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Segmentation of Brain Tumor in MRI using Multi-structural Element Morphological Edge Detection

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***Abstract* - MRI brain images are widely used in medical applications for research, diagnosis,treatment, surgical planning and image guided surgeries. MRI-based medical image analyses for brain tumor studies areessential for efficient and objective evaluation of large amounts of data. MR brain images corrupted with Intensity Inhomogeneity artifact causes unwanted intensity variations due to non- uniformity in RF coils and noises.Due to this type of artifact and noises, certain type of abnormal tissue in MRI may be misclassified as other type of normal tissue which leads to error in analysis. Using the segmentationmethods and morphological algorithm,this problem can be solved.**

In this paper, a new method is proposed which segments the brain tumortissues from MR images with noise and Intensity Inhomogeneity artifact.Here, preprocessing, enhancing, filtering and skull stripping done to remove noise and the skull region.Then themulti-structural element morphological algorithm is used to segment the tumor tissues.

***Index Terms* –Brain Tumor, Filtering, MRI, Multi-structuralelementMorphological Edge Detection,Segmentation.**

I. INTRODUCTION

A. Segmentation

Segmentation is a process in which image is partitioned into its constituentsalient image regions to acquire the regions of interest(ROIs). Being an importanttechnique of image processing, it has a lot of applications in many fields of whichmedical imaging is the one. Medical image segmentation is an important techniquein areas like, help in diagnosis,detection of lesions, tumors, cysts or otherabnormalities,surgical assessment and post-surgical assessment. It has long been used fortumor recognition as well as for determining tumor boundaries. These techniques are mostly used in medical field for detecting diseases in human bodystructures such as nerves damage, blood vessels extraction and tumor detection.[1].

If domain of the image $=I$,segmentation problem is to determine the sets $S_k \subset I$,whose union is the entire image I.

$$I = \cup_{k=1}^{K} S_k \qquad (1.1)$$

Segmentation methods vary depending on the application,imaging modality, noise, partial volumeeffects, and the motion. Better performance can be achieved by considering the priorknowledge. Selection of an appropriate approach to a segmentation problem is thedifficult dilemma in segmenting an object. The main applications of segmentationsare:

- To detect the tumor region by segmenting abnormal MRI image.
- Used in computer algorithms for delineation of anatomical structures and other regions of interest.
- Image segmentation algorithms are used in biomedical imaging applicationssuch as localization of pathology,study of anatomical structure,treatment planning,partial volume correction of functional imaging and computer integrated surgery.

B. Brain tumors

Brain tumor is defined as an abnormal growth of cells within the brain orthe central spinal canal. Some tumors are brain cancers. The word ‘tumor’ is ofLatin origin and means swelling. It causes inflammation, brain swelling and pressurewithin the skull.[2]

Brain tumors include all tumors inside the human skull (cranium) or in thecentral spinal canal created by an abnormal and uncontrolled cell division, in the brain itself. Some growtharises from other tissues inside the skull, such as pituitary tumors which iscommonly known as *Primary brain tumors*,which arise within the skull. Anothergroup consists of tumors that spread to the head from another source, such as lung orbreast cancer known as *Secondary brain tumors* (or metastatic tumors).[3]

Brain tumors can be classified according to their origin or degree of aggressiveness.Different types of tumors are shown in Figure 1.1 and their appearances in brain areshown in Figure 1.2. [5]

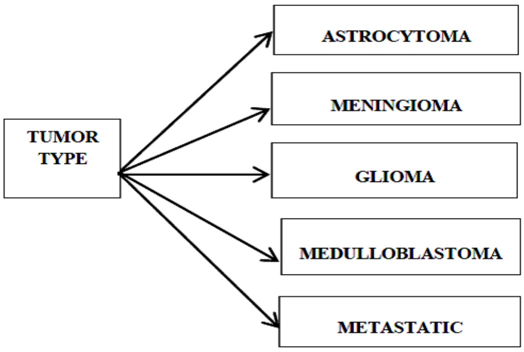


Figure1.1: Different types of tumors in brain

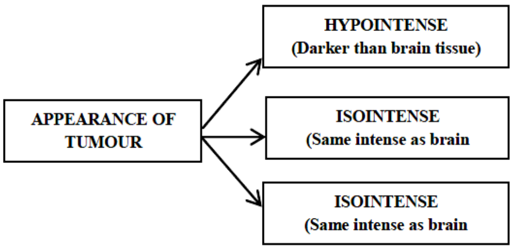


Figure 1.2: Appearance of brain tumors

C. Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI),or nuclear magnetic resonance imaging (NMRI),or magnetic resonance tomography (MRT) are medical imaging techniques used inradiology which uses the magnetic field and pulses of radio waves to visualize internalstructures of the body in detail. MRI makes use of the property of nuclearmagnetic resonance (NMR) to image nuclei of atoms inside the body which gives bettervisualization of soft tissues of human body thereby helps in easy diagnosis anddoes not affect human body as no radiation is used. It aids segmentation becauseof high contrast between different tissues. Different components in object are highlightedby carefully choosing relaxation timings and RF pulses[4]. MRI scanner is a device used to scan the brain images, in which the patient lies within a large, powerfulmagnet where the magnetic field is used to align the magnetization of some atomicnuclei in the body, and radio frequency fields to systematically alter the alignmentof this magnetization. [1]

Different image views and types of MRI are shown in Figure 1.3 and Figure 1.4.[6]

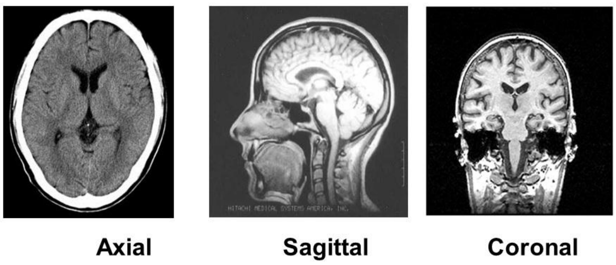


Figure 1.3: Different image views of MRI

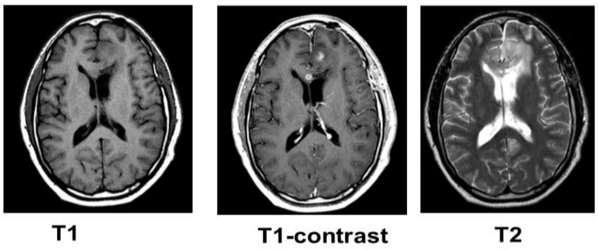


Figure 1.4: Different image types of MRI

MRI is of mainly 2 types:

- **T1-weighted MRI** Spin-lattice relaxation time
- **T2-weighted MRI** Spin-spin relaxation time or**T*2-weighted MRI** (ContrastEnhance)

One advantage of an MRI scan is that it is harmless to the patient. It uses strongmagnetic fields and nonionizing electromagnetic fields in the radio frequency range,unlike CT scans and traditional X-rays, which both use ionizing radiation. While CTprovides good spatial resolution (the ability to distinguish two separate structures anarbitrarily small distance from each other), MRI provides comparable resolution withfar better contrast resolution (the ability to distinguish the differences between twoarbitrarily similar but not identical tissues).[5]

In this paper, the segmentation of brain tumor in MRI images is discussed. First the pre-processing**,** enhancing, filtering and skull stripping is done for removal of noise, image enhancement and removal of skull regions. Then the morphological algorithm is used to segment tumor tissues. Rest of the paper is organized as follows. Relatedworks and the problems existing in previous methodswere given in Section 2. Multi structural element morphological edge algorithm is been explained in Section 3. The implementation of the method is discussed in Section 4. Section 5, demonstrates the results whenapplied to a suitable example. The conclusion is given in Section 6.

II. RELATED WORKS

Several approaches have been used for MRimages in order to segment tissues in human brain.M. Masroor Ahmed & et.al (2008) [7] explained about the automatic brain tumorsegmentation for the extraction of tumor tissues from MR images. This method explained about the process of removal of the skull region known as skull stripping in order to avoid the chances of misclassification. Skull tissueswere removed in the preprocessing step by morphological functions such as erosionand dilation. Partial Differential Equation was used for image denoising and enhancement.K means algorithm was used for solving clustering problem which aims at minimizing an objective function (a squared error function). Finally, by applying certain postprocessing operations, the tumorous region can be extracted.Even though this model provided reliable results with less error sensitive andsimple output, tumor extracted from noisy image marked portions of normal tissues,results obtained from enhanced image and the clean image were similar.

Prof. J. Mehena (2011) [8] proposed a novel mathematical morphologicalalgorithm to detect medical MRI image edge. The morphological edge detectionalgorithm was compared with a variety of existing operators such as Sobel algorithm,Prewitt algorithm, etc. for edge detection. Edge detection, is an essential preprocessingstep in medical image segmentation which is not fit for noise medicalimage edge detection, since noise and edge belongs to high frequency. Prewitt operatoris the oldest and best understood method of edge detection which consistsof two masks, one for detecting image derivatives in X and the other for detectingimage derivative in Y in which convolves an image with both masks, producingtwo derivative images($dx\&dy$). Sobel operator is based on convolving the imagewith a small, separable, and integer valued filter in horizontal and vertical directions.Roberts method is also the oldest method, which is used frequently in hardware implementations(simplicity and speed -dominant factors).

The basic mathematical morphological operators are erosion, dilation, openand close. Edge of an image is calculated in two ways. One is the difference set ofthe dilation domain of the image and the domain of image itself and the other wayof calculation is the difference set domain of the image and erosion domain of image.Morphological gradient is then computed by finding the difference between theedges thus calculated. Using the opening and closing operation, the morphologicaledge is been found out. The results showed that the algorithm is more efficient formedical image denoising and edge detection than the usually used edge detectionalgorithms such as Sobel, Prewitt, Robert and canny edge detector, and general morphologicaledge detection algorithm such as morphological gradient operation. Butthe computation is more complex compared to general morphological edge.

The Existing methods are Partial derivatives, Wavelet based denoising, thresholdingand K means clustering methods for segmentation.The drawbacks of these methods are:

- PDE-Loss of edge details
- Wavelet denoising-failure to detect edge details at curved region.
- K means - It is not suitable for all lighting condition of images.
- Difficult to measure the cluster quality

III. MULTI STRUCTURAL ELEMENT MORPHOLOGICAL EDGEALGORITHM

Mathematical morphology is a new mathematical theory and a powerful toolfor dealing with various problems in image processing and computer vision to processand analyze the images. It is been composed by a series of basic morphologicalalgebraic arithmetic operators, namely erosion, dilation, opening, closing etc. and areused for detecting, modifying, manipulating the features present in the image basedon their shapes.

Morphological techniques probe an image with a small shape or template calleda *Structuring Element (SE)*. The SE is positioned at all possible locationsin the image and it is compared with the corresponding neighborhood of pixels.Some operations test whether the element “fits” within the neighborhood, while otherstest whether it “hits” or intersects the neighborhood. A morphological operationon a binary image creates a new binary image in which the pixel has a non-zero valueonly if the test is successful at that location in the input image.

The shape and the size of SE play crucial roles in such type of processing .Thusthe choosing of structure element (SE) decides the performance of morphologicaloperation. Generally, simple and symmetrical shape structure elements such as crisscross,diamond and disk are adopted but they are sensitive to image edge which hasthe same direction of structure elements, and are not so effective to the edge whichhas the direction other than the structure elements. Therefore, they are difficult todetect complex edge feature. Here, multi-structure elements morphology of eightdifferent directions is proposed which comprises almost all the directions of linesextendin the image. By using *multi-structural element* morphological gradient edge detector respectively, 8different edge detection results areformed and the final edge result is produced byusing synthetic weighted method.

In the two-dimensional Euclidean space,Z^2, Let $F(x, y)$ denote a gray-scale2D image, B denote SE. Dilation of a gray-scale image $F(x, y)$ by a gray-scale SE$B(s, t)$ is denoted by

$$(F \oplus B)(x, y) = max\,\{F(x - s, y - t) + B(s, t) \quad (3.1)$$

Erosion of a gray-scale image $F(x, y)$ by a gray-scale SE $B(s, t)$ is denoted by

$$(F \ominus B)(x, y) = min\,\{F(x + s, y + t) - B(s, t)\} \quad (3.2)$$

Opening and closing of gray-scale image $F(x, y)$ by gray-scale SE $B(s, t)$ are denotedrespectively by

$$F \circ B = (F \ominus B) \oplus B, \quad (3.3)$$
$$F \cdot B = (F \oplus B) \ominus B \quad (3.4)$$

Erosion is a transformation of shrinking, which decreases the gray-scale value ofthe image, while dilation is a transformation of expanding, which increases the grayscalevalue of the image. Erosion filters the inner image while dilation filters the outerimage. Opening is erosion followed by dilation and closing is dilation followed byerosion. Opening generally smoothens the contour of an image, breaks narrow gaps.As opposed to opening, closing tends to fuse narrow breaks, eliminates small holes,and fills gaps in the contours. Therefore, morphological operation is used to detectimage edge, and at the same time, denoise the image.

The edge of image F, which is denoted by $E_d(F)$, is defined as the differenceset of the dilation domain of F and the domain of F. This is also known as *dilationresidue edge detector*:

$$E_d(F) = (F \oplus B) - F \quad (3.5)$$

Accordingly, the edge of image F , which is denoted by $E_e(F)$, can also be definedas the difference set of the domain of F and the erosion domain of F . This is alsoknown as *erosion residue edge detector*:

$$E_e(F) = F - (F \ominus B) \qquad (3.6)$$

The dilation and erosion often are used to compute the morphological gradient ofimage , denoted by $E(F)$:

$$E(F) = (F \oplus B) - (F \ominus B) \qquad (3.7)$$

The morphological gradient highlights sharp gray-level transition in theinput image,and therefore, it is often used as edge detector. The basic theory of multi-structureelements morphology is to construct different structure elements in the same squarewindow.Let $\{F(m,n)\}(m,n \in Z)$ is a digital image, and (m,n) is its center, then structureelements in $(2N+1) \times (2N+1)$ square window can be denoted by:

$$B_i = \{F(m+m_0, n+n_0), \theta_i = i \times \propto \mid -N \leq m_0, n_0 \leq N\} \qquad (3.8)$$

Where, $i = 0, 1, \ldots, 4N-1$, $\propto = 180^0/4N$ and θ_i is the direction angle of SE. In thispaper, we choose N = 2, then in the 5×5square window, the direction angles ofall structure elements are 0^0 , 22.5^0 , 45^0 , 67.5^0 , 90^0 , 112.5^0 , 135^0 *and* 157.5^0 . Thestructure elements B_i can be got by decomposing 5×5square SE B as shown inFigure3.1.

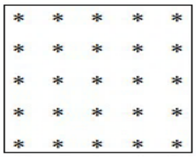


Figure 3.1:5×5 square structure element B

Therefore, $B_i$and B satisfy:

$$B_1 \cup B_2 \cup B_3 \cup B_4 \cup B_5 \cup B_6 \cup B_7 \cup B_8 = B \qquad (3.9)$$

IV. IMPLEMENTATION OF THE PROPOSED METHOD

The Proposed method for the segmentation of tumor from MRI brain structures and its analysis based on multi structural element morphological edge detection algorithm is beenexplained as follows.

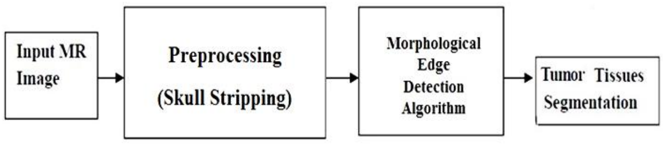


Figure4.1: Methodology

The various steps involved in the implementation of this method are.

- Image acquisition
- Image preprocessing
- Skull stripping
- Morphological operations
- Multi structural element selection
- Morphological Edge detection algorithm
- Tumor tissue segmentation

A. *Image acquisition and preprocessing*

Image preprocessing includes the image acquisition, denoising and skull stripping.The input image is an MRI image of DICOM format. For the smoothingpurpose, the Gaussianfilter is been used to remove high-frequency components fromthe image. Skull stripping is a major phase in brain imaging applications and it refersto the removal of skull.

Normally, mathematical morphology operations (i.e. erosion and dilation) areapplied to the binary image to remove the non-cerebral tissue. The operation convolvesthe binary image with a disk shape structuring element to produce the skullstrippedimage. In most cases, because of the oval-shape of brain image ,disk-shape structuring element is used. Both erosion and dilation uses same structuring elementwith different size. [9]

Another method for skull stripping is by subtracting two imagesor subtracts a constant from the input image. If X and Y are two arrays from theircorresponding elements, then there occurs the subtraction of each element in arrayY from the corresponding element in array X and returns the difference in the correspondingelement of the output array, Z. X and Y are real, non-sparse, numeric orlogical arrays of the same size and class, or Y is a double scalar. The output array, Z,has the same size and class as X unless X is logical, in which case Z is double. Thus aSkull Stripped Image is been produced. It is then further filtered to get a better result.[10]

B.Multistructuralelement Morphological Edge Detection Algorithm

The steps for the Multi-structure elements morphological edge detection algorithmare:

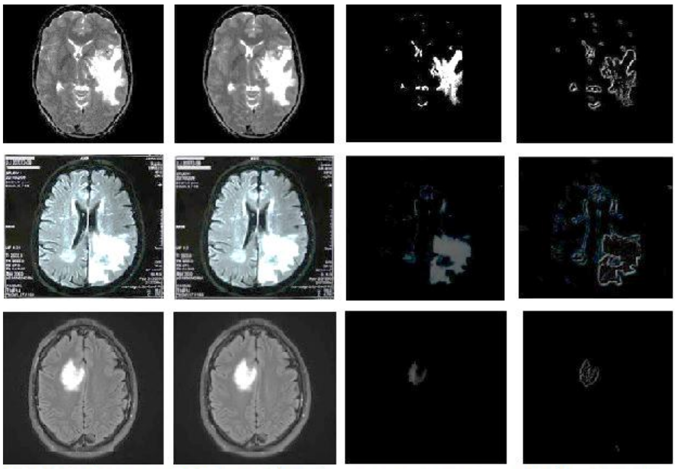
1. Construct structure elements $B_i$of different directions according to the Equation 3.9 given in section 3.
2. Use the structure elements got in step 1 respectively to detect the edges $E_i(F)$ of original image by morphological gradient edge detector.
3. According to every detected edge $E_i(F)$in step 2,use synthetic weighted methodto calculate final detected edge by:

   $$E(F) = \sum_{k=1}^{M} w_i E_i(F) \qquad (4.1)$$

   where $E(F)$ is the final detected edge of original image,M is the number ofstructure elements and w_i is the weight of different detected edge information. $w_i = \frac{\propto_a}{180}$ where $\propto_a = 0^0$, 22.5^0 , 45^0 , 67.5^0, 90^0, 112.5^0, 135^0, 157.5^0 [11].
4. The resulted output shows the segmented image.

V. RESULT OF MULTISTRUCTURAL ELEMENT MORPHOLOGICAL EDGE DETECTION

The result after the segmentation of brain image using morphological edge detectionalgorithm for different brain MRI images are shown in Figure 5.1.



(a) Original Image (b) Filtered Output (c)Substracted Output (d) Edge detection

Figure 5.1: Observed Results

Advantages of this method are:

- It is suitable for low contrast image
- It gives better result for overlapped data
- High performance accuracy and cluster efficiency

VI. CONCLUSION

A new method,morphological based edge detectionalgorithm using multi structural element is been implemented to segment the tumorous brain tissue. MATLAB 7.9was used for the simulation work. The input images were acquired from the dataset BRAIN WEB. Also,the skull stripping process has doneusing the subtraction of an array in the image using a constant.Better simulation results were found for this methodcompared to the other morphological operators such as Sobel, Prewitt, Robert and canny edge detector, and general morphologicaledge detection algorithm such as morphological gradient operation.

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