Enhanced Marker-Controlled Watershed Segmentation Algorithm for Brain Tumor Segmentation

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Abstract. Image processing has always been a vivid area of research that helps mankind unveil the wondrous works. In this paper, the proposed image segmentation algorithm is used to segment the region of interest (ROI) from the MR images. The ultimate idea behind the process of segmentation is to segregate tumor region from the homogenous anatomical structures. The paper proposes an enhanced marker controlled watershed segmentation algorithm which will help in the precise segmentation of the region of interest (ROI) from the provided input image. The Enhanced Marker-Controlled Watershed Segmentation Algorithm helps in identifying the tumor region and segment it such that the tumor can be analyzed for further diagnosis. The proposed method provides a precise accuracy of 99.14% which determines the fact that the tumor region is being segmented accurately with few false positive rate.

Keywords: Tumor · Magnetic resonance imaging · Image segmentation · Gradient magnitude · Watershed segmentation

1 Introduction

In a healthy human, old cells are being replaced with new cells within every particular period of time and when this process fails it leads to an unnecessary mass growth of tissues which is referred to as tumor. Thus the abnormal mass of tissues in the brain is known as brain tumor. They are also called as lesion or neoplasia. Brain tumors are further classified as Primary and Metastatic tumors. Primary tumors also known as benign or non-cancerous, are the ones that originate from brain tissues and its surrounding. Metastatic brain tumor also called as cancerous or malignant, are the ones that originate from other parts of the body and migrated to the brain through the bloodstream. Early detection of brain tumor can increase the survival rate up to 90% [13]. There is no specified reason for the cause of brain tumor has been proved yet.

MRI is a scanning technique for creating detailed images of the human body. It uses large magnets that produces strong magnetic field and radio waves that will help in generating images of the internal parts of the body. MRI scan is one among the most

popular methods used, benefits in visualizing the anatomy in various planes that include Axial, Sagittal and Coronal planes [14]. MRI is much more effective than CT since it has low radiation and high contrast features. The main advantage of the usage of MRI when to other imaging techniques is that there is absolutely no risk of ionizing radiation.

A MRI image of the brain is a way of transferring the anatomical information about the internal structures and also helps in the detection of various brain conditions. The MRI image needs to be analyzed in order to diagnose the abnormality that is present in the brain [15]. The first step to analyze the image is to understand the information that is being conveyed by the image. It is often clear that the entire image is not required for analysis, but only certain areas that contains the same characteristics. In order to segregate the areas with similar characteristics, segmentation is performed to the image as the primary step in image processing. Image segmentation is the process of segregating the set of pixels on the basis of their similarities. In other words, it is the process of identifying, grouping and isolating of the regions and surfaces of the image which often is referred to as structural units or segments, in order to extract and the relevant information that is required for the diagnosis of brain tumor [16]. Segmentation is often carried out based on features like color, intensity or even texture. Early diagnosis of the tumor helps in increasing the survival rate by reducing the critical issues. Segmenting the image according to the similarities help in identifying tumor region in a much efficient way.

The process of segmenting an image is an essential procedure when it comes to extracting relevant information from the grey or RGB images. It helps in the conversion of complex image into a simple image, in order to locate boundaries and identify tumoral region in the image. Figure 1 denotes the basic process of segmentation. Based on the basic properties such as discontinuity and similarity, segmentation algorithms are being developed to segment the images. The motive behind the process of segmentation is to analyze homogenous criteria and to understand the image complexity.

The segmentation process characterized based on discontinuity is referred to as edge-based segmentation whereas the segmentation based on similarity is the one referred to as region-based segmentation. Segmentation technique can be done in various ways, that include manual, semi-automatic and fully-automatic [17]. Manual segmentation methods are usually performed by expert radiologist or specialized clinicians. Manual segmentation performed are considered and accepted widely as ground truth. The major advantage of using manual segmentation techniques is that we can utilise the knowledge of an expert in the field, whereas the disadvantages of this segmentation is that it is extremely time consuming and is prone to intra and inter-observer variability. Since the segmentation process is carried out slice-by-slice [19], there is quite a chance of larger variability.

The disadvantages in the manual segmentation technique has led to the discovery of future advancements referred to as the semi-automatic segmentation technique. It reduces the time consumption in the process of segmentation, since the user intervention in the process is being replaced by various algorithms either at the beginning or the final stages of the segmentation process. Though it aims in solving some of the major disadvantages including intra-observer variability and time consumption, it still contains inter-observer variability since the manual user intervention and the algorithm equally influences the result [20]. Automatic segmentation techniques are the ones that does
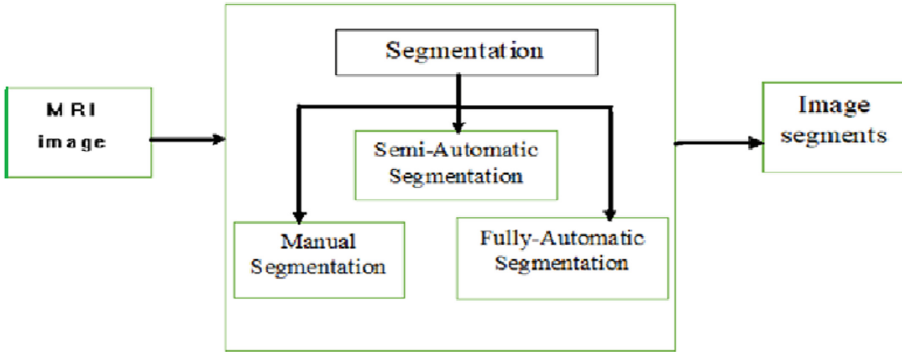
Fig. 1. Process of segmentation

not rely on any user interaction and the segmentation can be done by two methods: learning and non-learning. Deep learning methods are one among the recently popular learning methods, where the segmentation is performed by a neural network that is being trained with labelled examples. The major advantage of automatic segmentation is that it drastically reduces the time consumption once the method is being trained. Depending on the size of image that needs to be segmented, it ranges from seconds to a few minutes, but usually faster and efficient when compared to that of the methods with user interaction. The disadvantage of automatic segmentation is that it requires large amount of labelled data in order to train an accurate model and it also requires long training time and specialized software like GPU to train the model efficiently. The errors in automatic segmentation are systematic errors whereas the errors in the case of manual and semi-automatic segmentation are incidental errors.

The drawbacks of watershed algorithm is the segmented image is further being segmented into small segments and is uniform in size. Over-segmentation extracts important boundaries but may create insignificant boundaries. The presence of noise affects the quality of the output of the segmentation process. Watershed segmentation suffers from the major drawback of over segmentation and this drawback is being controlled with the help of markers. The concept of markers helps in controlling over-segmentation. This algorithm is affected by noise and irregularities in the edges. The advantages of enhanced marker controlled watershed segmentation that will overcome the disadvantages of marker controlled watershed segmentation are the use of internal foreground and external background markers that'll help in overcoming the limitations of over-segmentation.

2 Literature Survey

In recent years, the research in the field of image segmentation has grown enormously leading to various segmentation algorithms. In this section, the related works of image segmentation techniques by various authors are being studied.

Sujatha Saini and Komal Arora [1] explained about the basic idea of image segmentation and the classification of image segmentation techniques. It discusses about various segmentation algorithms that can be used in a variety of segmentation techniques.

Song Yuheng and Yan Hao [2] have discussed about various segmentation techniques, analyses the algorithms of image segmentation techniques and compares their advantages and disadvantages. It is finally being accepted that it may be cynical to find an image segmentation technique that adapts with all the images. In near future, algorithms that tend to adapt with various images will be proposed.

Vairaprakash Gurusamy and Subbu Kannan [3] explained how segmenting an image is a major step when it comes to analysing an image. The review paper mainly focuses on the basic properties of an image including discontinuity and similarity and speaks about various techniques that are used for image segmentation. Image segmentation by using threshold technique is proven to provide much better results. It has been concluded that region-growing and threshold techniques are much better and efficient than clustering and edge detection techniques.

Sindhu Devanooru et al. [4] talks about introducing a taxonomy that consists of Data, Image Segmentation Processing and View (DIV), which is being demonstrated by state-of-the-art publications on deep neural networks. With the help of this detailed analysis, they have proven that Modified FCM produces brain segmentation results much accurately. The proposed solution has a wider view on the three major factors namely, Data, Image Segmentation Processing and View respectively. The future work on this field focusses on improving the quality of image segmentation and also in the processing of large amount of MRI data accurately and simultaneously.

N. Arun Kumar et al. [5] speaks about fully-automatic model-based segmentation using Artificial Neural Networks in identifying brain tumor identification and classification. The pre-processing stage of the segmentation method is to perform Fourier transform such that to improve or return the required data from Fourier domain to its original domain without losing any data during the inverse process. The ROI of the enhanced image is obscure thus to extract the required borders, they have performed feature extraction with the feature descriptor called as Histogram of Oriented Gradients (HOG). The non-brain region is being filtered with the use of histogram thresholding. The main challenge is to understand the homogenous nature of the brain. The performance measures of the segmentation are 92.14% accuracy, 89% sensitivity and 94% specificity.

Steven Lawrence Fernandes et al. [6] proposed a tool and associated methodology that will help in exploring a clinical brain image with much better accuracy thus providing a clearer insight on early and ideal treatment methods. This tool gives all the probable methods in which the treatment of brain tumors can be easily diagnosed and can be treated preventing permanent disability or even death.

S. U. Aswathy et al. [7] proposed an enhanced segmentation algorithm that is based on support vector machine and genetic algorithm. For FLAIR images, the algorithm shows better tumor detection that helps in determining boundary region more accurately. The accuracy and precision achieved through the proposed algorithm is about 99.65 respectively. The error rate in this algorithm is quite low when compared to other algorithms. The major advantage is that it drastically reduces the need for any pre-processing methods.

Suresha. D et al. [8] introduced a hybrid algorithm with a combination of K-means Clustering technique and Support Vector Machine (SVM) to detect whether tumor is present or not. This algorithm uses Machine Learning and requires less time for training sets, predicts accurately the region of tumors.

Hyunseok Seo et al. [9] speaks briefly on comparing around 40 different segmentation techniques and provides a new segmentation method under a specific network referred to as the Graph Neural Networks (GNN) and Generative Adversarial Network (GAN) which are implemented as powerful tools for the segmentation of non-Euclidean domain structures (medical images). GNNs are mainly used in the segmentation process of biomedical images since graph-structured images is bound to be more efficient since medical images do not have a constrained boundary. Deep learning methods requires many hyper parameters which means that minor deviations in these parameters will lead to major disproportionate changes that will affect the results at a greater extent.

Prabhjot Kaur and Tamalika Chaira [10] focuses that CT/MRI images are not clear and introduces a novel clustering approach based on fuzzy concept which enhances the vague image before the segmentation process. The enhanced image will be then segmented by Gaussian kernel-based Fuzzy C-means clustering. The proposed method has efficiently even amidst of noise.

V. Sivakumar and N. Janakiraman [11] proposes a modified watershed segmentation algorithm for segmenting the ROI from the MRI images. In this pre-processing stage, the input MR image is being pre-processed by high pass filter and then enhanced by the use of Enhanced Canny Edge Detection approach. Then modified watershed segmentation algorithm is performed such that to segment the required ROI. The proposed method is being implemented with Xilinx Virtex-5 FPGA. The proposed method is executed in three phases namely pre-processing, edge detection and segmentation. The authors have compared various methods of k-means clustering and fuzzy-means clustering.

V. Rajinikanth and M. S. Couceiro [12] introduces an optimal multi-level image segmentation using firefly algorithm. The new optimal multi-level image segmentation approach introduced is based on RGB Histogram using Brownian search-based Firefly Algorithm (BFA), Levy search-based Firefly Algorithm (LFA) and Conventional Firefly Algorithm (CFA). The obtained results prove that LFA and FA has faster convergence than BFA.

3   Enhanced Marker-Controlled Watershed Segmentation Algorithm

In this paper, an Enhanced Marker-Controlled watershed algorithm is introduced to segment MRI of the brain and detect its tumor region. In this algorithm, we use gradient magnitude which is used to pre-process the grayscale image before using the Enhanced Marker-Controlled Watershed Segmentation. The gradient is usually high at the borders and low at the inside which means that it'll help in analysing the region of tumor. Markers are used in order to modify the gradient magnitude. The proposed algorithm is mainly used in segmenting MRI images of the brain since the segmentation of cerebral ventricles can also be done with minimal interaction. The major criterion of this proposed algorithm is to locate the region of tumor by using the homogeneity of the grayscale image. The

Enhanced Marker-Controlled Watershed Segmentation algorithm is a region-based and contour detection algorithm which will be implemented based on region-growing in order to avoid over-segmentation. The number of markers used denotes the final number of watershed regions. The markers used in this proposed algorithm employ automatically in order to save human time. The segmentation process is done in six major steps.

The proposed algorithm performs morphological operations such as erosion-based and dilation-based reconstruction in order to mark the regions required for segmentation. The foreground and background markers are super-imposed with the original image. Application of the proposed algorithm helps in segmenting the region of interest.

Original Watershed Segmentation Algorithm uses grayscale images in either 2D or 3D form to proceed with the technique. The enhanced algorithm requires two or more images in order to perform the segmentation. This includes an input image and a mask image. The input image is usually a grayscale image in 2D or 3D form and the mask is the one referred to as the ground truth which is used as a template for the segmentation of the image. The initial step is to Read the Image. It includes RGB to grayscale conversion. It converts the true color RGB into grayscale image. The next step is to use the gradient magnitude as the segmentation function or mask. The gradient is often high at the borders and low at the objects. This mask will be the ground truth for the segmentation to take place. The mask is a binary image of the same dimensions of that of the input image. It performs watershed transform to the gradient magnitude. Once it performs the transform, the next step is to mark the foreground objects. This step includes morphological operations like opening which is an erosion followed by a dilation while opening by reconstruction is an erosion followed by a morphological reconstruction.

These steps are being explained followed by the results and discussion. For the segmentation process, FLAIR images are opted because to supress the cerebrospinal fluid effect on the MR image. Figure 2 denotes the work-flow of the Enhanced Marker-Controlled Watershed Segmentation. Segmentation using Enhanced Marker-Controlled Watershed Segmentation performs much better than the original Watershed Segmentation as it helps in identifying and marking the region of interest (ROI).

Once the foreground objects are being marked, the next step is to compute background markers. It includes the marking of background of the cleaned-up image. Dark pixels in the image belong to the background of the image. The markers used to mark the background are the ones that select to specify markers as binary and needs to be labelled. Once the dark pixels are marked, it is now time to start the process of thresholding operation. Now, it is time to compute the watershed transform of the segmentation function. Watershed Transform is the process of separating different objects based on the brightness of the grayscale image.
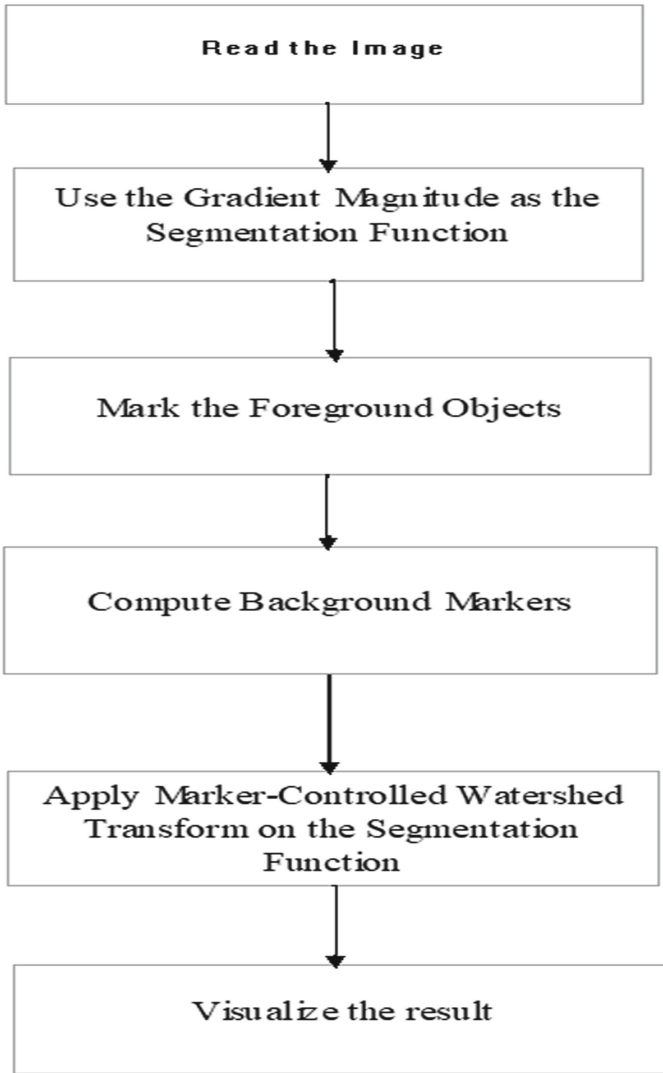
Fig. 2. Work flow of the proposed method

In this proposed algorithm, we introduce Binary markers and the pixel values in this algorithm are treated as elevation points. In this the original or input image is being super-imposed along with the mask or ground truth which will help in obtaining the ROI with greater accuracy. The images in Fig. 4 and its sub-ordinates represent the watershed transform of and the morphological operations that are performed on the gradient magnitude. The final step is to visualize the result which means that to display the label matrix as a color image. It can use transparency to superimpose the pseudo-color label matrix on top of the original intensity image.

The evaluation metrics considered are with the help of parameters like TP, TN, FP and FN where, TP – True Positive, TN – True Negative, FP – False Positive, FN – False Negative.

The evaluation metrics are Accuracy, Precision, Specificity and Sensitivity where each of these metrics are calculated with the help of formulae,

$$Accuracy = \frac{(TP + TN)}{(TP + FP + FN + TN)} \tag{1}$$

$$Precision = \frac{(TP)}{(TP + FP)} \tag{2}$$

$$Specificity = \frac{(TN)}{(TN + FP)} \tag{3}$$

$$Sensitivity = \frac{(TP)}{(TP + FN)} \tag{4}$$

Equation (1–4) denotes the formulae used for evaluating the metrics. The proposed method of enhanced marker-controlled watershed segmentation provides much better and enhanced results compared to that of the original watershed segmentation.

4 Results and Discussion

It has been proven that the Enhanced Marker-controlled Watershed Segmentation provides much better and improved results with an accuracy of about 99.14%, precision of 97.80% and sensitivity and specificity of 88.11% and 99.87% respectively. The watershed transform of the gradient magnitude in order to locate the light and dark pixels as high and low respectively before performing morphological operations. Once an operation is performed, then the result is being reconstructed and super-imposed with the original input image and ground truth in order to provide better and improved accuracy. The technique is used in image processing and segmentation and the software used is MATLAB R2019.

The images in Fig. 3 includes the original MR image and the gradient magnitude of the image. This proposed algorithm can't be directly applied to the gradient magnitude since it leads to over-segmentation. In order to avoid false segmentation, the concept of markers is used to mark the regions that ought to be segmented.

In this algorithm, we use morphological image reconstruction in order to create foreground and background markers. Figure 4 denotes the morphological operations that are performed in order to compute foreground markers that help in tumor region with higher accuracy and better clarity.
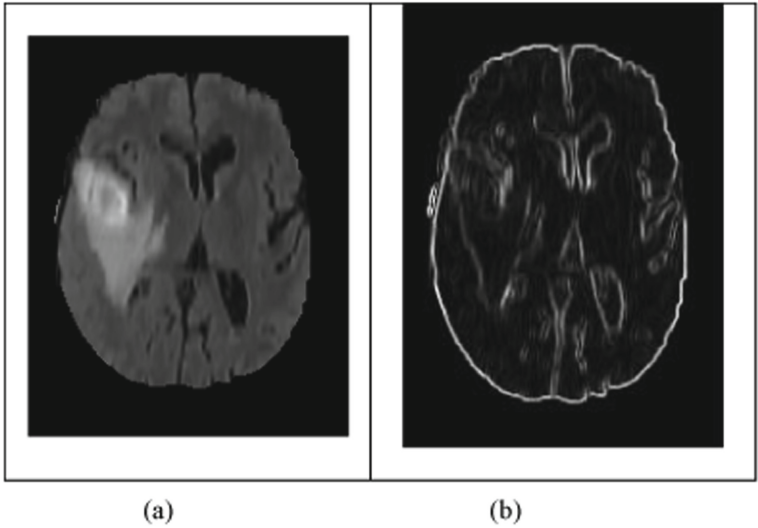
(a)   (b)

Fig. 3. (a) Original MR image of the brain, (b) Gradient magnitude

(a)   (b)   (c)
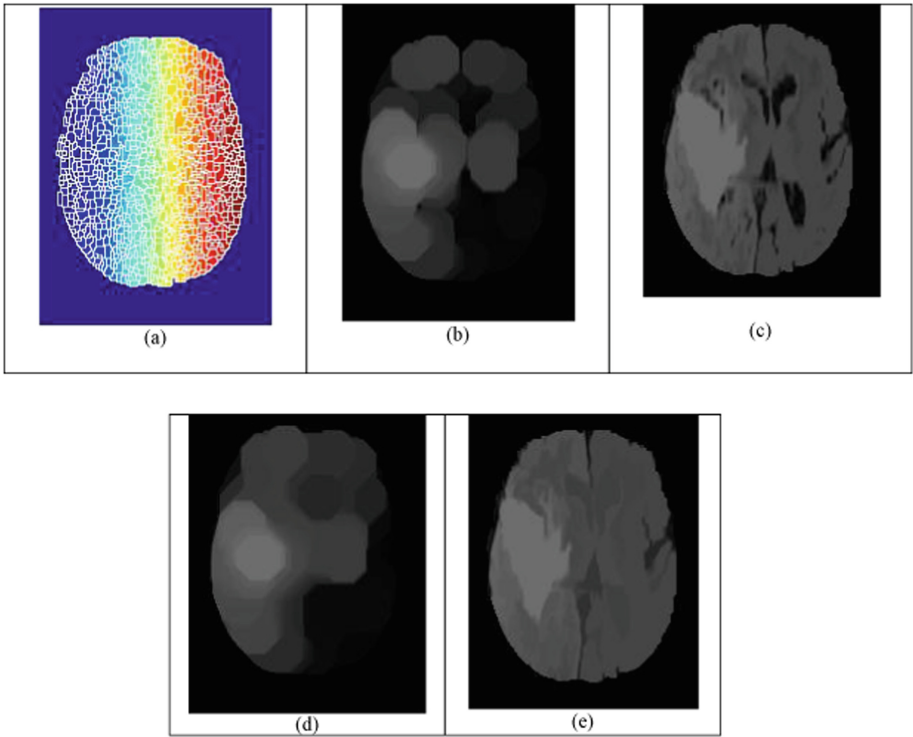

(d)   (e)

Fig. 4. (a) Watershed transform of the gradient magnitude, (b)–(e) Morphological operations performed on the gradient magnitude

The below Fig. 5 denotes the results of the parametric metrics which will in compare the output of all the given images. Considering various features of an MRI image, it proves that the accuracy of the segmented image is much better when compared to the original segmentation methods. Figure 6 shows the background markers and object boundaries super-imposed on original image that are performed in order to segment the ROI of the MRI image. The metrics of this algorithm is obtained with the help of comparing the image with the ground truth or the provided mask image which is of the same dimension of that of the input image.
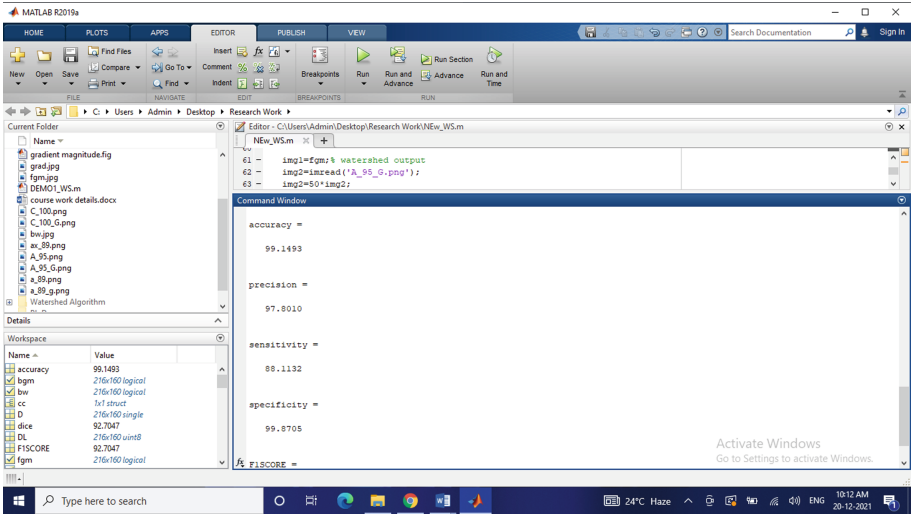

Fig. 5. Screenshot of the output

The below figures display the images where the background of the image is being marked such that it becomes easier to mark the boundaries of the image. Once the background of the image is being marked with the help of markers and then the image is being super-imposed on the original image. The super-imposed image helps in segmenting the tumor region with much accuracy and more clarity.

The below given Table 1 denotes the comparison of evaluated metrics with the previous techniques and algorithms that has been used in image segmentation process. The proposed algorithm provides higher accuracy in predicting the region of tumor and also has much better clarity than the related algorithms.
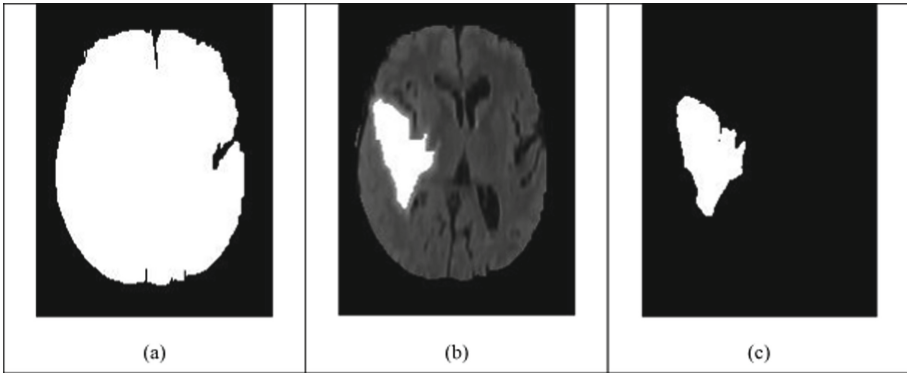
Fig. 6. (a) Background markers, (b) Object boundaries super-imposed on original image, (c) Segmented image

Table 1. Comparison of performance metrics with existing techniques

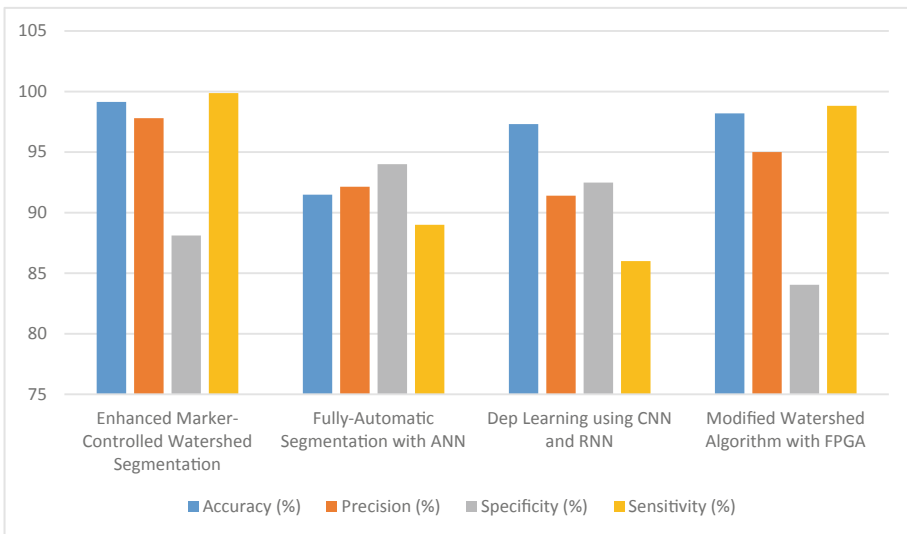| Methods	Accuracy (%)	Precision (%)	Specificity (%)	Sensitivity (%)
Enhanced Marker-Controlled Watershed Segmentation	***99.14***	***97.80***	88.11	***99.87***
Fully-Automatic Segmentation with ANN [5]	91.48	92.14	94	89
Deep Learning using CNN and RNN [9]	97.31	91.4	92.48	86
Modified Watershed Algorithm with FPGA [11]	98.21	95	84.04	98.82

Fig. 7. Pictorial representation of performance metrics

The above Fig. 7 denotes the pictorial representation of performance metrics. This figure helps in comparing the performance metrics of various existing approaches. The concept that sensitivity and specificity are inversely proportional to that of each other, which means that as sensitivity increases, specificity decreases and vice versa. High specificity values means that the output has got few false positive results. If the value of specificity keeps on decreasing, it could result in high number of false positives. Even when tumor is not present, it shows that it is present. Hence, increase in specificity is expected in future work. This automatic watershed segmentation has completed segmenting the tumor region with an accuracy of 99%.

5 Conclusion

Image segmentation is all about segmenting the ROI with better clarity and accuracy of the segmented image. This area has a promising future, since parameters such as precision, specificity and sensitivity needs to be improved each time. The proposed method of Enhanced Marker-Controlled Watershed Algorithm has been studied and has been proven to provide much better results when compared to that of the original Segmentation technique. The evaluation metrics such as accuracy, precision and sensitivity has been shown a drastic increase, thus providing better clarity and accuracy in segmenting the region of tumor. The accuracy of Enhanced Marker-Controlled Watershed Segmentation Algorithm is said to be 99.14% which plays a major role in defining the tumor region in the image.

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