A Survey of Brain MRI Image Segmentation Methods and the Issues Involved

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Abstract

This paper presents a survey on the existing methods for segmentation of brain MRI images. Segmentation of brain MRI images has been widely used as a preprocessing, for projects that involve analysis and automation, in the field of medical image processing. MRI image segmentation is a challenging task because of the similarity between different tissue structures in the brain image. Also the number of homogeneous regions present in an image varies with the image slice and orientation. The selection of an appropriate method for segmentation therefore depends on the image characteristics. This study has been done in the perspective of enabling the selection of a segmentation method for MRI brain images. The survey has been categorized based on the techniques used in segmentation.

Keywords: Human Brain, Magnetic Resonance Image (MRI), Segmentation, Thresholding, Clustering, Region Growin, Neural Networks, Deformable Models.

1. Introduction

Image processing is being extensively used in the field of medical imaging for analysis of images. Image analysis usually requires segmentation of the image (under consideration) into homogeneous

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regions for feature extraction and analysis. Medical images are acquired using various modalities like the Computed tomography (CT), Magnetic Resonance Image (MRI), X-radiation (X-ray), Polyethylene terephthalate (PET), Functional MRI (fMRI) to mention the commonly used ones. This study concentrates on the processing of images obtained using MRI. The Magnetic Resonance Image (MRI) produces images using radio wave energy and magnetic field. It is a non-invasive imaging technique that is used for human body structures [1]. MRIs are capable of producing information which cannot be produced by any other technologies such as X-ray, CT-scan and ultrasound. CT gives details of the bony structures and MRI provides tissue level details. The MRI images of the human brain are acquired in typically three orthogonal orientations. They are called as axial, coronal and sagittal image slices, depending on the orientation (views) in which it has been obtained. The human brain is composed many parts of which for automatic segmentation only a few are considered, depending on the necessity. The most commonly researched parts for segmentation are: Gray matter (GM), Cerebrospinal Fluid (CSF) and white matter (WM). In more detailed analysis the parts that have been segmented are the tumor regions [2, 3].

Segmentation is the process of extracting or classifying the required brain parts. The part to be segmented depends on the problem at hand. Segmentation is the primary step of image analysis. Image segmentation can be broadly classified into Basic and Advanced methods. At a finer level they can be further divided into the following categories: 1) Thresholding 2) edge based method, 3) region based methods, 3) clustering methods. 4) Morphology based method, 5) neural networks, 6) deformable models and 7) genetic algorithm

The survey given in this paper is also based on these categories and relevance to use in brain MRI image. Segmentation process is also influenced by the presence of artifacts in the images under consideration. Human brain MRI images have various degrees of defects such as: Intensity inhomogeneity or Intensity Non Uniformity (INU) and Partial Volume Effect (PVE). The INU is occurred due to non –uniformity in data acquisition, which results in shading of MRI, images (human brain parts). Region based methods are highly affected by the intensity inhomogeneity [4, 5]. Partial volume effect is referred to as the effect wherein several types of tissues may be contained in a single image voxel [5, 6]. In such cases the Edge based methods may not have very much use due to the complexity of the structure of tissue [4]. To analyze these issues a thorough study of the existing segmentation algorithms is needed and hence has been taken as a topic of study in this paper. The organization of the paper is as follows:

Section II gives the review of literature on the existing segmentation techniques that are used in brain MRI image segmentation. The observations and findings from the literature have been discussed in section III, followed by the conclusions in section IV.

2. Review of Literature

This section presents a survey of the methods that have been used in the recent past for segmentation of brain MRI images. A survey of the segmentation methods has been done by many researches in different perspectives [5, 1, 7, 2, 3, 8]. A lot of literature is available for tumor segmentation [2, 3]. Kasiri et.al [1] conducted a comparative study of three different software tools which are used to segment the brain tissues based on both quantitative and qualitative aspects. The software's are SP M8 (Statistical Parametric Mapping), FSL 4.1, and Brain Suit 9.1 was used for segmenting the brain parts into white matter, grey CSF. They concluded that BrainSuit classifies WM and GM, show robust in performance tissue classification. SPM8 classifies Skull-striping and tissue segmentation and distinguishing CSF from other tissues

Liu et.al [2] has presented a survey on the segmentation methods that are used for Tumour detection. Yang et.al [3] gives a survey on the brain tumour segmentation methods such as atlas based segmentation, clustering based segmentation, continues deformable model based segmentation. A quantitative analysis of the results using standard evaluation parameters has also been discussed. The paper concludes that no one single segmentation method can be used for segmentation of all brain parts. The study is categorized based on the segmentation technique being implemented. It also gives details of the type of the brain parts that have been segmented using a particular technique.

2.1. Segmentation Process and Classification

Segmentation is the process of splitting images into segments according to the property specified according to which each region is to be extracted. The fundamental process of image analysis, understanding, interpretation and recognition, is image segmentation. There are different algorithms for segmenting brain MRI images. These segmentation algorithms can be broadly classified into basic and advanced methods based on the techniques that are used.

The brain images are generally classified into mainly three parts: White Matter (WM), Gray Matter (GM) and the Cerebrospinal Fluid (CSF).

2.2.*Basic Segmentation Method*

2.2.1. Threshold Based Segmentation Methods.

Threshold based segmentation is the process of segmenting images based on the threshold value. The threshold value could be hard or soft. This method works well in cases where there is a large variation in the intensity between the pixel values. Thresholding is sensitive to noise and intensity in-homogeneities, when the image is a low contrast image it produces scattered output rather than connected regions. This affects the threshold selected and hence the segmented output. Thresholding method of image segmentation was used by different researchers in different variation and used in combination with other methods such as [10, 11, 12, 13, 14]

Evelin et.al [10] segmented brain MRI tissues into Grey matter, White matter and Cerebrospinal Fluids using thresholding based segmentation. A single fixed threshold was used in this case and hence only two classes of regions could be generated. The author reports that thresholding cannot be used for multi-channel images, but is an effective method for segmentation of Tumor regions. Aja-Fern´andez et.al [11] proposed a soft computing method which is fully automatic. They compared the results of proposed soft computing results with hard thresholding, k-means, fuzzy c-means (FCM), and thresholding. Further, concluded that soft computing is more efficient and faster because it is fully automatic, so manual selection of thresholds can be avoided. Since the operations are conducted in special level the system will be robust to noise and artifacts. This method can also be used in the segmentation of Ultrasound images and Radiography images.

2.2.2. Region Growing

Region growing works by grouping of pixels with similar intensities. It starts with a pixel or a group of pixel and grows to the neighbouring pixels with the same intensity. Region growing grows until it finds a pixel with does not satisfy the required pixel intensity. The major advantage is that region growing helps in extracting regions with the same intensity and it also extracts connected components. The region growing based segmentation method segments, regions with same intensity values. Region growing can be useful only if the region to be segmented contains maximum intensity variation. The main disadvantage of region growing is that it requires manual choosing of seed points.

Deng et.al [15] proposed a system which overcomes the difficulty in selecting the seed point the system used an adaptive region growing method based on variance and gradient inside and along boundary curves. This system gives an optimized segmented contour, for the detection of tumour and other abnormality in brain MRI. Since the results obtained are optimal this method can be used for clinical purposes in diagnosing diseases. Zabir et.al [16] has developed a system to segment and detect Glioma (which is a malignant tumour) from brain MRI image using region growing and level sets evaluation. Xiang et.al [17] suggested a hybrid 3D segmentation of brain MRI images which uses fuzzy region growing, mathematical morphological operators, and edge detection using Sobel 3D edge detector to segment white matter and the whole brain. Thus, from the results shown it is clear that the hybrid model is much more accurate and efficient in the 3D segmentation of the results. The hybrid system produces better result than the individual algorithms. Alia et.al [18] segmented brain parts of sclerosis lesions brain MRI images using a new clustering algorithm based on Harmony Search and Fuzzy C-means algorithm. This algorithm improves the standard HS algorithm to automatically evolve the appropriate number of clusters. The paper concludes that the proposed algorithm is able to find the appropriate number of naturally occurring regions in MRI images.

2.2.3. Morphological segmentation.

Morphological operators were used by [12, 17, 19]. This can be used in combination with other methods to get accurate and good results. Nandi [19] detected brain tumour from brain MRI images using morphological operators. The system is a hybrid combination of thresholding, watershed algorithm and morphological operators. Results obtained clearly suggest that a morphological operator gives a clear segmentation of tumour cells rather than k-means clustering. Further, they conclude that more work can be done to classify the tumour as malignant or benign tumour. Roger Hult [12] segmented cortex from MRI slices based on Grey level morphology on brain MRI images. The system uses a histogram based method and hence finds the threshold value for the segmentation of brain parts from the non-brain parts. Binary and morphological operators are used in the segmentation of the brain parts of the brain MRI. They have suggested that the algorithm can be used in the segmentation of coronal MRI data.

2.3.Advance Segmentations Methods

2.3.1. Cluster Based Segmentation

Clustering is the process of classification of pixel values into different classes, without training or knowing previous information of the data. It clusters pixels with the same intensity or probability into same class. Clustering based segmentation is of different types basically they k-means, FCM. Clustering methods were used in detecting brain tumours. It has been observed that a combination of one or more basic and advanced segmentation enables the tumour detection more efficient. Such work, by combining multiple methods for tumour detection has seen reported by many researchers [20, 21, [22]. Qurat-ul et.al [20] proposed a system to segment brain tumour which detect the tumour region using naives Bayes classification and segment the detected region using k-mean clustering and boundary detection. The system was capable of achieving accuracy of 99% in detecting the tumour affected area.

The classification of regions of the brain image into WM, GM, and CSF uses different clustering algorithms has been reported by various researchers [4, 8, 13, 23, 25, 32]. Jun and Cheng [4] segmented WM, GM, CSF based on adaptive k-means clustering method and statistical Expectation-Maximization (EM) segmentation. From the results obtained they conclude that adaptive k-means clustering works better than the EM segmentation. They conclude that the system is capable of generating DE MR Images. Agarwal et.al [24] segmented brain MRI based on level sets segmentation and bias-field corrected fuzzy c-means. Further, concludes that the hybrid model produces an output which is better than the one obtained from the conventional level set and c-means clustering and this method can be used by the Radiologists and suggested that the proposed system suitable in detecting tumours development.

Zhidong et.al [26] proposed an automatic method for the 3D segmentation of brain MRI images using fuzzy connectedness. The paper focuses on two areas they are accurate extraction of brain parts and second focus is on the automatic seed selection. The proposed system accurately selects the seed point and extracts the MRI brain parts.

2.3.2. Neural Networks based segmentation.

Neural networks are used for the segmentation of GM, WM, and CSF by many researchers [9, 27, 28, 39]. Hussain et.al [9] detected Tumour and Edema in the human brain from MRI. They have claimed a segmentation accuracy of 99%, 82% and 99 % for segmentation of WM, GM, CSF tissues respectively. Tumour and edema tissues are segmented at a rate of 98% and 93% mean accuracy rate respectively. Hence, the paper concluded that proposed system can be used in segmenting tumour and edema with a high efficiency.

Segmentation using Neural Networks has also been used widely for detection of brain tumour [30, 31, 32, 33]. Sumithra and sexena [30] presented a neural network based system of classifying MRI images. The system consists of namely 3 different steps they are feature extraction, dimensionality reduction and classification. The classifier classifies the MRI images as benign, malignant and normal tissues and the classification accuracy of the proposed system is given as 73%.

2.3.3. Deformable Models

WM, GM, and CSF were segmented from MRI brain images using deformable models also [34, 35]. Anami et.al [34] using level set based approach. Modified fuzzy C means (MFCM) are used in the initial segmentation. Thus obtained result is given to levelsets methods. The results obtained from such a combinational system are more accurate than the individual MFCM and level sets. The time complexity of the combinational segmentation system is less than the levelsets method. With the accuracy level of segmentation this method can be used for further investigation of the Radiologist in diagnosing abnormalities. Chenling et.al [35] proposed a system using the AntTree algorithm. Further, they concluded that the improved AntTree algorithm is characterized as fast, robust, accurate and time complexity of the proposed system is less than the one obtained from k-means and FCM algorithm. Shaker and Zadeh [36] used level sets and atlas based segmentation for segmenting Hippocampus, Amygdala and Entorhinal cortex from the brain MRI image. GM is segmented from the brain MRI using atlas based segmentation and level sets are applied to the GM to produce the Hippocampus, Amygdala and Cortex.

Soleimani and Vincheh [37] proposed a system to detect the tumour present in brain MRI images using ant colony optimization. The system also improved the performance of the ant colony algorithm and the paper concludes that the suggested improved algorithm gives a more accurate result than the one with conventional algorithm. Karim [38] proposed a system which detects the organs in risk from a brain MRI. They used atlas based segmentation method and snakes to detect the organs which are at risk. They have also used canny edge detector to detect the edges and segment them. The use of deformable models made it accurate to segment the parts with accurate precision. The paper concludes that this model can be used in finding abnormal organs in human brain and this can be very beneficial for doctors in diagnosing. Zabir et.al [39] detected glioma tumour cells from human brain MRI. The segmentation and recognition process of Glioma cells are done by region growing and level sets method.

Juhi and Kumar [40] proposed a system which automatically segments brain tissues using random walker and active contours.

The boundary box algorithm makes a box around the tumour affected area and further segments the parts. They have compared the two and concluded that random walker is the best method with fast segmentation and provide accurate results.

3. *FINDINGS AND OBSERVATIONS*:

I. It has been observed from the survey that the Thresholding has been a widely used method for segmentation and is found to work well in cases where the intensity differences between the regions are more. This method is generally used for tumor detection from brain MRI images. From the above study it is evident that most of the research has been done for the segmentation, brain MRI images into White Matter, Gray Matter, and Cerebrospinal Fluid.

II. In cluster based methods, the use of FCM is most commonly followed by researchers for the segmentation of brain parts. Level sets can be used for segmenting intricate brain parts, but the issues with this approach are the seed pixel selection and the computational time. Another method that is generally used is the Atlas Based Segmentation. But this requires a proper Atlas to be available for all cases.

III. From this survey, it has been found that there is sacristy of literature in terms of segmentation of all regions of the brain MRI image. Brain image consists of more than 300 regions, of which the existing segmentation techniques are able to segment only a few (approximately 3-10). The maximum number of regions that can be segmented using any single segmentation algorithm is 3 to 5. There is no single segmentation algorithm that can extract every part present in the brain image. In applications like generic Atlas creation from the brain MRI images all parts have to be segmented and labeled. Hence, for this we need to use different algorithms or hybrid methods.

The table 1 gives the summary of the survey conducted.

Table 1: Segmentation methods and their segmented regions.

Segmentation Method	Author's name	Segmented Region	Methodology used
Thresholding	Evelin et.al [10]	GM,WM,CSF	Single value thresholding

	Dawngliana et.al's [14]	Tumour	Multilevel thresholding, morphological operators and level sets
Region Growing	Zabir et.al [16]	Glioma	Region growing and level sets
Morphological	Nandi [19]	Tumour	Thresholding, watershed algorithm and morphological operators
	Roger Hult [12]	Cortex	Histogram based method, Binary and morphological operators,
Cluster Based Segmentation	Qurat-ul et.al [20]	Tumour	Naives Bayes classification, k-mean clustering, boundary detection
	Singh et.al [21]	Tumour	FCM and LSM, level set segmentation and fuzzy c-means clustering
	Jun and Cheng [4]	WM,GM,CSF	Adaptive k-means clustering method and statistical Expectation-Maximization (EM) segmentation
	Kong et.al [23]	WM,GM,CSF	Super voxel-level segmentation
	Agarwal et.al [24]	WM,GM,CSF	On level sets, bias-field corrected fuzzy c-means
	Liu and Guo [25]	WM,GM,CSF	Wavelets and k-means clustering method
Neural Networks.	Talebi et.al [27]	WM,GM,CSF	MLP feed-forward neural network, FCM
	Amin and Megeed [32]	Tumour	PCA and WMEM
Deformable Models	Anami et.al [34]	WM,GM,CSF	Modified fuzzy C means, level sets method
	Chenling et.al [35]	WM,GM,CSF	Anttree algorithm
	Shaker and Zadeh [36]	Hippocampus, Amygdala and Entorhinal cortex	Level sets and atlas based segmentation
	Soleimani and Vincheh [37]	Tumour	Ant colony optimization
	Karim [38]	Tumour	Atlas based segmentation
	Zabir et.al [39]	Glioma	Region growing and level sets method
Genetic Algorithm	Tohka [6]	GM,WM,CSF	FCM and genetic algorithm.

4. CONCLUSION

In this paper review of existing literature on segmentation of brain MRI images has been discussed.

Hence, a thorough understanding of image under consideration and the segmentation methods is necessary for proper segmentation of the image. We hope that this review will help, researchers have an understanding of the algorithms that can be used for segmentation. This study shows that there is immense scope for further research in the field of segmentation of brain MRI images.

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