A Review on Brain Tumor Segmentation

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***Abstract* - Manually detecting and segmenting brain tumors from brain MRI, in cases where a large number of MRI scans are taken for each patient, is tedious and subjected to inter and intra observer detection and segmentation variability. Therefore, there is a need for computer aided brain tumor detection and segmentation from brain MR images to overcome the tedium and observer variability involved in the manual segmentation. A number of methods have been proposed in recent years to fill this gap, but still there is no commonly accepted automated technique for use in clinical floor by clinicians due to accuracy and robustness issues. This paper, presents a review of the methods used for MRI brain tumor segmentation. The review covers imaging modalities, magnetic resonance imaging and methods for noise reduction and segmentation approaches.**

Index Terms - Brain, MRI, Segmentation, Pre-processing, Cellular automata.

I. INTRODUCTION

With the increase of aging population, cancer has now become a global public health problem. According to the latest statistics by World Cancer Research Fund, cancer is the world's first cause of death. In the world, every year, 12.7 million people are diagnosed with cancer, and 7.6 million people die of cancer. Meanwhile, the annual incidence of cancer continues to rise. By the year 2030, there will be 26 million new cases, and the death toll will reach to around 1.7 million people.

Brain tumor, which is one of the most common brain diseases, has affected and devastated many lives. According to study of International Agency for Research on Cancer (IARC), it is estimated that more than 126,000 people are diagnosed for brain tumor per year around the world. The mortality rate is around 97,000 per year [4]. The statistical reports shows low survival rate of brain tumor patients although brain tumor diseases has been the centre of attention of thousands of researchers over several decades, around the world. In the recent years, researchers from different disciplines ranging from medical to mathematical and computer sciences have combined their knowledge and efforts for better understanding of the disease and to find more effective treatments.

In the past years many researchers have prepared important research in the field of brain tumor segmentation but still now it continues as a very important research field. Standard x-rays and computed tomography (CT) images can initially be used in the diagnostic process. However, MRI is generally more useful because it can provide more detailed information about tumor type, position and size. For this reason, MRI is the imaging study of choice for the diagnostic purposes and, thereafter, for surgery and monitoring treatment outcomes.

A. Brain Tumor

Brain is considered as a kernel part of the body and has a very complex structure. The brain consists of mainly two types of tissues: gray matter (GM) and white matter (WM). The brain also contains a cerebrospinal fluid (CSF) that consists of enzymes, glucose, salts, and white blood cells. A brain tumor is usually an abnormal mass of tissue in which some cells grow and multiply uncontrollably, apparently unregulated by the mechanism that control normal cells. The growth of a tumor occupies space within the skull and interferes with normal brain activity. A tumor can cause damage by shifting the brain or pushing against the skull, by increasing pressure in the brain, and by invading and damaging nerves and healthy brain tissues. Brain tumors are classified based on the type of tissues involved in the brain, the positioning of the tumor in the brain, whether it is benign tumor or malignant tumor and other different considerations. Brains tumors are the solid portion that spread throughout the surrounding tissues or distort the surrounding structures. The different types of brain tumors are i) Gliomas, ii) Medulloblastoma, iii) Lymphoma, iv) Meningioma, v) Craniopharyngioma, vi) Pituitary adenoma.

B. Imaging modalities

The main constituents of our body are water and bones. Some trace of elements such as iodine, iron etc are also present in certain specific parts of our body such as thyroid or blood. The main principle of medical imaging lies in the efficient use of different properties of these body constituents. The important brain imaging modalities are x-ray, computed tomography (CT), positron emission tomography (PET), single-photon emission computed tomography (SPECT), ultrasound magnetic resonance imaging (MRI) and Cerebral angiography. The x-ray, which was invented by Wilhelm in 1895, is based on the measurement of the transmission of x-ray through the body. But, due to the high level of radiations emitted by x-ray, it may cause diseases such as cancer, skin disease or eye cataract. In x-ray based computer assistance tomography (CT), image is reconstructed from a large number

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of x-rays. In case of positron emission tomography (PET), radio nuclides are injected into patient's body which attach to a specific organ. SPECT is a nuclear medicine based tomographic imaging technique and it uses gamma rays. It is capable of producing 3D images. Ultrasound is the best modality for investigation of soft body tissues. It measures the reflection of ultrasonic waves transmitted through the body [2]. Cerebral angiography is a kind of angiography that allows detection of brain abnormalities by providing images of blood vessels in and around the brain.

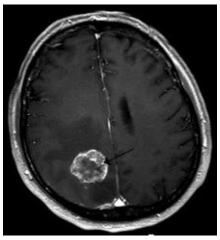

Fig 1: An MRI image of brain tumor.

B. MR Imaging (MRI)

Magnetic Resonance Imaging (MRI) is a non invasive method and can be used safely as often as necessary for brain imaging. MRI images are used to produce detailed and accurate pictures of human organs from different angles for diagnosing abnormalities. There are two types of MRI high field for producing high quality images and low field MRI for smallest diagnosis condition [2]. MRI images can be used by physicians for visualizing even hair line cracks and tears in injuries to muscles, ligaments and other soft tissues. The main principle of MRI is based on the absorption and emission of energy in radio free range of electron magnetic spectrum. Magnetic resonance imaging (MRI) is excellent for showing abnormalities of the brain such as tumor, multiple sclerosis or lesions, stroke, haemorrhage. Fig.1 shows an MRI image of brain tumor. Accurate anatomical three-dimensional (3D) models derived from 2D MRI medical image data helps in providing accurate and precise diagnostic information about spatial relationships between critical anatomical structures such as vascular structures, eloquent cortical areas, etc and other pathological findings which otherwise were indistinguishable by the naked eye (X. Hu et.al 1990). MRI is commonly used for brain tumor imaging because of the following reasons:

i. It does not use any ionizing radiations like CT, SPECT and PET.
ii. Its contrast resolution is higher than above mentioned techniques.
iii. Ability of MRI devices to generate 3D space images enables them to have superior tumor localization.
iv. Its ability in acquisition of both anatomical and functional information about the tumor during the same scan.

II. LITERATURE REVIEW

Segmentation is the process of dividing or partitioning an image into several segments. The main difficulties in the process of segmentation [2] are:

a. Noise
b. The bias field (the presence of smoothly varying intensities within tissues)
c. The partial-volume effect (a voxel contributes in multiple tissue types)

A. Preprocessing

Most of the real life data is noisy, inconsistent and incomplete and therefore pre-processing becomes necessary. Image preprocessing is one of the preliminary steps that are highly required to ensure the high accuracy of the subsequent steps. The raw MR images usually consist of many artifacts such as patient motions duration imaging times, intensity in-homogeneities, cranial tissues, thermal noise and existence of any metal things in imaging environment and film artifacts or label on the MRI such as patient name, age and marks etc. which reduces the overall accuracy. Linear filters reduce noise by updating the pixel values by the weighted average of neighbourhood pixels but it degrades the image quality substantially. On the other hand, non linear filters preserve edges but degrade the fine structures. Several preprocessing techniques have been analyzed and surveyed in this section.

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1. *Median Filter:* It can remove the high frequency noise components from MRI images without disturbing the edges and is used to reduce salt and pepper noise [5]. It considers each pixel in the image in turn and looks at its nearby pixel neighbors to decide whether or not it is a representative of its surroundings. Filter replaces each pixel value with the median of neighboring pixel values. Its advantage over mean filter is that median is a more robust average than the mean and so the median value will not be affected signicantly by a single very unrepresentative pixel in the neighborhood.
2. *Weighted Median filter:* It can remove salt and pepper noise from MRI images without disturbing the edges and have the edge preserving and robustness capability of the classical median filter. WM filters have noise attenuation capability. WM filters belong to the broad class of nonlinear filters [6].
3. *Weiner Filter:* Weiner filter is a type of linear filter. It has been used extensively for the restoration of blurred and noisy images. It filters a gray scale image that has been degraded due to constant power additive noise[7].Wiener filtering method involves restoring of images in the presence of blur as well as noise. It involves removal of additive noise and inversion of the blurring simultaneously. Weiner filter, therefore, has two parts namely an inverse filtering part and a noise smoothing part. It not only performs removal of the noise with a compression operation (low pass filtering) but also the deconvolution by inverse filtering (high pass filtering). Weiner filter minimizes the mean square error between the desired process and the estimated random process.

4. *Adaptive center filter:* It is mainly used for impulsive noise reduction of an image without the degradation of an original image. Here the image is processed using an adaptive filter. The shape of the filter basis is adapted to match the high contrasted edges of the image. In this way, the artifacts introduced by a circularly symmetric filter at the border of high contrasted areas are reduced [8].
5. *Wavelet-based methods:* In the frequency domain these methods are used for denoising and preserving the signal. Application of wavelet based methods for denoising on MRI images makes the wavelet and scaling coefficients biased. This problem can be solved by squaring the MRI image by non central chi-square distribution method [9]. This makes the scaling coefficients independent of the signal and thus can be easily removed. In case of low SNR images, finer details are not preserved [10].
6. *Analytical correction method:* This method attempts to estimate noise and subsequently noise-free signal from the observed image. This method uses maximum likelihood estimation (MLE) [11] to estimate noise level and subsequently generate noise free images. In this method for estimating a noise free image, by considering signal in a small region to be constant, it uses neighborhood smoothing. Edges in the image are usually degraded.
7. *Non-local (NL):* This method exploits the redundant information present in the images [12]. The pixel values are substituted by using the weighted average of the neighborhood similar to the neighborhood of the image. MRI images consists of blur during acquisition, non-repeated details due to noise, complicated structures and the partial volume effect originating from the low sensor resolution that is eliminated by this method.

B. Image Segmentation Methods

The main objective of the image segmentation is to partition an image into mutually exclusive and exhausted regions such that each region of interest is spatially continuous and the pixels within the region are homogeneous with respect to some predefined criterion. Widely used homogeneity criteria include values of intensity, color, range, texture, surface normal and surface curvatures.

In medical image processing variability of data is quite high especially for analyzing anatomical structure and tissue types; hence segmentation techniques that provide accuracy, flexibility and convenient automation are of paramount importance.

1. *Threshold Based Segmentation*: Thresholding is a simple and effective method of segmentation for images with different intensities. These threshold techniques are very useful for image binarization which is very essential for any type of segmentation [13]. This method assumes that images are composed of regions with different gray level ranges. A thresholding procedure determines an intensity value, called the threshold, which separates the desired classes. Fig. 2 shows the bimodal histogram of an image f(x, y) with threshold as T.

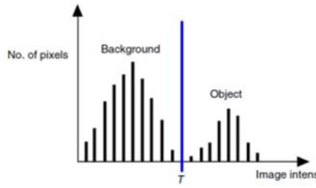

Fig 2: Histogram of an image f(x, y) with threshold T

The threshold image *g(x,y)* can be represented as below:

$$g(x,y) = \begin{cases} 1, if\ (x,y) > T \\ 0, if\ (x,y) \leq T \end{cases}$$

2. *Region Growing*: Region growing / region merging segmentation technique involves grouping of pixels with similar intensities [3]. The first step of this technique involves choosing a pixel or group of pixels known as seeds belonging to the structure in focus. Pixels in the neighborhood region are then examined in the next step and added to the growing region on the basis of some homogeneity criterion. This step continues until no more pixels can be adjoined to the growing regions. Finally, the object illustration is done by all added pixels to the growing regions.
3. *Watershed Method*: The watershed transform can be considered as a region-based segmentation approach.It is one of the best methods used for grouping pixels of an image on the basis of their intensities. Watershed algorithm is based on morphological process although it can be mixed up with edge based segmentation to yield a hybrid technique. Normally, images obtained by various techniques in the electromagnetic spectrum, possesses a large no of discontinuities in the intensity and this ultimately results in over segmentation when morphological segmentations like watersheds are carried out [14]. Pixels having similar intensities are grouped together. It is a good segmentation method for dividing an image to separate a tumor from the image. Watershed is a mathematical morphological operating tool. Watershed segmentation method is very sensitive to noise and will have over segmentation. This problem can be solved by combining level set and fast marching transforms for increasing result accuracy.
4. *Marker controlled watershed Segmentation:* This method is fast and simple to use. It can be applied to all types of 2D MRI images representing all types of tumors irrespective of their location in human body and their size [15]. Watershed can be carried out efficiently by using a marker image. A marker image should be accurately calculated. There are mainly two types of markers, i.e. internal and external markers. Internal markers are usually imposed inside the objects to be identified whereas external markers are imposed outside the objects. Markers can be computed using different methods such as linear filtering, nonlinear filtering, or morphological processing. The choice of marker computing method usually is determined by the nature of the processed image. Brain based markers mostly needs to be specified by both internal and external markers. The procedure of the marker controlled watershed method is as follows; (1) Internal markers are computed by using the extended

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minima transform. (2) External markers are obtained by using distance transform. (3) Regulate the minima markers by using a morphology mask at the internal markers. (4) Watershed the imposed image by using its markers.

5. *Segmentation of brain with anatomical deviations:* The main challenge in segmentation arises in the case of brain with anatomical deviations like tumor that has different shape, size, location and intensities. The tumor not only changes the part of brain where tumor exists but also sometimes it influences the intensities and shape of other structures of the brain also. Thus the existence of such anatomical deviations makes use of prior information about intensity and spatial distribution challenging. Segmentation of the tumor, its surrounding edema and other structures of the brain is very important for treatment and surgical planning [16].
6. *Graph cut based:* In this method, the image segmentation is considered as a graph partitioning problem, A global criterion that measures both total dissimilarity among the different groups and the total similarity inside then is used [17]. An efficient method based on generalized Eigen value treatment is used to optimize the criterion to segment image.
7. *Cellular Automata Method:* Cellular Automata has attracted researchers from different fields because of its simplicity, and potential in modeling complex systems. A cellular automaton (CA) is a triple A = (S, N, δ), where S is a nonempty set, called the state set, N is the neighborhood, and $\delta: S^N \rightarrow S$ is the local transition function (rule); S^N which is the argument of δ, indicates the states of the neighborhood cells at a given time, while S, which is its value, is the state of the central cell at the next time step. Grow-cut method makes use of a continuous state cellular automaton to interactively label images using user supplied seeds. The cells correspond to image pixels, and the feature vector corresponds to RGB or gray scale intensities. The state set S (θ, l, $\hat{C}$) for each image pixel consists of a "strength" value θ in a continuous interval |0, 1|, a label l and an image feature vector $\hat{C}$. The automaton is always initialized by assigning corresponding labels at seeds with a strength value between 0 and 1 where a higher value reflects a higher confidence in choosing the seed. Strengths for unlabeled cells are set to 0.

III. CONCLUSION

We have discussed several existing brain tumor segmentation and detection methodology used for MRI images of brain. Almost all steps including pre-processing steps for detecting brain tumor have been discussed here.

The most challenging and active research area in the field of image processing for the last few decades is image segmentation. In spite of the availability of a large variety of methods for MRI brain tumor segmentation, but still, MRI brain tumor segmentation is a challenging task and there is a need and huge scope for future research to improve the speed, accuracy and precision of segmentation methods. Combining different methods and introducing parallelization can be the future roadmap for providing improvements in brain tumor segmentation methods. Because of the ongoing researches in biological world, increasing new knowledge about the relationship between different disorders with anatomical deviation is coming up. So, brain tumor segmentation is gaining importance in using as the first stage in tools for detection and analysing anatomical deviation.

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