Comparison of Standard Image Segmentation Methods for Segmentation of Brain Tumors from 2D MR Images

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***Abstract*- In the analysis of medical images for computer-aided diagnosis and therapy, segmentation is often required as a preliminary step. Medical image segmentation is a complex and challenging task due to the complex nature of the images. The brain has a particularly complicated structure and its precise segmentation is very important for detecting tumors, edema, and necrotic tissues in order to prescribe appropriate therapy. Magnetic Resonance Imaging is an important diagnostic imaging technique utilized for early detection of abnormal changes in tissues and organs. It possesses good contrast resolution for different tissues and is, thus, preferred over Computerized Tomography for brain study. Therefore, the majority of research in medical image segmentation concerns MR images. As the core juncture of this research a set of MR images have been segmented using standard image segmentation techniques to isolate a brain tumor from the other regions of the brain. Subsequently the resultant images from the different segmentation techniques were compared with each other and analyzed by professional radiologists to find the segmentation technique which is the most accurate. Experimental results show that the Otsu's thresholding method is the most suitable image segmentation method to segment a brain tumor from a Magnetic Resonance Image.**

I. INTRODUCTION

The image segmentation process can be considered as one of the basic, yet very important, steps in digital image processing and computer vision applications. The extraction of objects from the background of a digital image has been a challenging task in the field of digital image processing. With the increasing demand for complex image analysis and interpretation, the demand for accurate segmentation of images has also grown stronger and as a result many image segmentation methods and algorithms have been developed over the past few decades.

Segmentation involves partitioning an image into a set of homogeneous and meaningful regions so that the pixels in each partitioned region possess an identical set of properties or attributes. Segmentation algorithms are based on different parameters of an image like gray-level, color, texture, depth or motion. In medical images, segmentation is mainly done based on the gray-level value of pixels, because the majority of medical images are gray-scale representations. Image segmentation algorithms based on gray-level values of pixels of an image can be divided into two categories: those based on similarity and those on discontinuity. The former method involves segmenting an image based on the similarity of intensity between pixels within a region, while the latter uses sudden changes in gray-level to indicate the discontinuity of a region.

Medical imaging techniques like Magnetic Resonance Imaging (MRI), Computerized Tomography (CT), Ultrasound (US) and Positron Emission Tomography (PET) are the tools used for extraction of vital information by medical field specialists. Thus, accurate segmentation which aid in image analysis and unerring diagnosis is of immense importance.

Compared to other medical imaging techniques, Magnetic Resonance Imaging has the benefit of having excellent contrast between soft tissues. But, because of the convoluted nature of the regions of interest, accurate segmentation of these regions is still a challenging task.

Since MR images are gray level images the segmentation algorithms used in this study are gray-level image segmentation algorithms. The resultant segmented images were analyzed to determine the most accurate image segmentation algorithm for the segmentation of a brain tumor from 2D MR images.

II. ANALYSIS METHODS

All MR images were acquired from the Teaching Hospital Kandy, Sri Lanka. The algorithms were implemented and tested on a personal computer with a CPU 1.83GHz Intel Core 2 Duo using MATLAB as the programming language.

As a preliminary study, a set of different segmentation algorithms were implemented. Image segmentation by Expectation maximization [1,2], Fuzzy c-means [3,4], K-means [3], and mean-shift segmentation [5,6] were among the clustering methods chosen. Iterative thresholding and Otsu's method [7] were chosen as thresholding methods and a seeded region growing method [8] using pixel intensities were also experimented. Clustering, thresholding and region growing methods were selected because image segmentation using the gray-level value of images is performed mainly using these methods.

The k-means clustering method classifies the pixels in the image into a predefined number of classes or clusters such that each pixel belongs to only one cluster. In other words it employs hard partitioning. The Fuzzy c-means clustering method on the other hand employs fuzzy partitioning of the pixels allowing a pixel to belong to two or more clusters where the number of clusters is predefined. The mean shift algorithm estimates the local density gradient of similar pixels in the image. These gradient estimates are used in an iterative procedure to find the peaks in the local density. All pixels that are drawn upwards to the same peak are then considered to be members of the same segment. The Otsu's method, the only thresholding method chosen from the preliminary study, assumes that the image contains two classes of pixels, foreground and background. Then calculates the optimum threshold separating those two classes so that their combined spread (intra-class variance) is minimum.

A set of raw MR images were segmented using the above mentioned algorithms. A questionnaire was prepared to assess the different methods on their performance of isolating the tumor from each of the MR images. The questionnaires were given to consultant radiologists to be completed. Each of the algorithms was scaled from 1 to 10 according to the accuracy of the segmentation of the tumor. Scale 10 was given when the segmentation was perfect while the scale 1 was given when the segmentation accuracy was unacceptable.

From this initial study, all the algorithms where the average accuracy was greater than 5 were selected for further study. According to the above criteria, we discovered that the Otsu's method [7], mean-shift segmentation algorithm [5, 6], K-means [3], Fuzzy c-means [3, 4] performed well in segmenting a brain tumor from a 2D MR image.

In the next stage of the comparison, 10 MR images were manually segmented in the presence of a consultant radiologist and the correct boundary of the brain tumors were identified to obtain a ground truth. The selected images were of the same quality but with tumors of different shapes and sizes. Then, for detailed analysis the amount of false negatives and the amount of false positives of all resultant images with respective to the ground truth were calculated in terms of the number of pixels of the tumor region. First a logical AND operation was performed between the ground truth and the resultant image to obtain the true positive image. Next the difference between the ground truth image and the true positive image was taken as the false negative image of the respective segmented image. The difference between the segmented image and the true positive image was taken as the false positive image of the respective segmented image.

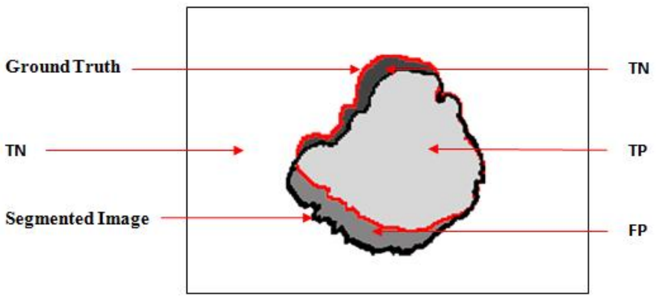

Fig. 1. Ground truth region of tumor (Red) and segmented tumor region (Black)

The number of pixels from the true positive image, the false negative image and the false positive image were taken as TP, FN and FP respectively.

From this study the completeness [9] and correctness [9] of the segmented images were determined. Completeness can be defined as the percentage of the ground truth region extracted by the segmentation algorithm and can be calculated using (1).

$$completeness = \frac{TP}{TP + FN} * 100\% \tag{1}$$

Correctness can be defined as the percentage of correctly extracted region (ground truth) by the segmentation algorithm and can be calculated using (2).

$$correctness = \frac{TP}{TP + FP} * 100\% \tag{2}$$

III. Experimental Results

The degree of accuracy of the segmentation for each image was decided by comparison of the area of the brain tumor of the segmented image with that of the original image estimated by the physician. Then the average level of accuracy for each algorithm was calculated.

Table I shows the results obtained from the preliminary study done through visual comparison of the images.

TABLE I
RESULTS FROM THE PRELIMINARY STUDY

Segmentation Method	Degree of Accuracy of the Segmentation (out of 10)
Otsu's method	8.1
Mean Shift	6.1
K-means	6.0
Fuzzy c-means	5.2
Expectation maximization	4.5
Discrete Topological Derivative	4.2
Continuum Topological Derivative	3.9
Iterative thresholding	3.8
Two Seed Region Growing	2.2
One Seed Region Growing	2.2

From these results the Otsu's method, mean-shift segmentation algorithm, K-means and Fuzzy c-means clustering were chosen for further study.

The original MR images shown in Fig. 2(a) are of 256 × 256 pixel size. In Fig. 2(c), Fig. 2(d) and Fig. 2(e), the tumor regions segmented by the clustering methods mean-shift, K-means, and Fuzzy c-means, respectively, are shown. The tumor regions were manually isolated from the segmented images. In Fig. 2(f) the tumor area of the resultant image from the Otsu's method is shown.

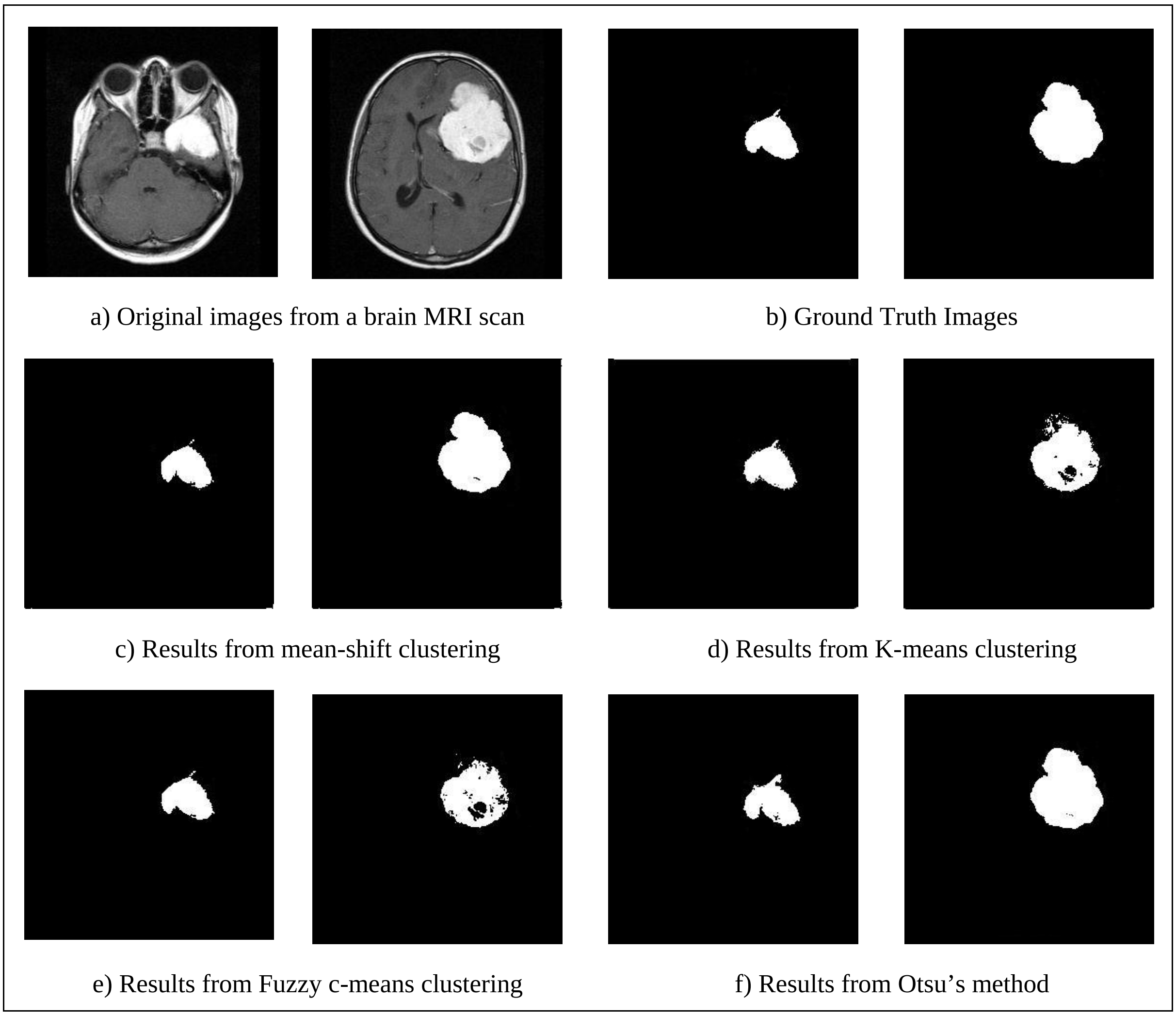

Fig. 2. (a) Original MR images taken along the axial plane (b) Manually segmented images used as ground truth (c) Isolated tumor regions of the segmented images using mean-shift clustering (d) Isolated tumor regions of the segmented images using k-means clustering (e) Isolated tumor regions of the segmented images using fuzzy c-means clustering (f) Isolated tumor regions of the segmented images using Otsu's method.

Table II shows the completeness and the correctness of the four, image segmentation methods mentioned above.

TABLE II
COMPLETENESS AND CORRECTNESS OF SEGMENTATION

Segmentation Method	Completeness of the Segmented Images (%)	Correctness of the Segmented Images (%)
Mean-Shift	94.2	99.7
K-Means	98.3	96.4
Fuzzy C-Means	78.6	99.9
Otsu's Method	99.2	95.5

In Table II the results for K-means and Fuzzy c-means are taken from images segmented using the optimum number of classes such that the errors are minimum.

From the experimental results shown in Table II, both the completeness and correctness measures greater than 95% can be considered as suitable for the segmentation of 2D magnetic resonance images. The Mean Shift clustering method performs well in terms of correctness but is marginally below the significance level in completeness (with 94.2%). The Fuzzy c-means clustering method shows a highly low completeness (with 78.6%) value compared to the other methods but performs well in terms of correctness (with 99.9%). The Otsu's thresholding and the K-means clustering methods however have a significance level above 95% in both completeness and correctness.

But the experimental results show that when the tumor is very close to bone, K-means and Fuzzy c-means segment the tumor region and a part of the bone as a single object, thereby giving rise to a false positive area. This can be overcome by increasing the number of clusters the image is segmented into. But this alternative over-segments the image and the amount of false negative area increases.

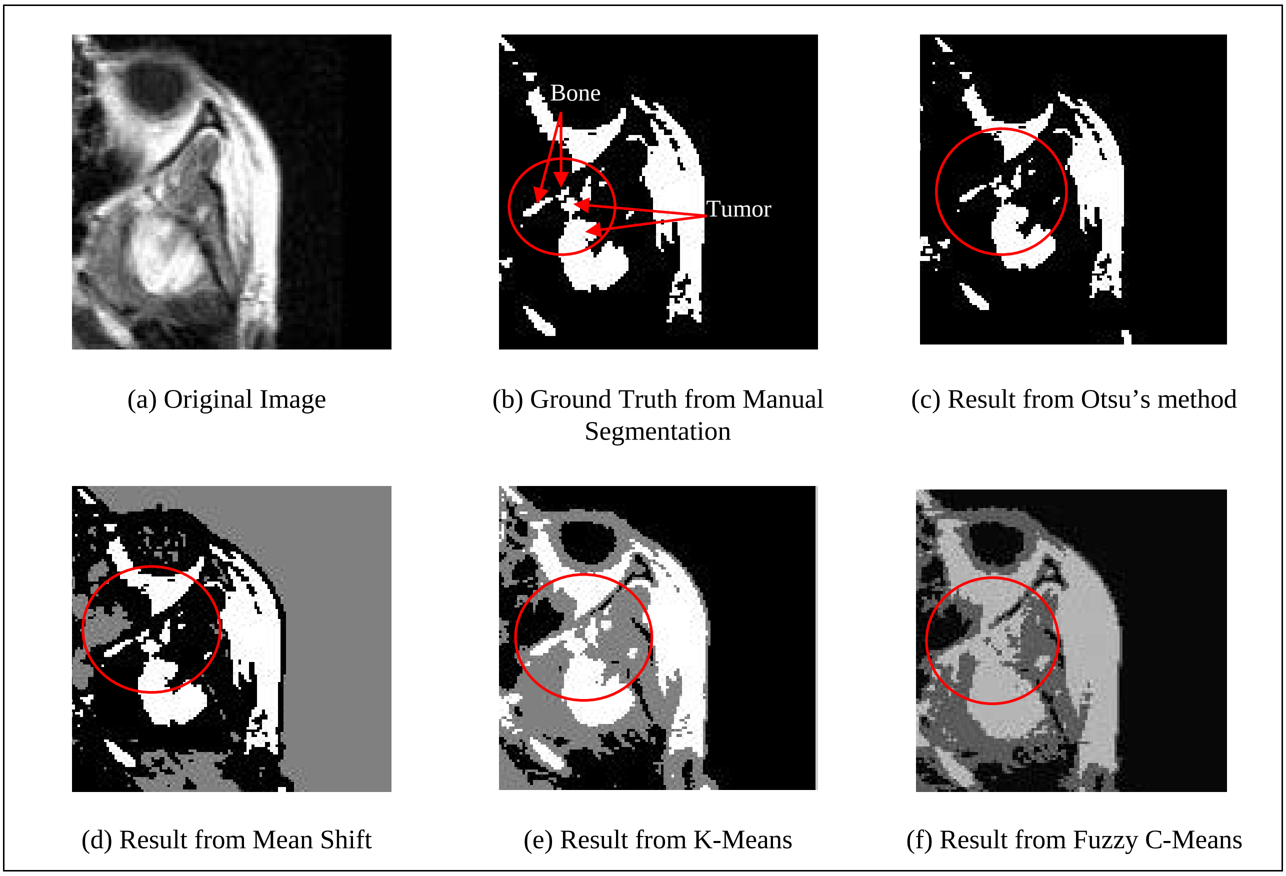

Fig. 3. Segmentation of a tumor very close to bone. Note that in (b), (c) and (d) the tumor region and the bone area are clearly separated. But, in (e) and (f) the tumor area and the bone region are connected and indicate a single region.

TABLE III
COMPLETENESS AND CORRECTNESS OF THE IMAGE IN FIG. 3.

Segmentation Method	Completeness of the Segmented Images (%)	Correctness of the Segmented Images (%)
Mean-Shift	84.9	100.0
K-Means	100.0	83.8
Fuzzy C-Means	99.8	19.4
Otsu's Method	89.9	100.0

In Table III the results show that the performance of K-means and Fuzzy c-means decrease significantly when there is bone present very close to the tumor. But, still, the Otsu's method performs well comparatively to other methods.

IV. CONCLUSION

This paper compares well-known gray-level image segmentation methods to identify the most suitable method(s) for the segmentation of a brain tumor from a 2D magnetic resonance image.

From the results obtained from the study Otsu's thresholding method can be recommended as suitable for the segmentation of 2D MR images to isolate a brain tumor.

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