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A Study of Brain Magnetic Resonance Image Segmentation Techniques

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ABSTRACT: **In recent times, biomedical imaging & medical image processing have become one of the most challenging fields of engineering & technology. Imaging modality like MRI provides detailed information about the anatomy, it also helps in monitoring disease, and it is beneficial for effective diagnosis. It also plays a key role in the tracking of the disease and its progressive treatment. Image segmentation is an important step for further post-processing of medical images. This paper provides an introduction to the field of image processing and gives details about how image segmentation techniques may be applicable to the different imaging modalities available. In the case of MRI of brain, image segmentation constitutes a basic step for detection of tumor. This paper provides a survey of various image segmentation methods that have been applied to brain MRI images, to segment the brain into its constituent parts, including the tumor (if present).**

Keywords: image segmentation, magnetic resonance imaging, brain, tumor, imaging modality

I. INTRODUCTION

The field of digital image processing refers to processing digital images by means of a digital computer [1]. A digital image consists of a fixed number of elements, each having a location/position and a value associated with it. This value is called as the intensity of that element, and each such element is called a pixel.

A lot of content is available in the form of images. Image processing finds its application in the fields of Office automation, Industrial automation, Bio-medical, Remote sensing, Criminology, Astronomy, Entertainment, Military applications. Image Processing can be divided into three major stages: a) Discretization & representation- the visual information is converted to a discrete form, (b) Processing- input & output both are images, but the output is an improved version of the input, (c) Analysis- here, input is an image but output is description of the contents of that image [2].

In the image analysis technique, the output image gives some detailed description of the input image/scene being considered. Thus, image segmentation forms the basis of most image analysis algorithms as the first step of the analysis process.

Image segmentation is the process in which the image is sub-divided into regions or parts that are meaningful. The meaningful region can be a complete object or a part of the object. The level up to which the segmentation has to be performed depends on the problem under consideration.

Image segmentation finds a wide range of application in the field of medical imaging. It forms a key step in the future analysis of the medical image under consideration.

The rest of this paper is organized as follows: Section II describes the different imaging modalities available. Section III presents the various image segmentation techniques and the related work done. Finally, we conclude our survey paper in Section IV followed by the acknowledgement.

II. IMAGING MODALITIES

Medical imaging plays an important role in the improvement of public health amongst all age groups. Medical imaging consists of different imaging procedures to acquire image of human body for diagnostic and treatment purposes. Such imaging procedures are called imaging 'modalities'.

Such procedures are helpful not only to detect the abnormality, but are also used after the detection process, for monitoring the progress of recovery or while the treatment is being done post surgery. Medical imaging is very challenging and is a combination of expertise from the fields of medicine (doctors), medical physicists, technicians, biomedical engineers & radiographer. Thus it combines the engineering knowledge with medical physics and biomedical engineering.

Medical imaging examinations like X-Ray, USG (ultrasonography) and MRI are important steps in every medical diagnosis procedure. Though medical/clinical judgment maybe sufficient in treatment of many conditions,

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the use of diagnostic imaging services is paramount in confirming, correctly assessing and documenting course of the disease as well as in assessing response to treatment [3].

A. Magnetic Resonance Imaging

Magnetic resonance imaging is a medical imaging technique used to visualize detailed internal structures. It uses magnetic radiation. It provides real-time view and three- dimensional views of organs (mostly soft-tissue). It provides good soft tissue contrast, making excellent visualization of soft-tissue structures like brain, spine, muscles, and joints. The MRI machine operates in multiple planes; hence the images can be captured in multiple body planes without changing the physical positions of the patient under scanning. MRI findings are based on compilation of sequences that are an ordered combination of RF and gradient pulses designed to acquire the data to form the image [4].

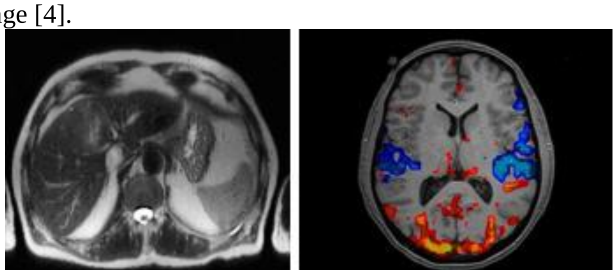

Fig. 1 Sample Brain MRI images

When undergoing MRI examination, the patient has to remove metallic objects like watches, jewellery and piercings. Surgical implants and other foreign bodies must be carefully evaluated for MRI safety. Ear plugs are provided because during the scanning procedure the patient will hear loud noises. Intravenous contrast media may be injected into the patient for enhancement of the organ in the MRI images under study.
Image segmentation can be used in MRI images of brain to detect tumor and other lesion-like abnormalities. Also image segmentation can be useful to detect or enhance bone fractures from MRI images. Image segmentation on MRI images is also useful after surgery to track the progress of treatment or to monitor the growth of tumor before surgery.

B. Computed Tomography

Computed tomography (CT) is a medical imaging technique that uses x-ray photons for producing an image, with digital reconstruction. The CT scanner essentially consists of an x-ray tube and detectors. The x-ray tube produces an x-ray beam that passes through the patient and this beam is captured by the detectors and reconstructed to create a two or three dimensional image.

The analog data captured by the scanner is digitally converted by various algorithms into reconstructed images, which represent a cross-sectional slice through the patient at that level. Each image is acquired at a slightly different angle and results from a different reconstruction algorithm. The individual volume elements that make up the image are each displayed as a two-dimensional pixel, each of which carries a designation of density or attenuation, represented by a Hounsfield unit (HU) [5]. Intravenous or oral contrast agents may be used to look for organs of similar density. Many abnormalities become more evident through contrast injection. Image segmentation can be applied to CT-scans to detect and enhance tumors & other abnormalities present in the body.

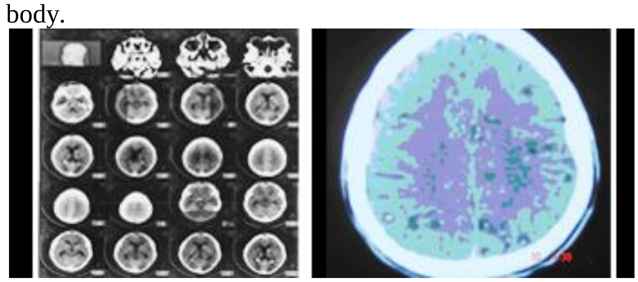

Fig. 2 Sample CT-scan images

C. Mammography

Mammography is an imaging modality that uses low energy x-rays specifically for imaging of breast tissue [6]. Mammography uses standardized views of the breasts for the assessment of breast lesions and is also used for screening of breast cancer. Each breast is examined separately and compressed against the film to obtain maximum visualization of masses or calcifications.

Fig. 3 Doctors analyzing mammograms

If breast cancer is detected at earlier stage, then treatment can be started soon and the survival rate of the patient is increased.

Image segmentation techniques can be used on mammograms to segment & detect breast cancer from the MRI images and for better study of the cancerous tumor.

III. MRI BRAIN IMAGE SEGMENTATION TECHNIQUES

Various image processing techniques for the purpose of segmenting brain MRI images have been classified as followed in this paper:

A. Thresholding
B. Region-growing
C. Clustering
D. Soft computing
E. Atlas-Based
F. Image/Symmetry analysis
G. Other methods

A. Thresholding

Thresholding is one of the most commonly used and oldest methods used for image segmentation. In the thresholding process, the image is said to be composed of regions. These regions belong to different gray-scale ranges .When the histogram of this image is plotted, it consists of peaks and valleys, where each peak represents one region. The region between the peaks, i.e. the valley represents a threshold value. This threshold value groups the pixels into such a manner that intensity values lying below the threshold our grouped as one class and those lying above (or equal to) the threshold value are grouped in to another class. From a grayscale image, thresholding can be used to create binary images [7]. Thresholding has been used in mammography to group the tissue type in to normal/healthy and abnormal/tumorous class [8], [9]. Presence of issues like intensity inhomogeneity and noise which occur often in MRI images, disrupt the thresholding process and corrupt the histogram of the image. A survey of thresholding techniques is given in [10].

B. Region-growing

The main goal of segmentation is to partition an image into its constituent regions. Methods like thresholding achieve this goal by looking for the boundaries between regions based on discontinuities in intensities (gray-level or color value). Region-based segmentation determines the region directly. Region growing is a region-based image segmentation technique, also called as a pixel-based image segmentation method because it involves the selection of initial seed points. This approach to segmentation examines neighboring pixels of initial seed points and determines whether the pixel neighbors should be added to the region [11]. Region-growing can get affected due to noise resulting in presence of holes in the image or may lead to disconnected regions. Region growing is used within a set of image processing operations, for the delineation of tumor-like structures [12]. A study on seeded region growing technique is provided in [13].

C. Clustering

The method of clustering organizes the objects into groups based on some feature, attribute or characteristic. Hence a cluster consists of groups of similar objects. Clustering can be supervised or unsupervised. In supervised approach, the criteria for clustering are specified by the user. In unsupervised approach, the criteria are decided by the clustering system itself. A survey of clustering-based image segmentation methods can be found in [14].

1) K-Means Clustering: Automation of detection & segmentation of brain tumors in MRI images is a very challenging task due to occurrence of high degree of gray-level similarity in the image. T. U. Paul and S. K. Bandhyopadhyay have proposed a fully automated two-step segmentation process of brain MRI images. In the first step, skull stripping is performed by generating a skull mask from the MRI image and in the second step, an advanced K-means algorithm improvised by two-level granularity oriented grid based localization process based on standard local deviation is used to segment the image into gray matter, white matter and tumor region and the length & breadth of the tumor is assessed [15].

M. Masroor Ahmed and Dzulkifli Bin Mohammad have proposed an efficient method for automatic brain tumor segmentation for the extraction of tumor tissues from MR images. They have combined Perona and Malik anisotropic diffusion model for image enhancement and K-means clustering technique for grouping tissues belonging to a specific group. They have found that the proposed system is efficient and is less error sensitive [16].

N. Valliammal and Dr. S. N. Geethalakshmi have discussed their method on Discrete Wavelet Transform associated with the K-means clustering for efficient plant leaf image segmentation. They have measured the performance by Jaccard, dice, variation of index and global consistency error method. They have used real-time plant leaf database. The proposed approach gave better convergence when compared to conventional segmentation [17].

B. C. Patel and Dr. G. R. Sinha have implemented k-means clustering algorithm for breast image segmentation for the detection of micro calcifications and also a computer based decision system for early detection of breast cancer in modified way. The feature selection is based on the number, color and shape of objects present in the image; the number of bins, classes, sizes of the objects is considered as

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appropriate features for retrieval of image information. They have found that accuracy is improved if K-means algorithm is implemented adaptively [18].

2) Fuzzy C-Means clustering: Fuzzy C-means (FCM) clustering is a data clustering method in which each data point belongs to a cluster to a degree specified by a membership value. FCM divides a collection of n vectors, c fuzzy groups and finds a cluster centre in each group such that a cost function of dissimilarity measure is minimized [19].

Methods which integrate the K-means clustering algorithm with the marker-controlled watershed segmentation algorithm and Fuzzy C-means clustering algorithm with the marker-controlled watershed segmentation algorithm has achieved the objective of reducing the problem of over-segmentation when applied to MR brain images [19].

The effectiveness of the FCM algorithm in terms of computational burden rate is improved by modifying the cluster centre and membership value updation criterion and convergence rate is compared between the conventional FCM and the improved FCM [20].

The Demarcation of brain tumor has an important role in medical treatments of malignant tumors. A. Dasgupta has described an application of fuzzy set theory in brain tumor demarcation. The proposed method always results in better segmentation of brain tumor than conventional FCM [21].

A color-based segmentation method that uses the k-means clustering technique to track the tumor objects in MR brain images is used; the position of tumor objects is separated from other items of the image by K-means clustering and histogram-clustering [22].

D. Soft-Computing

A self-organizing map (SOM) or self-organizing feature map is a type of artificial neural network for unsupervised learning. SOMs organize in two modes: training and mapping [23]. Training process is also called as vector quantization. A self-organizing map consists of neurons each of which are associated a weight vector of same dimension as the input data vectors and a position in the map space. An SOM describes mapping from higher dimensional input space to a lower dimensional map space. The target area was segmented using HSOM and the evaluation of this tool from the doctor was positive and this tool helped doctors in diagnosis, treatment plan making and state of the tumor monitoring [23].

Reference [24] has provided clear description from brain tumors using Gabor wavelets, energy, entropy, contrast and other statistical features such as mean, median, variance, correlation, values of maximum and minimum intensity. The tumors can be found precisely according to the length, breadth and the exact position of the infected area using the soft computing technique [25].

E. Atlas-based Techniques

The method in [26] offers opportunities in atlas-based segmentation of tumor-bearing brain images as well as for improved patient-specific simulation and prognosis of tumor progression.

Reference [27] has used three steps for brain atlas deformation in the presence of large-space occupying tumors, based on a priori model of lesion growth that assumes radial expansion of the lesion from its starting point; results show that automatic segmentation can be performed and that the method can be applied to automatic segmentation of structures and substructures in brains.

Ali Gooya et al. Have proposed a method based on the Expectation Maximization algorithm that incorporates a glioma growth model for atlas seeding, a process which modifies the original atlas into one with tumor and edema adapted to best match a given set of patient's images [28].

F. Image/Symmetry Analysis

Reference [29] has proposed an interactive segmentation method that in addition to area of the region and edge information uses prior information, also its symmetry analysis which is more consistent in pathological cases.

A conceptually simple supervised block-based and image-based (shape, texture and content) technique has been used to analyze MRI brain images with relatively lower computational requirements. Classifying regions using their multi-parameter values makes the study of the regions of physiological and pathological interest easier and more definable [30].

Tumor detection is often an essential preliminary phase to solve the segmentation problem successfully; in visual analysis of the MRI, the first step of the experts cognitive process, is the detection of an anomaly respect the normal tissue, whatever its nature [31].

G. Other Segmentation Methods

The method given in [32] incorporates some noise removal functions, segmentation and morphological operations which are the basic concepts of image processing. They have used the Meyer's watershed algorithm. Since Watershed algorithms suffer from over segmentation, they are usually followed by a post-processing step to merge separate regions that belong to the same structure in medical imaging [33].

Segmentation & volumetry are essential tasks of a software assistant for oncological therapy monitoring; methods in [34] are based on a hybrid algorithm originally developed for lung nodules that combines a threshold-based approach with model-based morphological processing.

Modulus Maxima method by Stephane Mallat provides the method for edge detection using Wavelet transform; a complex wavelet function use could help to improve results of edge detection in real images [35].

IV. Conclusion

We have presented a survey of various techniques applicable to brain image segmentation. These techniques automate the process of segmentation and thus are faster and easier than the manual procedures.

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