. Future work of Fuzzy segmentation will focus on adaptively deciding the penalized parameter of this algorithm as well as compensating for the intensity inhomogeneity while segmenting the image data.

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Vol 2, No.6, 2012

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