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Brain Tumour Detection Using Image Segmentation: A Review

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Abstract: Medical Image Processing is one of the most challenging and emerging fields. MRI, CT scan , ultra scan, X-rays etc. are different machines to diagnose the condition of the patient. Human body is made up of several types of cells. Brain is a highly specialized and sensitive organ of human body. Brain tumour is one of the severe problems in the medical science. MRI imaging is often used when treating brain tumour. There are various image segmentation algorithms in order to detect brain tumour using image processing. Firstly quality of scanned MRI image is enhanced and then different image segmentation techniques are applied to detect the tumour in the scanned image. Different segmentation methods reviewed here are thresholding, kmeans, watershed, edge detection, morphological, fuzzy c-means. Here sample 5 MRI images are taken and processed by using MATLAB software. With the help of these techniques, area of the tumour, execution time, number pixel can be determined.

Keywords: MATLAB, segmentation, thresholding , kmeans, watershed, edge detection, morphological, fuzzy c-means.

I. INTRODUCTION

A brain tumour is a mass or growth of abnormal cells in a brain. Many different types of brain tumours exist. Some brain tumours are noncancerous (benign), and some brain tumours are cancerous (malignant). In a healthy human body, normal cells grow old or die and new cells take their place. Sometimes, this process goes wrong. Some unnecessary new cells are produced when the body doesn't need them, and old or damaged cells don't die as they should. The formation of these extra cells often forms a mass of tissue called a growth or tumour. The growth rate as well as location of a brain tumour determines how it will affect the function of human nervous system. Brain tumour treatment options depend on the type of brain tumour you have, as well as its size and location. Adult brain tumours occur typically between the ages of 40 and 60 years. An additional 150,000 individuals are diagnosed with brain tumours each year. The cure rate for most brain tumours is significantly lower when compared to other types of cancer. Brain tumours are diagnosed, based on medical history, physical examination and various specialised Tests.

II. LITERATURE REVIEW

There are different research works that were carried out in past and contributed to this field of brain tumour detection. So many approaches are developed for the detection of brain tumour which were played important role to carry out this work.

Rajesh C. Patil and Dr. A. S. Bhalchandra proposed an algorithm for the detection of brain tumour extraction in MRI images which incorporates with some noise removal functions, segmentation and morphological operations which are the basic concepts of image processing. Detection and extraction of tumour from MRI scan images of the brain have done by using MATLAB software [2].

Roopali R. Laddha, S. A .Ladhake proposed an efficient algorithm for tumour detection based on segmentation and morphological operators. Firstly quality of scanned image is enhanced and then morphological operators are applied to detect the tumour in the scanned image. They also proposed an efficient wavelet based algorithm for tumour detection which utilizes the complementary and redundant information from the Computed Tomography (CT) image and Magnetic Resonance Imaging (MRI) images. Hence this algorithm effectively uses the information provided by the CT image and MRI images there by providing a resultant fused image which increases the efficiency of tumour detection [3].

Anam Mustaqeem , Ali Javed, ,Tehseen Fatima , conducted research to detect brain tumour using medical imaging techniques. The main technique used was segmentation, which is done using a method based on threshold segmentation, watershed segmentation and morphological operators. The proposed segmentation method was experimented with MRI scanned images of human brains, thus locating tumor in the images. Samples of human brains were taken, scanned using MRI process and then were processed through segmentation methods thus giving efficient end results [4].

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Alyaa H. Ali, Kawther A. Khalaph, Ihssan S. Nema ,developed a technique to detect presence of brain tumour based on thresholding .The segmentation of the brain is also being done while detecting the presence of the tumour. The physical dimension of the tumour which is of utmost importance to the physicians can also be calculated using the present technique. Enhanced thresholding algorithm is modified form of standard thresholding algorithm. In this work, first instead of considering each gray value as threshold initially, threshold vector is limited to intensity values in the region of interest marked by user. This leads to selection of an appropriate threshold. This also leads to high compression by saving only region of interest. Second, to enhance the performance of thresholding for tumour area extraction, thresholding is followed by reconstruction based morphology [5]. Alan Jose, S.Ravi, M.Sambath, proposed system which has mainly four modules namely pre-processing, segmentation using k-means and fuzzy c-means, feature extraction, and approximate reasoning method to recognize the tumour shape and position in MRI image using edge detection method. This method scans the RGB or gray scale, converts the image into binary image by binarization technique and detects the edge of tumour pixels in the binary image. Also, it calculates the size of the tumour by calculating the number of white pixels (digit 0) in binary image. The stage of the tumour is based on the area of tumour [6].

III. SEGMENTATION

Digital image processing is the use of a digital computer to process digital images through an algorithm. Image segmentation is a branch of digital image processing which focuses on partitioning an image into different parts according to their features and properties. In image segmentation, you divide an image into various parts that have similar attributes. The parts in which you divide the image are called image objects. In the medical sector, image segmentation is used to locate and identify cancer cells, measure tissue volumes, run virtual surgery simulations, and performs intra-surgery navigation. Image segmentation has many applications in the medical sector. It helps in identifying affected areas and plan out treatments for the same.

Image segmentation is a very broad topic and has different ways to go about the process. We can classify image segmentation according to the following parameters.

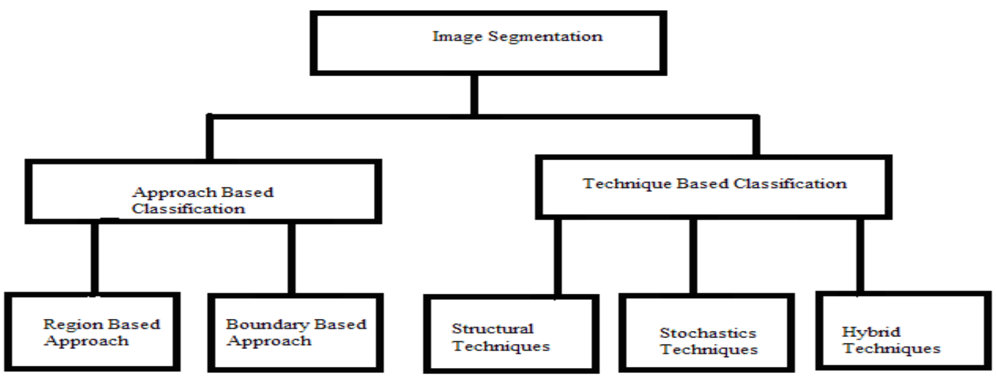

Fig. 1 Classification of image segmentation

A. *Approach-Based Classification*

In its most basic sense, image segmentation is object identification. An algorithm cannot classify the different components without identifying an object first. From simple to complicated implementations, all image segmentation work based on object identification. So, we can classify image segmentation methods based on the way algorithms identify objects, which means, collecting similar pixels and separating them from dissimilar pixels. There are two approaches to performing this task:

1) *Region-based Approach (Detecting Similarity)*: In this method, similar pixels in the image are detected according to a selected threshold, region merging, region spreading, and region growing. Clustering and similar machine learning algorithms use this method to detect unknown features and attributes. Classification algorithms follow this approach for detecting features and separating image segments according to them.
2) *Boundary-based Approach (Detecting Discontinuity):* The boundary-based approach is the opposite of the region-based approach for object identification. Unlike region-based detection, where pixels having similar features are detected, pixels that are dissimilar to each other are detected in the boundary-based approach. Point detection, edge detection, line detection, and similar algorithms follow this method where they detect the edge of dissimilar pixels and separate them from the rest of the image accordingly.

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B. Technique-Based Classification

Both of the approaches have their distinct image segmentation techniques. These techniques are used according to the kind of image we want to process and analyse and the kind of results we want to derive from it. Based on the parameters, we can divide image segmentation algorithms into the following categories.

1) *Structural Techniques:* These algorithms require to have the structural data of the image you are using. This includes the pixels, distributions, histograms, pixel density, colour distribution, and other relevant information. Then, you must have the structural data on the region you have to separate from the image. You'll need that information so your algorithm can identify the region. The algorithms we use for these implementations follow the region-based approach.
2) *Stochastic Techniques*: These algorithms require information about the discrete pixel values of the image, instead of the structure of the required section of the image. Due to this, they don't require a lot of information to perform image segmentation and are useful when you have to work with multiple images. Machine learning algorithms such as K-means clustering and ANN algorithms fall in this category.
3) *Hybrid Techniques*: From the name, these algorithms use both stochastic and structural methods. This means they use the structural information of the required region and the discrete pixel information of the whole image for performing image segmentation.

IV. TYPES OF IMAGE SEGMENTATION TECHNIQUES

Following are the primary types of image segmentation techniques:

A. Thresholding Segmentation

The simplest method for segmentation in image processing is the threshold method. It divides the pixels in an image by comparing the pixel's intensity with a specified value (threshold). If pixel value is higher than the threshold, the pixel is considered to be "foreground" and is set to white, and if it is less than or equal to the threshold it is considered "background" and set to black . Most of the existing thresholding methods are bi-level, which use two levels to categorize the image into background and object segments. It is useful when the required object has a higher intensity than the background (unnecessary parts). Threshold value (T) can be consider to be a constant but it would only work if the image has very little noise (unnecessary information and data).Threshold value can be kept constant or dynamic according to requirements. The thresholding method converts a gray-scale image into a binary image by dividing it into two segments (required and not required sections). According to the different threshold values, we can classify thresholding segmentation in the following categories.

1) *Simple Thresholding:* In this method, the image's pixels can be replaced with either white or black. Now, if the intensity of a pixel at a particular position is less than the threshold value then replace it with black. On the other hand, if it's higher than the threshold, replace it with white. This is simple thresholding.
2) *Otsu's Binarization*: In simple thresholding , a constant threshold value is picked up and used it to perform image segmentation. However, how do you determine that the value you chose was the right one? While the straightforward method for this is to test different values and choose one, it is not the most efficient one. Take an image with a histogram having two peaks, one for the foreground and one for the background. By using Otsu binarization, you can take the approximate value of the middle of those peaks as your threshold value. In Otsu binarization, the threshold value is calculated from the image's histogram if the image is bimodal. This process is quite popular for scanning documents, recognizing patterns, and removing unnecessary colours from a file. However, it has many limitations. You can't use it for images that are not bimodal (images whose histograms have multiple peaks).
3) *Adaptive Thresholding*: Having one constant threshold value might not be a suitable approach to take with every image. Different images have different backgrounds and conditions which affect their properties. Thus, instead of using one constant threshold value for performing segmentation on the entire image, the threshold value can be kept variable. In this technique, different threshold values have to be kept for different sections of an image. This method works well with images that have varying lighting conditions. An algorithm to be used that segments the image into smaller sections and calculates the threshold value for each of them.

A number of thresholding techniques have been proposed using global and local techniques. Global methods apply one threshold to the entire image while local thresholding methods apply different threshold values to different regions of the image. The value is determined by the neighbourhood of the pixel to which the thresholding is being applied .The binarization techniques for gray scale documents can be grouped into two broad categories as global thresholding binarization and local thresholding binarization. Global methods find a single threshold value for the whole document. Then each pixel is assigned to page foreground or background based on its gray value comparing with the threshold value. Global methods are very fast and they give good results for typical scanned documents. For many years, the binarization of a grayscale document was based on the global thresholding statistical algorithms. These statistical methods, which can be considered as clustering approaches, are inappropriate for complex documents, and for degraded documents. If the illumination over the document is not uniform global binarization methods tend to produce marginal noise along the page borders. To overcome these complexities, local thresholding techniques have been proposed for document binarization. These techniques estimate a different threshold for each pixel according to the gray scale information of the neighbouring pixels. This technique can be expressed as:

$$g(x,y) = \begin{cases} 1 \ \text{if} & f(x,y) > T \\ 0 \ \text{if} & f(x,y) \le T \end{cases} \quad \rightarrow (1)$$

$$g(x,y) = \begin{cases} a & \text{if} \quad f(x,y) > T_2 \\ b & \text{if} \quad T_1 < f(x,y) \le T_2 \\ c & \text{if} \quad f(x,y) \le T_1 \end{cases} \quad \rightarrow (2)$$

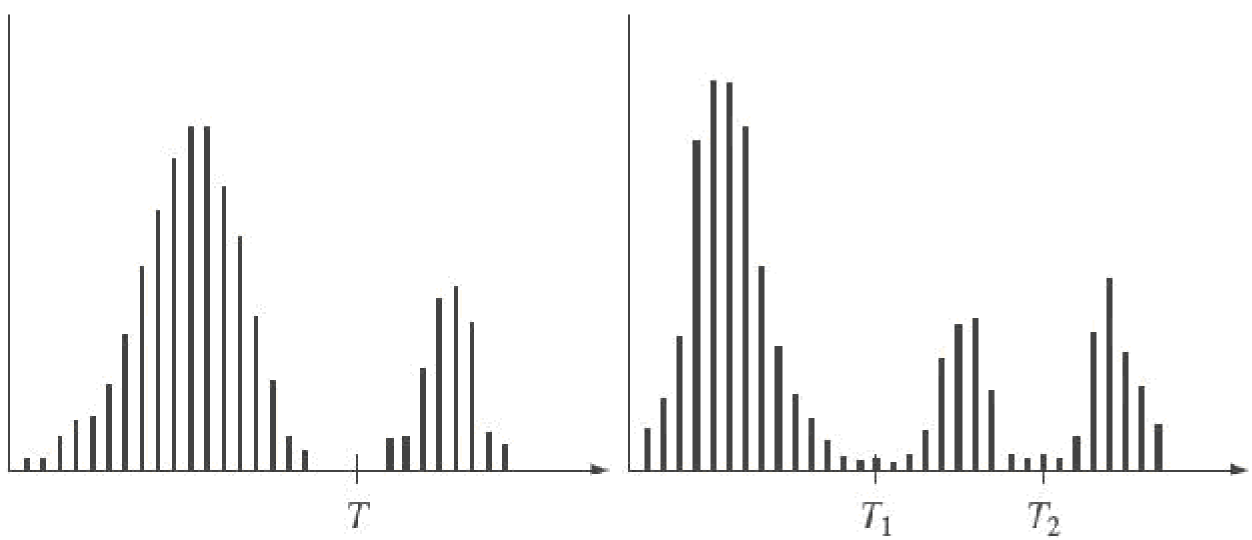

Fig. 2 (a)

Fig. 2 (b)

Fig. 2 Intensity histograms that can be partitioned (a) by a single threshold and (b) by a dual thresholds

Equation 1 shows segmented image g(x,y) when T is a constant applicable over an entire image .Equation 1 shows the process referred as global thresholding .When the value of T changes over an image ,the term variable thresholding is used. Equation 2 shows segmented image g(x,y) for T1 and T2 .In equation 2 ,a, b , and c are any 3 distint intensity values. Fig. 2 shows intensity histograms that can be partitioned by a single threshold T shown in Fig. 2(a) and by a dual thresholds as T1 and T2 as shown in Fig. 2 (b). [1].

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B. Edge-Based Segmentation

Edge-based segmentation is one of the most popular implementations of segmentation in image processing. It focuses on identifying the edges of different objects in an image. This is a crucial step as it helps to find the features of the various objects present in the image as edges contain a lot of information that can be used. Edges on the region are traced by identifying the pixel value and it is compared with the neighbouring pixels. In this edge based segmentation, there is no need for the detected edges to be closed. Edge detection is widely popular because it helps in removing unwanted and unnecessary information from the image. It reduces the image's size considerably, making it easier to analyse the same. Algorithms used in edge-based segmentation identify edges in an image according to the differences in texture, contrast, grey level, colour, saturation, and other properties. The quality of results can be improved by connecting all the edges into edge chains that match the image borders more accurately.

There are many edge-based segmentation methods available. They can be divided into two categories:

1) *Search-Based Edge Detection:* Search-based edge detection methods focus on computing a measure of edge strength and look for local directional maxima of the gradient magnitude through a computed estimate of the edge's local orientation.
2) *Zero-Crossing Based Edge Detection*: Zero-crossing based edge detection methods look for zero crossings in a derivative expression retrieved from the image to find the edges.

Typically, first to pre-process the image to remove unwanted noise and make it easier to detect edges. Canny, Prewitt, Deriche, and Roberts cross are some of the most popular edge detection operators. They make it easier to detect discontinuities and find the edges. In edge-based detection, goal is to get a partial segmentation minimum where all the local edges can be grouped into a binary image. In newly created binary image, the edge chains must match the existing components of the image in question. There are various edge detectors that are used to segment the image as shown in Fig.3.

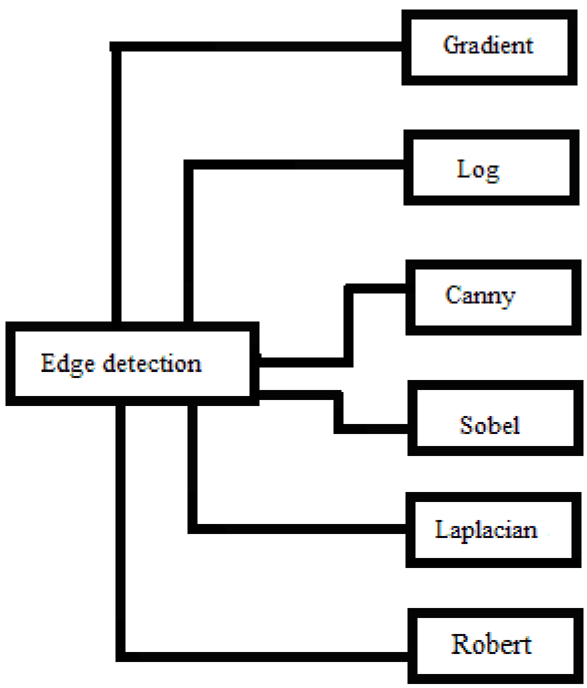

Fig. 3 Various edge detectors

The edges are detected by calculating the minimum and maximum of first derivative in gradient edge detector. Zero Crossing is found in second derivative to identify the edges in Laplacian edge detector. Sobel Edge Detector uses Convolution Kernel to detect the edges. Magnitude of the spatial gradient is calculated for edges in Robert's Edge Detector. Canny Edge Detector also uses high spatial gradient but it takes more computation than Sobel and Robert's Edge Detector.

C. Region-Based Segmentation

Region-based segmentation algorithms divide the image into sections with similar features. These regions are only a group of pixels and the algorithm find these groups by first locating a seed point which could be a small section or a large portion of the input image. After finding the seed points, a region-based segmentation algorithm would either add more pixels to them or shrink them so it can merge them with other seed points.

Region-based segmentation can be classified into the following categories:

1) *Region Growing:* In this method, start with a small set of pixels and then start iteratively merging more pixels according to particular similarity conditions. A region growing algorithm would pick an arbitrary seed pixel in the image, compare it with the neighbouring pixels and start increasing the region by finding matches to the seed point. When a particular region can't grow further, the algorithm will pick another seed pixel which might not belong to any existing region. One region can have too many attributes causing it to take over most of the image. To avoid such an error, region growing algorithms grow multiple regions at the same time. Region growing algorithms can be used for images that have a lot of noise as the noise would make it difficult to find edges or use thresholding algorithms.
2) *Region Splitting and Merging:* As the name suggests, a region splitting and merging focused method would perform two actions together, splitting and merging portions of the image. It would first the image into regions that have similar attributes and merge the adjacent portions which are similar to one another. In region splitting, the algorithm considers the entire image while in region growth , the algorithm would focus on a particular point. The region splitting and merging method follows a divide and conquer methodology. It divides the image into different portions and then matches them according to its predetermined conditions. Another name for the algorithms that perform this task is split-merge algorithms.

D. Watershed Segmentation

In image processing, a watershed is a transformation on a gray scale image. It refers to the geological watershed or a drainage divide. A watershed algorithm would handle the image as if it was a topographic map. It considers the brightness of a pixel as its height and finds the lines that run along the top of those ridges. Watershed has many technical definitions and has several applications. Apart from identifying the ridges of the pixels, it focuses on defining basins (the opposite of ridges) and floods the basins with markers until they meet the watershed lines going through the ridges. As basins have a lot of markers while the ridges don't, the image gets divided into multiple regions according to the 'height' of every pixel. The watershed method converts every image into a topographical map. The watershed segmentation method would reflect the topography through the grey values of their pixels. Now a landscape with valleys and ridges would certainly have three-dimensional aspects. The watershed would consider the three-dimensional representation of the image and create regions accordingly, which are called "catchment basins". It has many applications in the medical sector such as MRI, medical imaging, etc. Watershed segmentation is a prominent part of medical image segmentation.

E. Clustering-Based Segmentation Algorithms

Clustering algorithms are unsupervised algorithms and help you in finding hidden data in the image that might not be visible to a normal vision. This hidden data includes information such as clusters, structures, shadings, etc. As the name suggests, a clustering algorithm divides the image into clusters (disjoint groups) of pixels that have similar features. It would separate the data elements into clusters where the elements in a cluster are more similar in comparison to the elements present in other clusters. Some of the popular clustering algorithms include fuzzy c-means (FCM), k-means, and improved k-means algorithms. In image segmentation, k-means clustering algorithm are mostly used as it's quite simple and efficient. On the other hand, the FCM algorithm puts the pixels in different classes according to their varying degrees of membership.

The most important clustering algorithms for segmentation in image processing are:

1) *K-means Clustering*: K-means is a simple unsupervised machine learning algorithm. It classifies an image through a specific number of clusters. It starts the process by dividing the image space into k pixels that represent k group centroids. Then they assign each object to the group based on the distance between them and the centroid. When the algorithm has assigned all pixels to all the clusters, it can move and reassign the centroids.
2) *Fuzzy C Means:* With the fuzzy c-means clustering method, the pixels in the image can get clustered in multiple clusters. This means a pixel can belong to more than one cluster. However, every pixel would have varying levels of similarities with every cluster. The fuzzy c-means algorithm has an optimization function which affects the accuracy of your results.

F. Neural Networks for Segmentation

Neural networks for image segmentation is another important technique. In this AI to be use to analyse an image and identify its different components such as faces, objects, text, etc. Convolutional Neural Networks are quite popular for image segmentation because they can identify and process image data much quickly and efficiently. A deep learning architecture called Mask R-CNN is an enhanced version of the Faster R-CNN object detection architecture, which can make a pixel-wise mask for every object present in an image.

The Faster R-CNN uses two pieces of data for every object in an image, the bounding box coordinates and the class of the object. Mask R-CNN outputs the object mask after performing the segmentation. Thus in this process, an additional section can be obtained.

In this process, first pass the input image to the ConvNet which generates the feature map for the image. Then the system applies the region proposal network (RPN) on the feature maps and generates the object proposals with their objectness scores. After that, the roi pooling layer gets applied to the proposals to bring them down to one size. In the final stage, the system passes the proposals to the connected layer for classification and generates the output with the bounding boxes for every object.

V. METHODOLOGY

As MRI is a advance imaging technique, it is used here. MRI image is taken as input image. Input image is then pre-processed , segmented using different segmentation techniques. Then resultant image is a segmented image .i.e. brain image with tumour.

A. Pre-processing

The aim of pre-processing is to improve the quality of the image so that we can analyse it in a better way. By pre- processing we can suppress undesired distortions and enhance some features which are necessary for the particular application we are working for. In general the MRI scan images are gray scale images if the image is taken from the internet it may be in jpg format .If it is in jpg format we have to convert that image to gray scale.

B. Gaussian Filter

A Gaussian filter is a linear filter. It's usually used to blur the image or to reduce noise. By using gaussian filters (LPF & HPF) the noise present in the input images can be removed. LPF helps out in smoothening of the image and HPF helps out in sharpening of the image. Gaussian smoothing is low-pass filtering, which means that it suppresses high-frequency detail (noise, but also edges), while preserving the low-frequency parts of the image (i.e. those that don't vary so much). In other words, the filter blurs everything that is smaller than the filter. The extent to which the filtering needs to be done is based on the value of cut-off frequency.

Larger the cut-off frequency value, larger will be will be the extent of filtering. If the input image is found noisy, it is not necessary to add the noise (salt & pepper noise). The input may be a colour image or a gray scale image. If it is a colour image it is to be converted in to gray scale image. As a gray scale image consist of only two colours, black and white, it is easy to apply filtering. Black represents low frequency part and white represents the high frequency part. The output obtained will be either sharpened image or smoothened image depending on the filtering that is performed [11].

C. Median Filter

The median filter in image processing is normally used to reduce noise in an image, somewhat like the mean filter. However, it often does a better job than the mean filter of preserving useful detail in the image. Median Filter is a simple and powerful non-linear filter. It is used for reducing the amount of intensity variation between one pixel and the other pixel. In this filter, pixel value is replaced with the median value.

The median filter considers each pixel in the image in turn and looks at its nearby neighbors to decide whether or not it is representative of its surroundings. Instead of simply replacing the pixel value with the mean of neighboring pixel values, it replaces it with the median of those values.

The median is calculated by first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value. If the neighbourhood under consideration contains an even number of pixels, the average of the two middle pixel values is used.

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D. Segmentation

Segmentation refers to the process of partitioning a digital image into multiple regions (sets of pixels). The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. The result of image segmentation is a set of regions that collectively cover the entire image, or a set of contours extracted from the image. Segmentation refers to the process of partitioning a digital image into multiple regions (sets of pixels). The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. The result of image segmentation is a set of regions that collectively cover the entire image, or a set of contours extracted from the image.Following is the work flow graph.

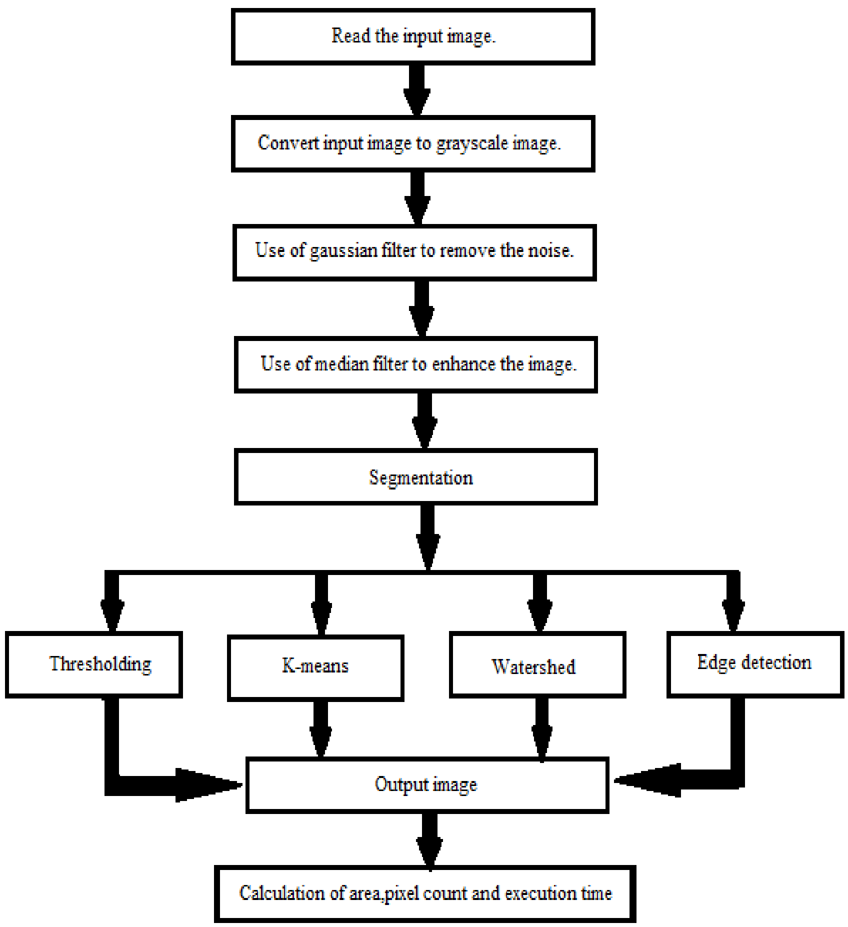

Fig. 4 Work flow graph

VI. RESULTS

TABLE I shows 5 input images and the corresponding output images for the different image segmentation techniques as threshold , kmeans ,watershed and edge detection .From the output images ,it is observed that the watershed segmentation gives the more accurate result as a tumour region . TABLE II shows 5 input images and the corresponding parameters such as number pixel, area and execution time calculated for different segmentation techniques .Number of pixel in the tumour area that is obtained for different techniques is different for the output images .Execution time is taken as average time during run time. Area of the tumour affected region is slightly varying for the output images for various segmentation techniques.

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Table I
Sample Input Images and Output Images for Different Segmentation Techniques

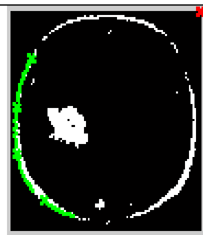
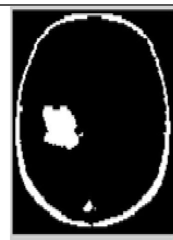
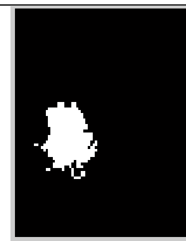
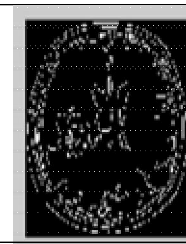
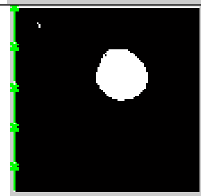
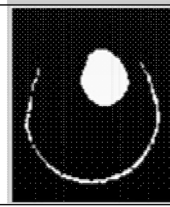
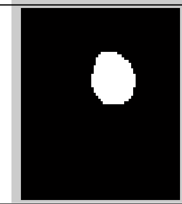
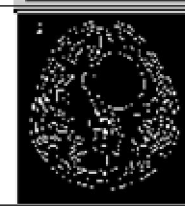
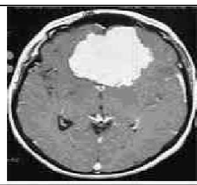
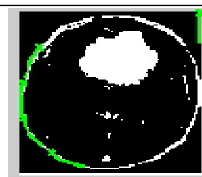
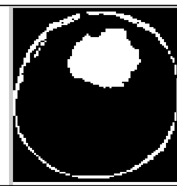
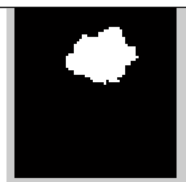
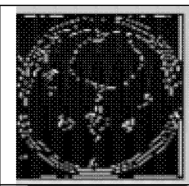
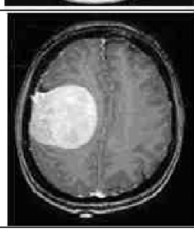
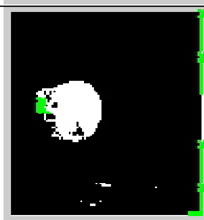
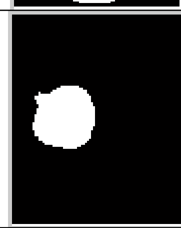
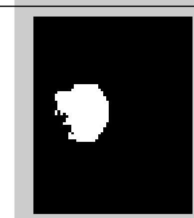
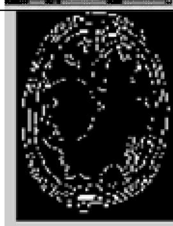
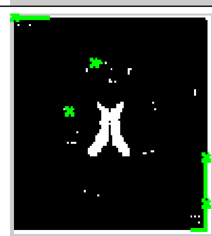
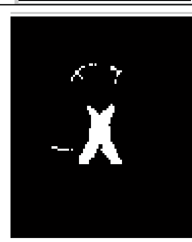
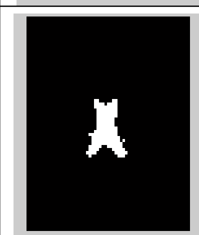
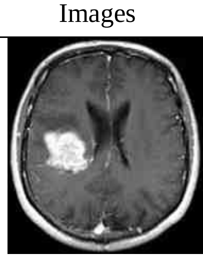
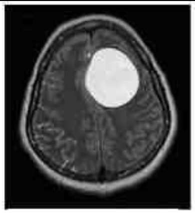
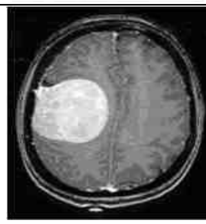
S. NO.	Input Images	Output Images			
		Threshold	**Kmeans**	**Watershed**	**Edge detection**
1					
2					
3					
4					
5					

Table II
Calculation of Various Parameters Of Output Images

S. No.	Images	Various Parameters	Threshold	Kmeans	Watershed	Edge detection
1		Number pixel	4956	5578	3138	3772
		Area	0.0756	0.1104	0.0621	0.0746
		Time (sec)	0.14	0.25	0.366	0.16

2		Number pixel	5222	5369	2884	3917
		Area	0.0797	0.1114	0.0599	0.0813
		Time (sec)	0.14	0.22	0.354	2.013
3		Number pixel	12153	5233	2707	2304
		Area	0.1854	0.1907	0.0986	0.0839
		Time (sec)	0.14	0.22	0.27	0.075753
4		Number pixel	6134	4499	2909	3476
		Area	0.0936	0.11	0.0723	0.0863
		Time (sec)	0.038	0.21	0.31	0.39
5		Number pixel	5403	10126	4168	6587
		Area	0.0824	0.0921	0.0379	0.0599
		Time (sec)	0.15	0.26	0.58	0.47

VII. CONCLUSION

In this paper various existing segmentation methods for brain MRI image have been discussed. Tumour is extracted using various segmentation techniques as threshold, kmeans watershed, edge detection. Sample 5 images are taken and different segmentation techniques are applied. Results obtained are tabulated in and TABLE I and TABLE II as above. Further the size of the tumour, area of the tumour are successfully obtained .Few steps in the MATLAB coding for image processing also gives time for execution for respective segmentation algorithms Further algorithm can be improved to obtain less execution time. Pixel counts are varying for different algorithms for respective images. Calculating the area of the tumour is helpful for finding the stage of the tumour .The discussed methods of brain tumour segmentation helps surgeon in detecting tumour automatically in lesser time as compare to manually calculation. Highlighted segmented part is obtained as the final output image .Other basic facilities such as magnification scaling , shrinking gives the better view of image. Thus different approaches can help the doctors/medical practitioners for faster detection and study of brain tumour, fracture etc.

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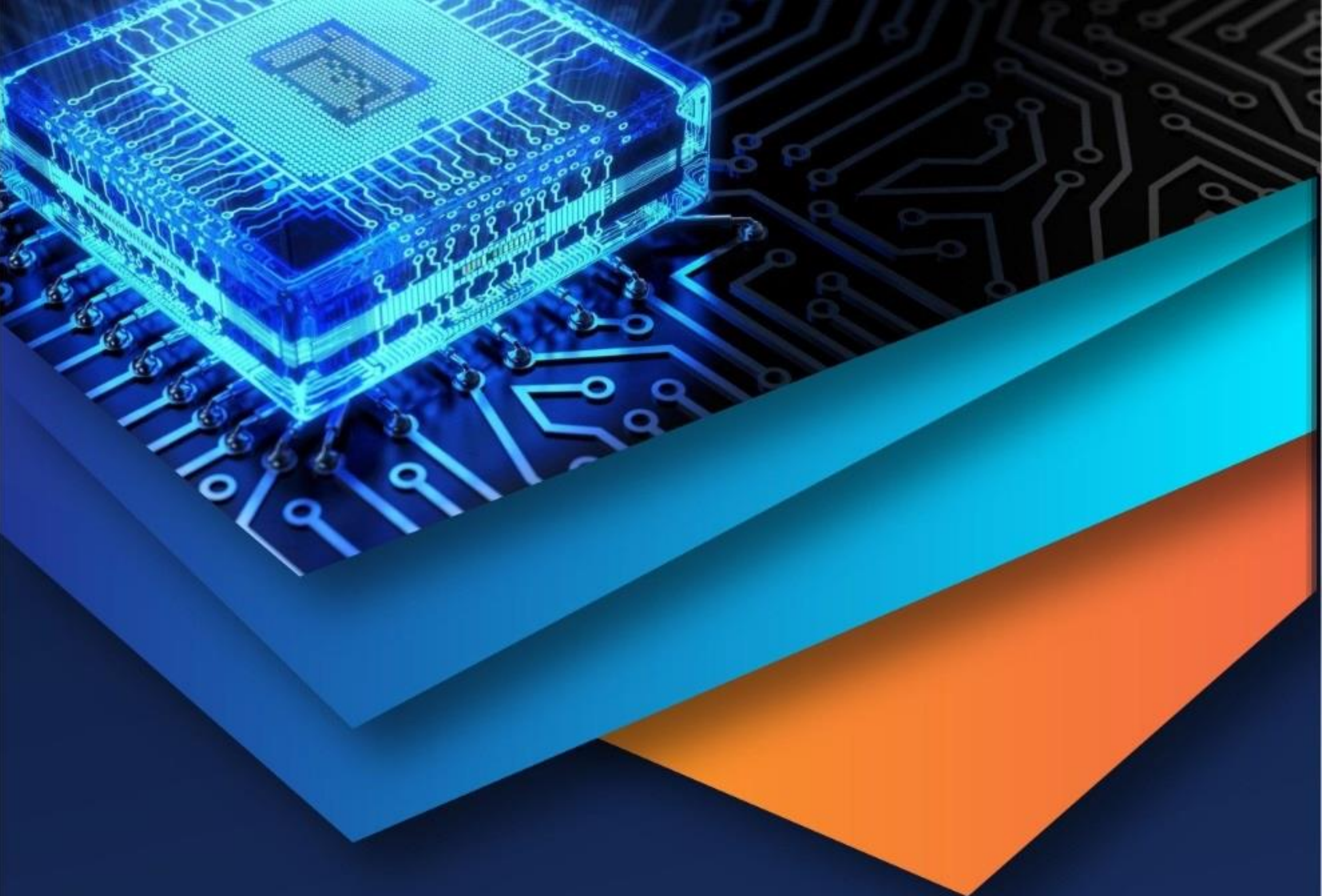

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