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Design and Implementation of 2D Spatial Filter for EEG and MRI Segmentation

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Abstract:- The Electroencephalography (EEG) of brain field continues to be an attractive tool in clinical practice due to its real time depiction of brain function .The aim of this paper is to give a review of digital image segmentation technique .This paper study and implements the different types of 2D spatial filter(weighted, smoothening ,derivative) for EEG segmentation . Paper focuses on developing an automated system to enhance and recover the corrupted EEG signal images and MRI images with the help of 2D spatial filter and it also helps in early and accurate diagnosis of brain tumour. It ensures fast and reliable detection and formal resolution of deformed images by implementing noise addition and removal, edge detection, cropping, histogram adjustment, scale conversion as required by the image.

Keywords- *EEG, 2D spatial filter, brain tumour*

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1. 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. Image segmentation is important part in many signal processing techniques and its application. The segmentation procedure is to find the better position of the shape, points according to the appearance information [4]. 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. In medical images, segmentation is mainly done based on the gray-level value of pixels, because the majority of medical images are grey-scale representations [21]. For segmentation of a medical image related to brain it's very important to understand the terms EEG and brain tumour. Electroencephalography (EEG) is the recording of electrical activity of brain along the scalp. EEG measures the voltage fluctuations resulting from ionic current flows within the neurons of the brain. EEG signal thus obtained may carry noise along. This will be shown with the help of an example-

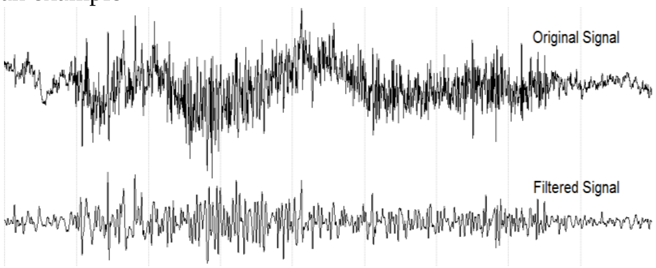

Fig.1 EEG signal image & filtered signal image

Figure 1 shows the image of corrupted EEG signal and the filtered signal, which has removed noise from the original EEG signal to improve its pictorial information.
Now let us understand what is tumour and what is the pre-processing done to examine the tumour.
Tumour –
The word tumour is synonym to the word neoplasm which is formed by abnormal growth of cells within the brain or spinal canal in centre [5] [6]. Tumour is something totally different from cancer. There are three common types of tumour:
1) Benign; 2) Pre-malignant; 3) Malignant (cancer can only be malignant) [8].

1) *Benign tumour-* A benign tumour is the one that does not expand in abrupt way, it doesn't affect its neighbouring healthy tissues and also does not expand to non adjacent tissues. Moles are the common example of benign tissues.
2) *Pre-Malignant tumour-* Pre-malignant is the precancerous stage, considered as a disease, if not properly treated it may lead to cancer.
3) Malignant tumour- Malignant tumour is a type of tumour which grows worse with the passage of time and ultimately results in the death of a person.

Brain is a kernel part of our body and it has very complex structure [18]. Due to complex structure of different tissues such as White Matter (WM), Gray Matter (GM), and Cerebrospinal Fluid (CSF) in brain images extraction of useful feature is fundamental task [20]. Now days, one of the main cause for increasing mortality among children and adults is the delayed detection of brain tumour. It is more difficult to detect tumour in early stage and also accurate measurements are quite hard because of its shape, size and position of the tumour in the brain [16].Tumour may be embedded in regions of the brain that are critical to provide the body's vital functions, while they shed cells to invade other parts of the brain, forming more tumours that are too small to detect using the normal imaging techniques [15]. It has been concluded from the research of most of the developed countries that number of people suffering and dying from brain tumours has been increased to 300 per year during last few decades [8]. Early and accurate diagnosis of brain tumour is the key for implementing successful therapy treatment planning. However the diagnosis is a very challenging task due to the large variance and complexity of tumour characterizations in images, such as size, shape, location and intensities [12]. According to National Brain Tumour Society, an estimated 688,000+ people are living with primary tumours of the brain and central nervous system (CNS) in the initial states, 138,000 with malignant tumours and 550,000 with non-malignant tumours. About 43% of brain and CNS tumours

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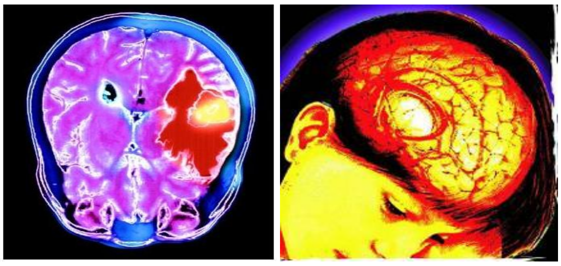
occur in men and about 57% occur in women. So efficient and accurate techniques are required for brain tumour detection [9]. The major problem that comes in the path of detection is noisy images which lead to wrong diagnosis. For right diagnosis the image can be segmented by applying various 2d-spatial filters to get proper diagnosis.
To examine human brain development and abnormalities of brain cells that is brain tumour or any other disorder there are several methodology used by radiologists to examine the patient physically by using magnetic resonance imaging (MRI), Computed tomography (CT) scan and EEG. Basically, for comparison, CT uses ionizing radiation while MRI uses strong magnetic field to align the nuclear magnetization that follows by changes the alignment of the magnetization by radio frequencies that can be detected by the scanner [13]. MRI is the state of the art medical imaging technology which allows cross sectional view of the body with unprecedented tissue contrast [19]. MRI images are essential in clinical diagnosis of neurodegenerative and psychiatric disorders, treatment, evaluation, and surgical planning [14]. MRI images shows the brain structures, tumor's size and its location [11].The images thus obtained using these techniques may carry noise which can create problem in proper detection of the disorder. So the spatial filtering is used here for the noise removal and hence the proper detection of disorder can be done. Let's take an example of a human brain shown below:

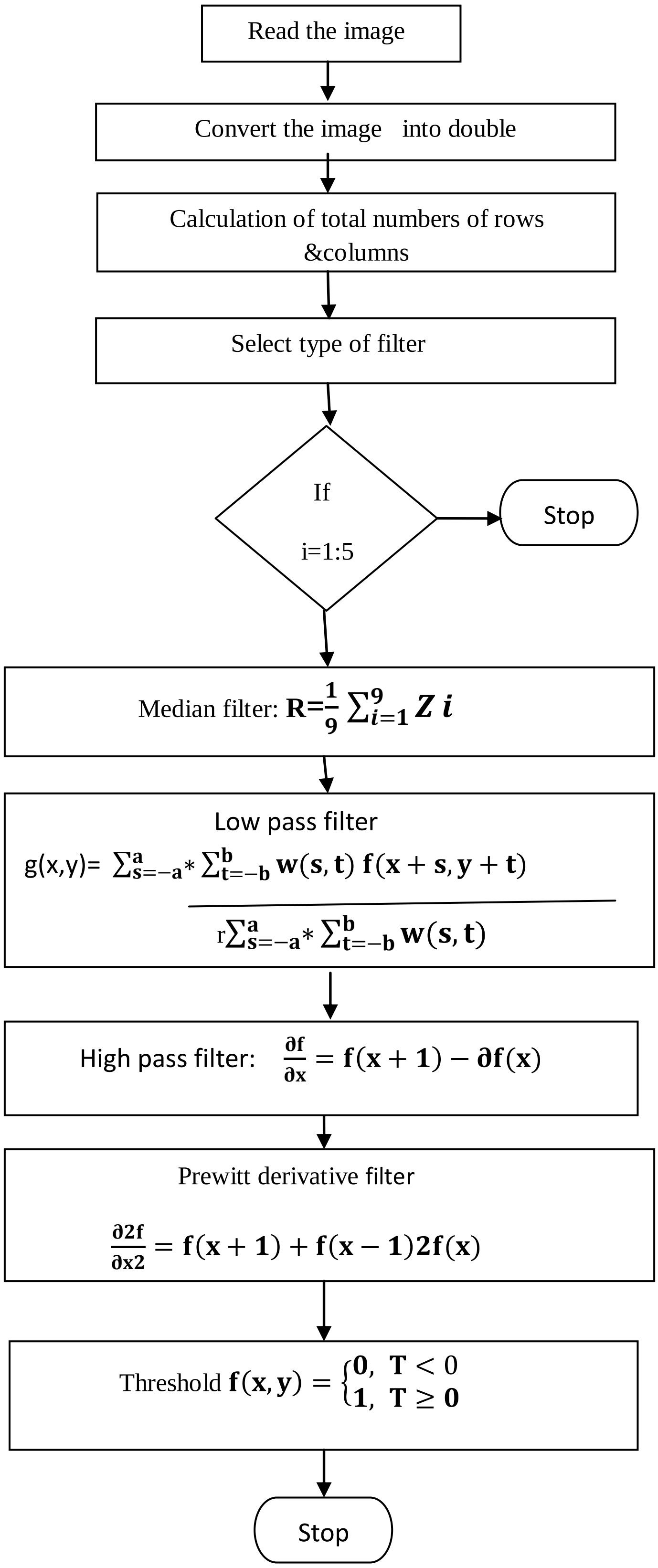


(a) (b)

Fig.2 Magnetic Resonance Image (MRI)

The image of a brain MRI shown here have some affected part or have some disorder, by examining this image we cannot differentiate between effected part of brain and other parts of brain. Along with effected part the veins of brain are not visible clearly in this image. The image so obtained may result in wrong interception. To avoid this problem image enhancement is done by applying various spatial filters which can detect the edges, remove unwanted information with the help of blur and sharpen the image.
The existing method of image processing is based on the threshold. At the threshold based segmentation the image is considered as having only two values either black or white. But the bitmap image contains 0 to 255 gray scale values. So it ignores the tumour cells also [10]. For tumour detection we need to detect the seed of tumour (i.e. center of the tumour cells) which may cause intensity homogeneity problems and also thresholded image will not provide the acceptable result for all the images.
In Digital Image Processing (DIP), we use computer algorithm to perform image processing, digital image processing has several advantages over analog image processing (AIP) [1]. DIP sends image in the form of codes which is more secure than analog image processing which includes sending of image in the form of analog signal and secondly it conveys information with greater noise immunity as compare to A.I.P.

2. PROPOSED METHODOLOGY



In the first part of this paper authors presented a set of MATLAB based applications useful for image processing and image quality assessment. The image processing and image quality assessment includes application of low pass filter, high pass filter, Prewitt derivative filter, median filter and threshold filter. We have proposed segmentation of the brain MRI images for detection of tumour using different filter techniques. MRI scans of the human brain forms the input images for our system where the gray scale MRI input images are given as the input. The pre-processing image will convert the RGB input image to gray scale [3].

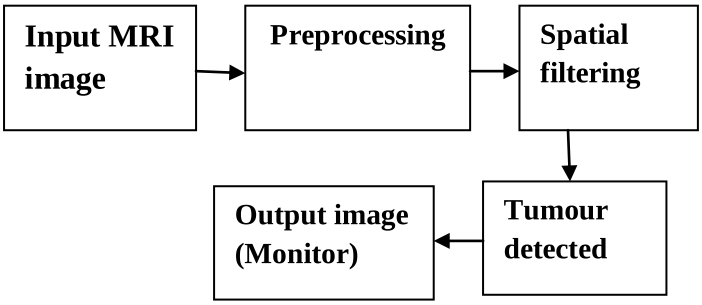


Fig.3 Block Diagram of proposed solution

SPATIAL FILTERS

Image processing is of great importance nowadays as it involves changing the nature of an image in order to either improve its pictorial information for human interpretation or

Render it more suitable for autonomous machine perception. It consists of four subunits [1]. Image processing methods helps in the development of diagnostic imaging system with the help of filtering, restoration, segmentation, reconstruction [17].

The first unit is intensity transformations

The second unit is spatial domain filtering which operate directly on the pixels of an image. These techniques are efficient computationally and require less processing resources to implement. The spatial domain processes can be denoted by the expression-

$$S(u,v)=X[f(u,v)]$$

Where f (u,v) is the input image, s(u,v) is the output image and X is an operator on f defined over a neighbourhood of (u,v).

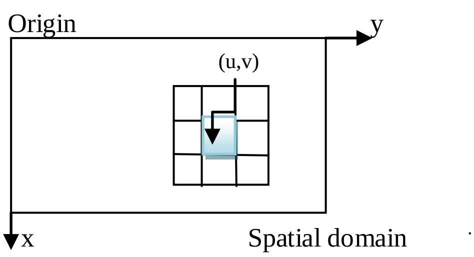


Fig.5 Spatial Domain Filter Mask

To improve the required pictorial information of an image of brain or EEG signal we will use five types of spatial filters which are as follows-

2.1 SMOOTHENING SPATIAL FILTER

It is one of the simplest spatial filtering which can be performed. This filtering can be done simply by averaging all of the pixels in a neighbourhood around a central value. The smoothening filter is also known as averaging filter and low pass filter. A major use of averaging filter is in the reduction of "irrelevant" detail in an image. By irrelevant it means pixel region that are small with respect to the size of filter mask. Another important application of spatial averaging is to eliminate small objects from an image which are undesirable so that intensity of smaller objects blends with the background and larger object become "blob like" and easy to detect.

$$\mathbf{R}=\frac{1}{9}\sum_{i=1}^{9} Z\, i \qquad ....1$$

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

*

104	100	108
99	106	98
95	90	85

Fig.3 Simple averaging filter

$$\mathbf{e = {}^1/_9*106 + {}^1/_9*104 + {}^1/_9*100 + {}^1/_9*108 + {}^1/_9*99 + {}^1/_9*98 + {}^1/_9*95 + {}^1/_9*90 + {}^1/_9*85 = 98.3333}$$

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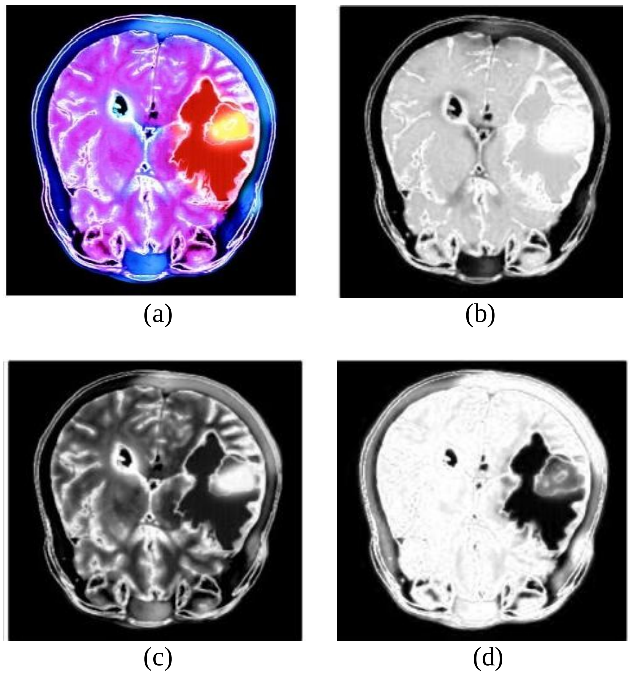

Fig.6 (a) Original MRI image (b) Gray-scale image (c) Median filter image with less intensity (d) Median filter image with more intensity

The second type of averaging filter is weighted averaging spatial filter. In Weighted filtering the pixels are multiplied

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by different coefficients to give more importance to some pixels. In this pixel closer to the central pixel are more important as compared to other pixels. The other pixels are inversely weighted as a function of their distance from the centre of the filter. The basic strategy behind weighing the centre point the highest and then reducing the value of the coefficients as a function of increasing distance from origin is simply an attempt to reduce blurring in the smoothening process. The general implementation for filtering an M*N image with a weighted averaging filter of size m*n (m & n are odd) is given by the expression-

$$g(x,y)= \frac{\sum_{s=-a}^{a} * \sum_{t=-b}^{b} w(s,t)\, f(x+s,y+t)}{\sum_{s=-a}^{a} * \sum_{t=-b}^{b} w(s,t)} \quad ......2$$

Let's take examples to understand low pass filter more clearly-

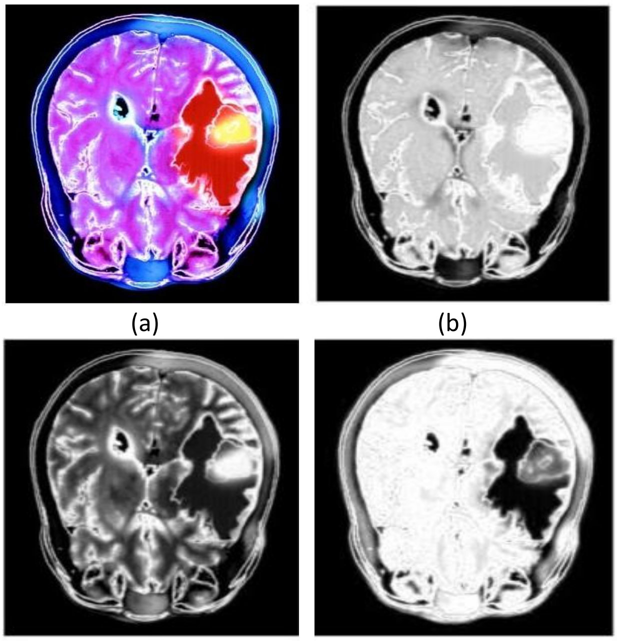
(a) (b)
(c) (d)

Fig.7 (a) Original MRI image (b) Gray-scale image after passing it through Low pass filter (c) Low pass filter image with less intensity (d) Low pass filter image with more intensity.

Figure 7 shows the response of brain which has a cavity. When the low pass filter is applied to the image it makes the background blur and makes the cavity highlighted as shown in the figure.

2.2 SHARPENING SPATIAL FILTERS:-The principal objective of sharpening is to highlight transitions in intensity. It is logical to conclude that sharpening can be accomplished by spatial differentiation. The image differentiation enances edges and other discontinuities and deemphasizes areas with slowly varying intensities. The derivatives of a digital function are defined in terms of differences. There are various ways to define these derivatives.[1] First derivative for an image can be defined as the given one-dimensional function f(x)-

$$\frac{\partial f}{\partial x} = f(x+1) - \partial f(x) \quad ......3$$

For the application of First derivative definition it requires-

- It must be zero in areas of constant intensity.
- It must be nonzero at the onset of an intensity step or ramp.
- It must be nonzero in constant areas.

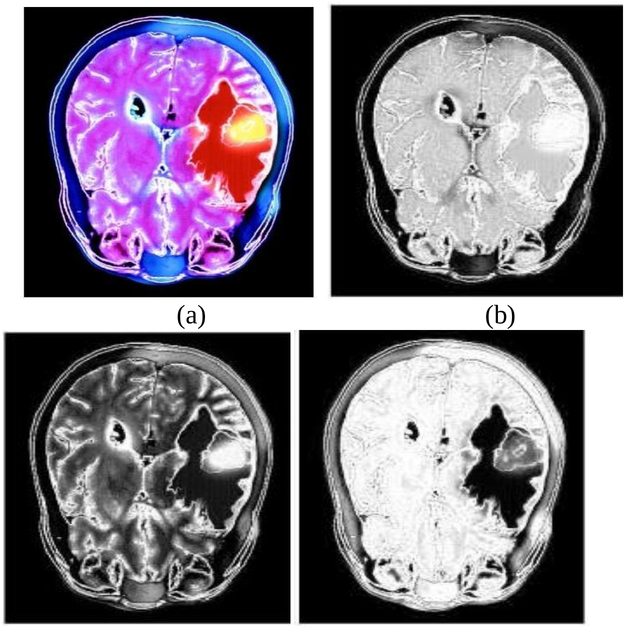
(a) (b)
(c) (d)

Fig.8 (a) Original MRI image (b) Gray-scale image (less sharp) (c) High pass filter image with less intensity (d) High pass filter image with more intensity

Figure 8 shows the response of high pass first derivative filter. In this image the veins and edges are sharper as compared to the image taken.

Second derivative for an image can be defined with the help of given expression-

$$\frac{\partial 2f}{\partial x2} = f(x+1) + f(x-1)2f(x)$$

......4

For the application of second derivative definition it requires-

- It must be zero along ramps of constant slope.
- It must be nonzero at the onset and end of an intensity step or ramp.
- It must be zero in constant areas.

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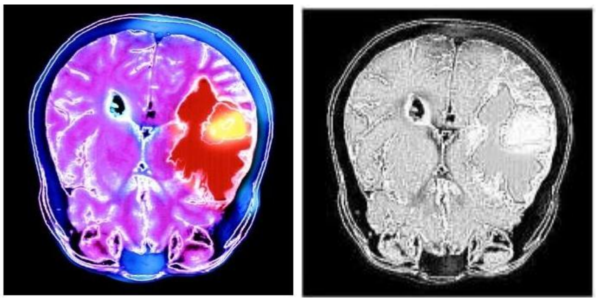
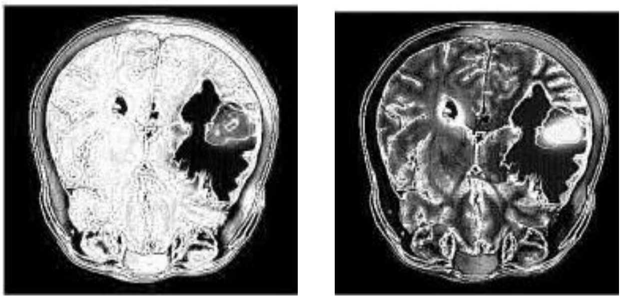


(a) (b)

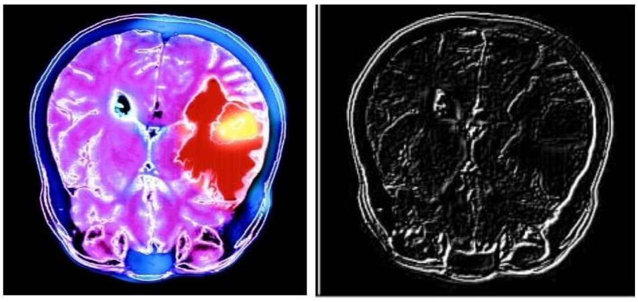


(c) (d)

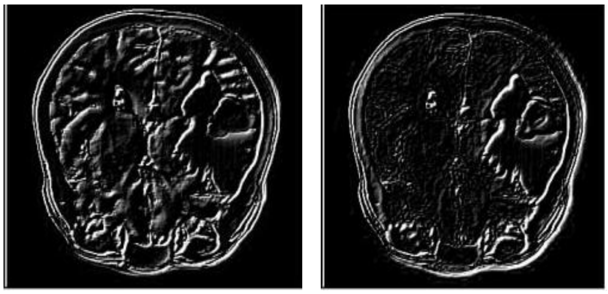
Fig.9 Original MRI image (b) Gray-scale image after passing it through high pass filter(more sharp) (c) High pass filter image with less intensity (d) High pass filter image with more intensity

Figure 9 shows the response of second derivative high pass filter which represents the veins and cavity sharper than the first derivative filter.

2.3 Prewitt derivative filter: Prewitt derivative is particularly an edge detection algorithm. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. In simple terms, the operator calculates the gradient of the image intensity at each point, giving the direction of the largest possible increases from light to dark and the rate of change in that direction. Mathematically, the operator uses the two 3*3 kernels which are convolved with the original image to calculate approximation of the derivatives- one for horizontal changes, and one for vertical. If we define A as the source image, and G_x and G_y are two images which at each point contain the horizontal and vertical approximations which are computed as-



(a) (b)



(c) (d)

Fig.10 (a) Original MRI image (b) Gray-scale image after passing it through Prewitt derivative filter (c) Prewitt derivative filter image with less intensity (d) Prewitt derivative filter image with more intensity

$$G_x = \begin{vmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{vmatrix} * A$$

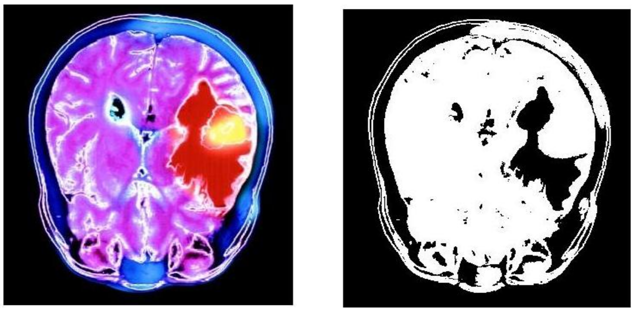
$$G_x = \begin{vmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ +1 & +1 & +1 \end{vmatrix} * A \qquad ......5$$

Figure 10 shows the filtered image of brain which only represents the edges of the image. This image can be helpful in detection of cavity in brain easily.

2.4 THRESHOLDING: It is the simplest method of image segmentation. It replaces each pixel in an image with a black pixel if the image intensity is less than some fixed constant value or white pixel if the image intensity is greater than that constant. It converts input gray-scale image into binary image format [7]. A binary image is a logical array of 0's (black) and 1's (white). For conversion of gray scale image to binary image, toolbox function *im2bw* is used [2]. It scales the entire range of the input values to the range [0 1]. It makes decision based on local pixel information and is effective when the intensity levels of the object fall squarely outside the range of levels in the background [21]. The thresholding concept has been used in this algorithm. The threshold concept works by choosing a threshold value, T, automatically and then extract (or separate) object from background [9].

The threshold function of binary image f(x,y) is defined as:

$$\mathbf{f(x,y)} = \begin{cases} \mathbf{0}, & \mathbf{T} < 0 \\ \mathbf{1}, & \mathbf{T} \geq \mathbf{0} \end{cases} \qquad ....6$$



(a) (b)

Fig. 11 Original MRI image (b) Threshold image

Figure 11 represents the image in the form of two colour levels that is black and white. This image is helpful in analysing the parts of brain.

CONCLUSION:-Segmentation of brain image is imperative in surgical planning and treatment planning in the field of medicine. In this paper author have proposed a computer aided system for brain MR image segmentation for detection of brain tumor. Here the different methods are classified and each method has its suitable application fields, and researchers should combine the application background and practical requirements to design proper algorithms. Accuracy, complexity, efficiency and interactivity of a segmentation method should all be the considered factors.

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