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 segmentation methods and morphological algorithm, this problem can be solved.

In this paper, a new method is proposed which segments the brain tumor tissues 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 the multi-structural element morphological algorithm is used to segment the tumor tissues.

Index Terms - Brain Tumor, Filtering, MRI, Multi-structural element Morphological Edge Detection, Segmentation.

I. INTRODUCTION

A. Segmentation

Segmentation is a process in which image is partitioned into its constituent salient image regions to acquire the regions of interest(ROIs). Being an important technique of image processing, it has a lot of applications in many fields of biomedical imaging and computer integrated surgery. Techniques such as morphological edge detection, image filtering and thresholding are mostly used in medical field for detecting diseases in human body structures such as nerve damage, blood vessel 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 $I$.

$$I = \bigcup_{k=1}^{K} S_k$$  \hspace{1cm} (1.1)

Segmentation methods vary depending on the application, imaging modality, noise, partial volume effects, and the motion. Better performance can be achieved by considering the prior knowledge. Selection of an appropriate approach to a segmentation problem is the difficult dilemma in segmenting an object. The main applications of segmentations are:

- 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 applications such 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 or the central spinal canal. Some tumors are brain cancers. The word ‘tumor’ is of Latin origin and means swelling. It causes inflammation, brain swelling and pressure within the skull.[2]

Brain tumors include all tumors inside the human skull (cranium) or in the central spinal canal created by an abnormal and uncontrolled cell division, in the brain itself. Some growth arises from other tissues inside the skull, such as pituitary tumors which is commonly known as Primary brain tumors, which arise within the skull. Anther group consists of tumors that spread to the head from another source, such as lung or breast 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 ar reflected in Figure 1.2. [5]
C. Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI), or nuclear magnetic resonance imaging (NMRI), or magnetic resonance tomography (MRT) are medical imaging techniques used in radiology which uses the magnetic field and pulses of radio waves to visualize internal structures of the body in detail. MRI makes use of the property of nuclear magnetic resonance (NMR) to image nuclei of atoms inside the body which gives better visualization of soft tissues of the human body thereby helps in easy diagnosis and does not affect human body as no radiation is used. It aids segmentation because of high contrast between different tissues. Different components in object are highlighted by 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, powerful magnet where the magnetic field is used to align the magnetization of some atomic nuclei in the body, and radio frequency fields to systematically alter the alignment of this magnetization. [1]

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

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 (Contrast Enhance)

One advantage of an MRI scan is that it is harmless to the patient. It uses strong magnetic fields and nonionizing electromagnetic fields in the radio frequency range unlike CT scans and traditional X-rays, which both use ionizing radiation. While CT provides good spatial resolution (the ability to distinguish two separate structures arbitrarily small distance from each other), MRI provides comparable resolution with far better contrast resolution (the ability to distinguish the differences between two arbitrarily 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. Related works and the problems existing in previous methods were 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 when applied to a suitable example. The conclusion is given in Section 6.
Prof. J. Mehena (2011) [8] proposed a novel mathematical morphological algorithm to detect medical MRI image edge. The morphological edge detection algorithm was compared with a variety of existing operators such as Sobel algorithm, Prewitt algorithm, etc. for edge detection. Edge detection, is an essential preprocessing step in medical image segmentation which is not fit for noise medical image edge detection, since noise and edge belongs to high frequency. Prewitt operator is the oldest and best understood method of edge detection which consists of two masks, one for detecting image derivatives in X and the other for detecting image derivative in Y in which convolves an image with both masks, producing two derivative images (dx & dy). Sobel operator is based on convolving the image with 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, opening, and closing. Edge of an image is calculated in two ways. One is the difference set of the dilation domain of the image and the domain of image itself and the other way of calculation is the difference set domain of the image and erosion domain of image. Morphological gradient is then computed by finding the difference between the two domains thus calculated. Using the opening and closing operation, the morphological edge has been found out. The results showed that the algorithm is more efficient for medical image denoising and edge detection than the usually used edge detection algorithms such as Sobel, Prewitt, Robert and canny edge detector, and general morphological edge detection algorithm such as morphological gradient operation. But the computation is more complex compared to general morphological edge.

The existing methods are Partial derivatives, Wavelet based, denoising, thresholding and 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 EDGE ALGORITHM

Mathematical morphology is a new mathematical theory and a powerful tool for dealing with various problems in image processing and computer vision to process and analyze the images. It has been composed by a series of basic morphological algebraic arithmetic operators, namely erosion, dilation, opening, closing etc. and are used for detecting, modifying, manipulating the features present in the image based on their shapes.

Morphological techniques probe an image with a small shape or template called a Structuring Element (SE). The SE is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of pixels. Some operations test whether the element “fits” within the neighborhood, while other tests whether it “hits” or intersects the neighborhood. A morphological operation is a binary image that creates a new binary image in which the pixel has a non-zero value only 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. Thus the choice of structure element (SE) decides the performance of morphological operation. Generally, simple and symmetrical shape structure elements such as crisscross, diamond and disk are adopted but they are sensitive to image edge which has the same direction of structure elements, and are not so effective to the edge which is the direction other than the structure elements. Therefore, they are difficult to detect complex edge feature. Here, multi-structure elements morphology of eight different directions is proposed which comprises almost all the directions lines extend in the image. By using multi-structural element morphological gradient edge detector respectively, 8 different edge detection results are formed and the final edge result is produced by using synthetic weighted method.

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

\[
(F \ominus B)(x, y) = \max \{F(x-s, y-t) + B(s, t)\} \tag{3.1}
\]

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

\[
(F \oslash B)(x, y) = \min \{F(x+s, y+t) - B(s, t)\} \tag{3.2}
\]

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

\[
F \circ B = \left( F \ominus B \right) \oplus B, \tag{3.3}
\]

\[
F \bullet B = \left( F \oslash B \right) \ominus B \tag{3.4}
\]

Erosion is a transformation of shrinking, which decreases the gray-scale value of the image, while dilation is a transformation of expanding, which increases the grayscale value of the image. Erosion filters the inner image while dilation filters the outer image. Opening is erosion followed by dilation and closing is dilation followed by erosion. Opening generally smooths 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 detect image 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 differences of the dilation domain of \( F \) and the domain of \( F \). This is also known as dilation residue edge detector:

\[
E_d(F) = (F \ominus B) - F \tag{3.5}
\]
Accordingly, the edge of image $F$, which is denoted by $E_e(F)$, can also be defined as the difference set of the domain of $F$ and the erosion domain of $F$. This is also known as erosion residue edge detector:

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

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

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

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

$$B_i = \{F(m + m_0, n + n_0), \theta_i = i \times \alpha | -N \leq m_0, n_0 \leq N\} \quad (3.8)$$

Where, $i = 0, 1, \ldots, 4N - 1$, $\alpha = 180^\circ / 4N$ and $\theta_i$ is the direction angle of SE. In this paper, we choose $N = 2$, then in the $5 \times 5$ square window, the direction angles of all structure elements are $0^\circ, 22.5^\circ, 45^\circ, 67.5^\circ, 90^\circ, 112.5^\circ, 135^\circ$ and $157.5^\circ$. The structure elements $B_i$ can be got by decomposing $5 \times 5$ square SE $B$ as shown in Figure 3.1.

**Figure 3.1:** $5 \times 5$ square structure element $B$

Therefore, $B_i$ and $B$ satisfy:

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

**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 explained as follows.

**Input MRI Image**

**Preprocessing**

**Morphological Edge Detection Algorithm**

**Tumor Tissue Segmentation**

**Figure 4.1:** 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 smoothing purpose, the Gaussian filter is been used to remove high-frequency components from the image. Skull stripping is a major phase in brain imaging applications and it refers to the removal of skull.

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

Another method for skull stripping is by subtracting two images or a constant from the input image. If $X$ and $Y$ are two arrays from their corresponding elements, then there occurs the subtraction of each element in array $Y$ from the corresponding element in array $X$ and returns the difference in the corresponding element of the output array. $Z$, $X$, and $Y$ are real, non-sparse, numeric, or logical 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, a skull stripped image is been produced. It is then further filtered to get a better result. [10]

**B. Multistructural element Morphological Edge Detection Algorithm**

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

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 method to calculate final detected edge by:

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

where $E(F)$ is the final detected edge of original image, $M$ is the number of structure elements and $w_k$ is the weight of different detected edges. $w_k = \frac{\alpha_k}{100}$, where $\alpha_k = 0^\circ, 22.5^\circ, 45^\circ, 67.5^\circ, 90^\circ, 112.5^\circ, 135^\circ, 157.5^\circ$.

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 detection algorithm for different brain MRI images are shown in Figure 5.1.

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

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

VI. CONCLUSION

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