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A Novel Method for Automatic Detection of Brain Tumor from MR Image

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***Abstract*—** Image processing is an important aspect of medical science to visualize the different anatomical structures of human body. Sometimes it becomes very difficult or impossible to detect or visualize such hidden abnormal structures by using simple imaging. Brain tumor is one of the major causes for mortality among children and adults. Extensive research is being carried out to develop automatic algorithms for detection of Tumor from Brain images captured using MR imaging. Still there are challenges like time requirements, inaccuracy, need of human intervention and complexity of images in detecting region of interest. In this study, an algorithm is proposed for detection of Tumor from MR Brain images, which is based upon thresholding, region growing and genetic algorithm. Performance evaluation of proposed algorithm and studied state-of-the-art algorithms suggests that proposed algorithm gives best results for Tumor detection from MR brain images.

***Keywords*—** Brain tumor detection, medical image, segmentation, magnetic resonance imaging (MRI).

I. INTRODUCTION

Image segmentation is one of the most important tasks in medical image analysis and is often used as the first and the most critical step in many clinical applications. It is the process of partitioning a digital image into multiple segments which consist of sets of pixels. More precisely, image segmentation is the process of assigning a label to each and every pixel in an image such that the pixels with the same label share certain visual characteristics [8]. In brain MRI analysis, it is commonly used for measuring and visualizing the brain's anatomical structures, for analyzing brain changes, for delineating pathological regions, and for surgical planning and image-guided interventions. It is also used to locate objects and boundaries (lines, curves, etc.) in a particular image [7]. The goal of segmentation is to simplify and/or change the representation of an image into something that is easier and more meaningful to analyze. Medical image segmentation aims to:

- Study anatomical structure.
- Identify the Region of Interest (ROI) i.e. locate tumor, lesion and any other abnormalities.
- Measure tissue volume to measure growth of tumor or decrease in size of tumor with treatment.
- Helps in treatment planning prior to radiation, therapy in radiation and dose calculation.

I.I **Brain Tumor:** Brain tumor is an abnormal growth of tissue inside the brain or central spine that can disrupt proper brain functioning. Many different types of brain tumors exist. Primary brain tumors originate from the brain cells. Primary brain tumors may spread to other parts of the brain or to the spine, but rarely to other organs. Metastatic or secondary brain tumors begin in another part of the body and then spread to the brain. These tumors are more common than primary brain tumors and are named by the location in which they begin [10].

Tumors can be of the following types:

- **Benign:** It is the least aggressive type of brain tumor as it does not contain cancer cells, grows slowly, and typically have clear borders that do not spread into other tissue. It originates from cells within or surrounding the brain.
- **Malignant:** Malignant brain tumors 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.

People with a brain tumor may experience the following symptoms or signs which may be general or specific. Sometimes, people with a brain tumor do not have any of these changes or the cause of a symptom may be a different medical condition and is not a brain tumor. General symptoms are caused by the pressure of the tumor on the brain or spinal cord whereas specific symptoms are caused when a specific part of the brain is not working well because of the tumor. The signs and symptoms vary greatly and depend on the brain tumor's size, location and rate of growth [12]. General signs and symptoms caused by brain tumor may include:

- New onset or change in pattern of headaches that gradually become more frequent & severe.
- Unexplained nausea or vomiting.
- Vision problems, such as blurred vision, double vision or loss of peripheral vision.
- Gradual loss of sensation or movement in an arm or a leg or difficulty with balance.
- Seizures, especially in someone who doesn't have a history of seizures.
- Speech and hearing difficulties.

In the selected case of MR image if edema is present with tumor it becomes difficult to distinguish between tumor and edema therefore tumor identification requires a lot of experience.

Figure 1 Brain MR Image showing Tumor Region

I.II **Scanning & Imaging Modalities:** A scan is the first step to identify the presence and location of the tumor exactly where it is growing and then it creates computerized images of the brain and spinal cord by examining it from different angles[5]. Some scans use a contrast agent (or a dye) to allow the doctors or radiologists to see the difference between normal and abnormal tissue. A patient may need more than one type of scan to diagnose a tumor, depending on its type and location. MRI is the most widely used scanning modality for brain tumor treatment as it gives high resolution images for obtaining detailed anatomical information to check brain development and for finding other abnormalities.

A. **MRI (Magnetic Resonance Imaging):** A lot of scanning modalities are available to us among those MRI is the most widely used as it is reliable, radiation-safe and non-invasive imaging modality [5]. MRI is used in radiology to form pictures of the anatomy and the physiological processes of the body in both health and disease. Figure 1 shows the sample MRI of brain. It provides visual details about the anatomy and the overall structure of the brain. An MRI scan can be used to study the supply of blood inside the brain. Hence it is important tool for detecting abnormality inside the brain [2]. There are different types of MRI that can be used on the basis of the results of a Neuro-examination done by the internist or neurologist.

In this paper we have proposed an algorithm using the combination of region growing and genetic algorithm that extracts brain tumor without the presence of edema. This method of segmentation of tumor neither requires too much time nor assistance of a physician. The proposed algorithm delivers satisfactory results and significant improvement in the accuracy as compared to existing methods.

This research paper has been organized as follows. Section I contains the introduction to image segmentation, brain tumor and Magnetic Resonance Imaging. Section II presents review on some state-of-the art segmentation methods that are used for medical images. Section III describes the proposed algorithm for automatic detection of tumor. Section IV presents experimental results of performance evaluation of the proposed algorithm and other studied algorithms. Section V presents the results and discussion. Section VI concludes the research work.

II. MEDICAL IMAGE SEGMENTATION METHODS

II.I **Thresholding Method**: Thresholding is one of the simplest and yet most important technique used for image segmentation. It tends to identify and extract a region of interest from its background on the basis of the distribution of gray levels or texture in image objects [4]. Most of the existing thresholding methods uses bi-level approach i.e. use two levels for categorizing an image into background and object segments on the basis of some common property e.g. intensity. But in case of MR images sometimes these methods are non-applicable as the MR images have many different parts. Due to this reason, issues like loss of information and misleading the diagnosis process can occur so multi-level thresholding algorithms are used so that all the important information from MR image can be retained. But due to the requirement of a large number of iterations for computing the optimum theroshold multi-level theroshold algorithms become computationally expensive. Otsu’s global thresholding method is the most suitable method for detecting the tumor region from MR brain images. It selects that gray level value as theroshold for which between-class variance is maximized. For segmenting the medical image thresholding alone is rarely used instead it is used as preprocessing function [10]. The pseudo code of the therosholding based algorithm is as follows:

II.I.I Initially, every gray level value in the image (I) is tested as a potential threshold to segment the image into two levels (binary image).

II.I.II For each threshold, segment image into binary as:

if (I(x,y) > T) then set BW(x,y) = 1
else BW(x,y)=0;

and compute the following terms:

- Probability of Foreground pixels, w0 is
  w0= No. of Foreground Pixels/ Size of image

- Probability of Background pixels, w1 is
  w1= No. of Background Pixels/ Size of image
- Mean of Foreground pixels, u0 is
  u0= Foreground Sum/ No. of Foreground Pixels
- Mean of Background pixels, u1 is defined as
  u1=Background Sum/ No. of Background Pixels

II.I.III Gray level value for which between-class variance maximizes is chosen as threshold, T to segment image: T=Max {wo*w1*(u0-u1)2}

II.II **Fuzzy C-Mean:** Firstly the Fuzzy C-Mean algorithm was introduced by Dunn [16] and later on it was extended by Bezdek. It's a kind of soft segmentation clustering method and delivers better results as compared to hard segmentation clustering method for retaining the information from an input image. The Fuzzy C-Mean algorithm is the most widely used clustering algorithm in which each item has the probability of belonging to more than one group hence named "fuzzy". For each item degree of membership is decided by probability distribution of each item over the clusters. FCM performs segmentation by classifying the pixels in such a way that each pixel may belong to multiple clusters with the degree of membership that ranges from 0 to 7. It delivers flexibility and also deals with the uncertainty factor as it allows the fuzzy boundaries to exist between the different clusters [11].

$$\mu_{ij} = 1 / \sum_{k=1}^{c} (d_{ij} / d_{ik})^{(2/m-1)}$$

$$v_j = (\sum_{i=1}^{n} (\mu_{ij})^m x_i) / (\sum_{i=1}^{n} (\mu_{ij})^m), \forall j = 1,2,.....c$$

The most striking feature of FCM is that it does not calculate the absolute membership of a data point instead it calculates the likelihood i.e. degree of membership and that's why FCM can be extremely fast as the number of required iterations in order to achieve a specific clustering exercise corresponds to the required accuracy.

II.III **K-Means Clustering:** K-Means is a kind of unsupervised segmentation technique. It is one of the simplest clustering technique that tends to optimize the partitioning decision on the basis of initial sets of cluster which are defined by the user and are updated after each iteration .K-Means uses the hard segmentation approach as it restricts the membership of a pixel exclusively to a single class .Moreover K-Means has low computational complexity and also takes lesser execution time as compared to FCM.As the number of clusters for segmenting the medical images is usually known so KM proves to be a suitable algorithm for segmentation of medical images [8].

$$J = \sum_{j=1}^{K} \sum_{n \in S_j} |x_n - \mu_j|^2,$$

K-Means aims to find groups or clusters in the data, where the variable K denotes the number of groups or clusters.

II.IV **Watershed and Edge Detection Method:** It is mostly used for colored MR images of the brain. The advanced watershed technique that uses the markers based approach has proved that the Tumor region detection is better in colored MR images than gray scale pixels [4]. Watershed techniques are mainly used for performing image segmentation and edge detection tasks. It is implemented in conjunction with K means clustering where k means technique is used for obtaining a primary segmented image. After that watershed technique processes that image for dividing it into markers and completes the watershed line with the help of these markers. Then the image is stored in the format of region adjacency graph (RAG).The initial segmentation results are obtained by the watershed algorithm and then edge maps are obtained on the basis of two edge strengths and mean gray values merging techniques [9].

III. PROPOSED ALGORITHM FOR BRAIN TUMOR DETECTION

Detection of Brain tumor at early stage is very difficult task due to complex nature of medical images and many other issues like poor contrast, uneven illumination, obscure contours etc. So it becomes difficult for doctors to identify tumor and their causes [10]. Here we come up with the system, where system will detect brain tumor from MR images. User has to select the image. The selected image will be uploaded into the system and system will process the image by applying image processing steps.We apply filter to image for removing noise, unwanted region and other environmental interference from image. Moreover it helps in removing additional cerebral tissues such as fat, skin, and skull etc. For removing noise from the uploaded image we have used bilateral filter. After removal of noise we apply a unique algorithm to detect tumor from brain image but edges of the image are not sharp so we apply Canny edge detector for detecting the diffused edges and boundaries. Then we apply image segmentation technique for extracting region of interest (ROI) i.e. brain tumor using the benefits of region growing and Genetic algorithm.

III.I **Edge Detection:** Edge detection is a critical element in image processing, since edges contain a major function of image information. The function of edge detection is to identify the boundaries of homogeneous regions in an image based on properties such as intensity and texture [9]. It performs a 2-D spatial gradient measurement on an image and returns edges at those points where the gradient of image is high. Many edge detection algorithms have been developed based on computation of the intensity gradient vector, which is sensitive to noise in the image. To suppress the noise, some spatial averaging may be combined with differentiation such as the Laplacian of Gaussian operator and the detection of zero crossing. In the proposed algorithm for clarifying the tumor boundaries from image Canny edge detector is used. Figure 2 represents the general processing functions performed by the proposed algorithm for extracting tumor region from MR image of brain.

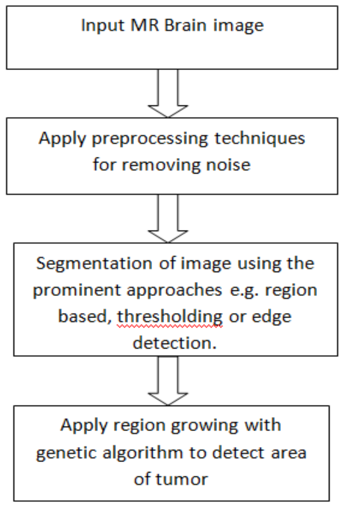


Figure 2 Flowchart of Proposed Algorithm for extracting Tumor from MR brain image

III.II **Region growing technique:** It is a simple image segmentation method based on the region. It is also classified as a pixel-based image segmentation method since it involves the selection of initial seed points. This approach to segmentation examines the neighboring pixels of initial "seed points" and determines whether the neighbors of the pixel should be added to the region or not, based on certain conditions and is iterated to yield different regions [8]. The region growing technique is carried out for the segmentation of image.

III.III **Genetic Algorithm:** Genetic algorithm proposed by Holland (1975) tends to determine the appropriate value of a criterion by simulating the evolution of a population until survival of best fitted individuals. The survivors are individuals obtained by crossing-over, mutation and selection of individuals from the previous generation [2].

Figure 3 represents the workflow of genetic algorithm .GA is considered as a good candidate for finding out the most appropriate combination of segmentation results due to the following two reasons:

- An evaluation criterion is not very easy to differentiate. GA is an optimization method that does not necessitate to differentiate the fitness function but only to evaluate it.
- If the population is important enough considering the size of the search space we have good guarantees that we will reach the optimal value of fitness [3].

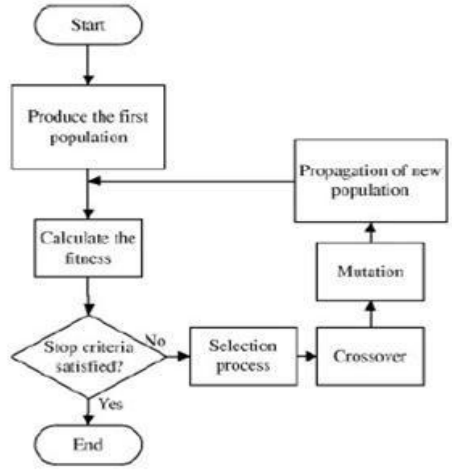


Figure 3 Flowchart of Genetic Algorithm

GA is a special kind of local search which tends to models our own understanding of evolution. In essence a number of simultaneous agents (the population) each having an encoded state (the chromosome) perform a random walk (mutations) around the search space, while forming new solutions from combinations of existing solutions (crossover) and, thus adjusting and refocusing the efforts of the search on exceptionally good areas once located [1].There are some important pinpoints that should be taken care while applying Genetic algorithm to an application:

- How the population can be encoded (binary, integer, decimal, etc).
- How the population can be mutated (mutate all genes, some genes, etc).
- How the parents should be selected for crossovers (roulette wheel, tournament selection).
- How the crossovers can be performed (uniform, single-point).
- For evaluation what fitness function should be used?

Although these pinpoints appear to be very intricate, but in cases where the energy functional has hundreds or even thousands of dependent parameters or variables, they can yield appropriate values of all these variables or parameters.

IV. PERFORMANCE EVALUATION OF PROPOSED ALGORITHM

The proposed system is evaluated using the following performance metrics:

IV.I **Correlation Coefficient**: In 1895, Karl Pearson comes up with the product-moment correlation coefficient. It is used to epitomize the degree of correlation and linear dependence that exists between measured quantities and depicts how strong the relationship is by returning a value that ranges between −1 and 1, value above 0.5 is considered as a candidate of better performance.

IV.II **Mean Square Error (MSE):** It measures the cumulative means of squares of error between the estimator, i.e., original image and what is estimated. It signifies the squared error loss in computations.

Possible Outcomes of Confusion Matrix are True Positive (TP), False Positive (FP), True Negative (TN), False Negative (FN); TN and TP are correctly segmented tumor and brain pixels, FP pixels are incorrectly detected as tumor and FN are falsely detected as brain element [10]. The outcomes of Confusion matrix are used for deriving the values of Precision, Recall, and F-measure.

IV.III **Precision** measures the exactitude of quality, i.e., fragments of fetched pixel elements that are admissible. It is Type 2 Error. Mathematically Precision can be represented as

Pr = (TP)/(TP + FP)

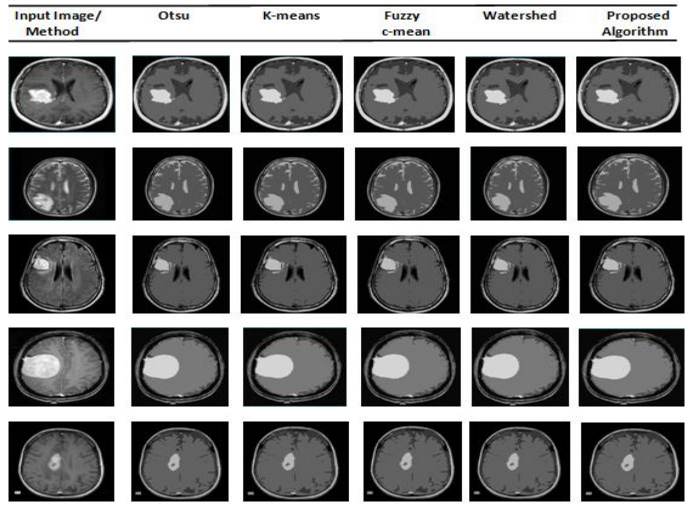
IV.IV **Recall** measures the completeness of quantity which means fragment of admissible pixel elements that are fetched. It is also known as sensitivity or Type 1 Error. Mathematically Recall can be represented as

Rc = (TP)/(TP+FN)

Table 1 Quantitative Results of proposed and other algorithms for various performance metrics

Image	***Method***	***Coorelation Coefficient***	***Mean Square Error***	***Precision***	***Recall***
Image 1	Otsu	0.68	4.30	0.77	0.70
	K-means	0.66	2.90	0.59	0.70
	Fuzzy c-mean	0.69	3.32	0.74	0.62
	Watershed	0.68	3.18	0.66	0.56
	Proposed Algorithm	**0.80**	**1.87**	**0.89**	**0.99**
Image 2	Otsu	0.69	2.84	0.73	0.72
	K-means	0.73	4.67	0.58	0.72
	Fuzzy c-mean	0.69	3.04	0.74	0.69
	Watershed	0.66	3.20	0.60	0.60
	Proposed Algorithm	**0.79**	**2.14**	**0.91**	**0.99**
Image 3	Otsu	0.70	3.41	0.72	0.65
	K-means	0.72	4.71	0.60	0.66
	Fuzzy c-mean	0.68	3.52	0.76	0.65
	Watershed	0.71	3.20	0.60	0.55
	Proposed Algorithm	**0.77**	**2.45**	**0.98**	**0.99**
Image 4	Otsu	0.66	3.67	0.77	0.73
	K-means	0.72	2.89	0.55	0.67
	Fuzzy c-mean	0.72	3.22	0.78	0.64
	Watershed	0.65	4.23	0.61	0.53
	Proposed Algorithm	**0.86**	**1.76**	**0.93**	**0.99**
Image 5	Otsu	0.73	3.34	0.70	0.65
	K-means	0.65	4.67	0.64	0.63
	Fuzzy c-mean	0.73	4.69	0.67	0.67
	Watershed	0.71	3.84	0.63	0.54
	Proposed Algorithm	**0.82**	**2.66**	**0.95**	**0.99**

Table 2 Outputs of various Segmentation algorithms for Brain Tumor Detection



V. RESULTS AND DISSUCIONS

For computing the results of performance metrics stated in Section IV experiments are implemented in Java, Jdk 1.8 version, Net beans 8.1on i5 processor. The performance of all the algorithms is evaluated using both Qualitative and Quantitative evaluation trends and results of the stated performance metrics are analyzed and compared. The Quantitative results (numerical values) are represented in Table1 for objective evaluation and Qualitative results (human observation based results) are represented in Table 2 for subjective evaluation.

An algorithm can deliver satisfactory results for one or more parameter but may not be suitable for rest of the parameters. So performance of studied algorithms is analyzed on a tested dataset out of which results of some images are presented in Table1 and Table 2 .Quantitative results in Table 1 depicts that among all the existing methods which are stated in Section II Otsu delivers satisfactory results for all the parameters. K-means provides good results for Correlation Coefficient, MSE and Recall but it delivers comparatively less suitable values for Precision as compared to Otsu. FCM is a tradeoff between K-means and Watershed. It behaves well for all the parameters. Among all the existing algorithms Watershed gives the lowest results when tested for all parameters.

Otsu attains highest performance among all state-of-the-art methods so the performance of proposed algorithm is mainly evaluated with Otsu method. The proposed technique has increased values of Correlation Coefficient, Precision, Recall and reduced value of Mean square error as compared to Otsu method. Quantitative results in Table 1 depicts that the proposed method has more accurate and satisfactory results for all the performance metrics stated in Section IV as compared to the methods stated in Section II.

VI. CONCLUSIONS

The proposed algorithm for automatic brain tumor detection from MR brain image is based upon genetic algorithm and region growing methodology. It produces satisfactory results giving appropriate number of regions in segmented output image. It automates the process while taking minimum time and space. The segmented tumor region is clearly visible in the outputs. Proposed algorithm gives best results for various performance metrics. Hence it outperforms other studied state-of-the-art algorithms for brain tumor detection from MR images.

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