Brain Image Segmentation

Brain Image Segmentation

N. Senthilkumaran* and R. Rajesh†
School of Computer Science and Engineering
Bharathiar University, Coimbatore - 641 046, India.
*senthilkumaran@ieee.org †kollamrajeshr@ieee.org

***Abstract*—Image segmentation has long been an important focus of research, yielding many automated methods to perform segmentation of different organs in the human body. Brain image segmentation is an important but inherently difficult problem in medical image processing. In general, it cannot be solved using straightforward, conventional image processing techniques. Among medical images, segmentation of brain images is a challenging problem that has received an enormous amount of attention recently, and this is because proper diagnosis of brain disorders greatly depends upon accurate segmentation of the complex structure of the brain. This paper provides the foundation of segmentation using various approaches and it can be extended in several directions for MRI brain images.**

***Index Terms*—Image Segmentation, Medical images, brain, MRI.**

I. Introduction

Medical image segmentation is an essential step for most subsequent image analysis tasks. The segmentation of anatomic structure in the brain plays a crucial role in Nero imaging analysis. Successful numerical algorithms can help researchers, physicians and neurosurgeons to investigate and diagnose the structure and function of the brain in both health and disease. This has motivated the need for segmentation techniques that are robust in application involving a broad range of anatomic structure, disease and image type [1],[3].

The process of partitioning a digital image into multiple regions or sets of pixels is called image segmentation. Actually, partitions are different objects in image which have the same texture or color. The result of image segmentation is a set of regions that collectively cover the entire image, or a set of contours extracted from the image [2],[6]. All of the pixels in a region are similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristics.

This paper is organized as follows. Section II presents details of MRI brain images. Section III is focused on showing the different approaches for brain image segmentation. Section IV presents the conclusion for different approaches to brain image segmentation.

II. MRI Brain Image

The rapid development of imaging technologies now routinely allows living organs and organisms to be explored non invasively. Medical images are obtained for various applications which includes image guided surgery, surgical simulation, nanoscience studies and therapy evaluation. When working with medical images, i.e. Magnetic Resonance Images(MRI), X-Ray, Ultrasound and Computed Tomography (CT) images etc., it is often to delineate the areas and volumes of interest. Medical experts face the task of finding or characterizing abnormalities within such images [2]. The rapid development of different kinds of highly equipped medical instruments and more use of such images have made it difficult for the medical experts to inerpret and infer correct diagnosis. Complicated image features, eye fatigue are the factors thar may cause an expert to miss an abnormality in an image. Hence, there is a great need for robust methods that process with the interpretation of huge amounts of data with greater accuracy. To alleviate these difficulties in clinical diagnosis, segmentation of medical images provides the potentiality for increasing the diagnostic accuracy.

Magnetic Resonance Imaging (MRI) is a well establised non-invasive diagnostic medical imaging technique based on the nuclear magnetic resonance phenomenon. Although qualitative image analysis is often sufficient for diagnosis of diseases, quantitative analysis is necessary for many applications, for which segmentation is a primary step. Segmentation

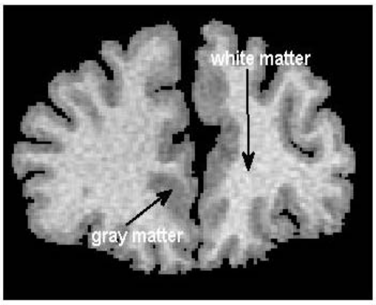

Fig. 1. MRI brain image

of MR Images is a challenging problem due to its complexity as well as to the absence of models of the anatomy that fully capture the possible deformations in each structure [3]. Conventional MRI relies on a difference in a weighted average of spectral and temporal information from tissue to tissue to make a diagnosis. The intensity of the MR image of human tissue is homogeneous and the structure of each tissue is connected, but is difficult to separate the adjacent tissue due to the small intensity changes and smoothed boundaries between tissues. Further, the lack of clearly defined edges includes intra and inter observer variability, which deteriorates the significance of the analysis. Brain tissue is a complex structure. The diagnosis of many brain disorders involves accurate tissue segmentation of brain MR images. Manual delineation of the two brain tissues, white matter (WM) and gray matter (GM) in brain MR image by an human expert is too difficult [5]. Thus, segmentation of brain MR images is an important step for the same, and has attracted the attention of many researchers for the last decade. Fig. 1shows the example MRI brain image.

III. Recent Approaches for Brain Image Segmentation

Four different approaches to brain image segmentation which are most frequently are used for comparison. These are (1) Edge based Technique for Brain Image Segmentation, (2) Splite and Merge Technique for Brain Image Segmentation, (3) Hybrid Method for Brain Image Segmentation and (4) Fuzzy Thresholding Method for Brain Image Segmentation. The details of Approaches as follows,

A. Edge based Technique for Brain Image Segmentation

Edge-based method is by far the most common method of detecting boundaries and discontinuities in an image. The parts on which immediate changes in grey tones occur in the images are called edges. Edge detection techniques transform images to edge images benefiting from the changes of grey tones in the images. As a result of this transformation, edge image is obtained without encountering any changes in physical qualities of the main image [6].

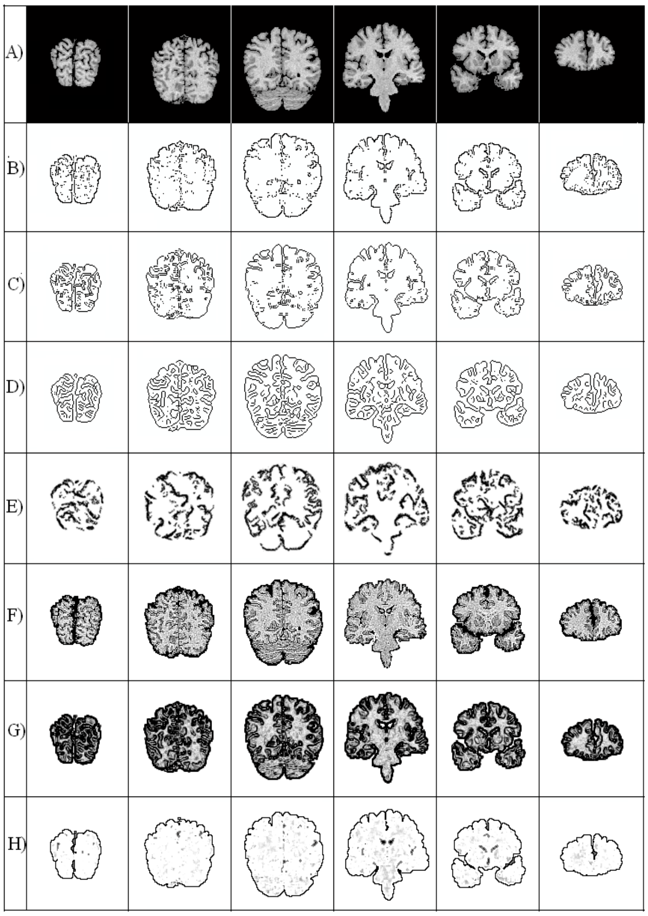

Fig. 2. Edge based technique for brain image segmentation, a) Original images, b) using Prewitt method, c) using Roberts method, d) using Sobel method, e) using ACO method, f) using Fuzzy logic, g) using GA, h) using Neural Network.

1) ACO Approach: The ACO-based image edge detection approach, proposed by Jing Tian et.al. , aims to utilize a number of ants to move on a 2-D image for constructing a pheromone matrix, each entry of which represents the edge information at each pixel location of the image [6]. Furthermore, the movements of the ants are steered by the local variation of the images intensity values. The proposed approach starts from the initialization process, and then runs for N iterations to construct the pheromone matrix by iteratively performing both the construction process and the update process. Finally, the decision process is performed to determine the edge.

2) Fuzzy Logic Approach: Cristiano Jacques Miosso and Adolfo Bauchspiess evaluated the performance of a fuzzy inference system (FIS) in edge detection. It was concluded that despite the much superior computational effort when compared to the Sobel operator, the FIS system presents greater robustness to contrast and lighting variations, besides avoiding obtaining double edges [6]. Fig. 2 shows the comparison of edge based techniques for brain image segmentation.

3) GA Approach: The largest body of research in the area of edge detection in medical images uses specially tailored algorithms. While these algorithms perform efficiently for detecting edges in a certain modality or a certain anatomical structure, they are brittle in the sense that they cannot be generalized to other modalities or other anatomic structures. A robust algorithm is thus required to overcome this brittleness. GAs are robust in that they are not affected by spurious local optima in the solution space. This robustness is backed up by a strong mathematical foundation. Many advanced GA operators have been designed for performing effective search of the solution space and speeding the convergence of solutions. GAs have been previously used in different areas of image processing such as edge detection, image interpretation, image segmentation, and contour matching [6].

Most interesting genetic application in edge detection is by Gudmundsson et al. and is as described below. Edges are represented in a binary image, where each pixel takes on either the value zero (off) for a non-edge pixel or one (on) for an edge pixel. Each pixel in the binary map corresponds to an underlying pixel in the original image. This edge representation is simple, allows direct illustration of results, location of edge points maps directly onto the original image and, adjacency and orientation are preserved. By using the edge map as a solution space for the GA, no special mappings are required, small neighborhood windows can be overlaid, and edge structures and pixels can be modified on a local, intuitive basis. Furthermore, this representation allows for easy transition into an extended type of chromosome for the GA, the bit array. The bit array as an array of bits, instead of the conventional bit vector, or string, is used in traditional GAs. A bit array is highly compact, leading to a compact memory usage, which is essential when running a simulation with a large population, or a large image [4].

4) Neural Nework Approach: Neural networks have been applied in many image segmentation problems like edge detection. There are many image based edge detection algorithms using neural networks, the most successful system was introduced by Rowley et al. The neural network technique in this section is such an approach, and functions just like a pattern classifier, which collects the input features and outputs the decisions [5].

B. Splite and Merge Technique for Brain Image Segmentation

One of the basic properties of segmentation is the existence of a predicate which measures the region homogeneity. If this predicate is not satisfied for some region, it means that that region is inhomogeneous and should be split into sub regions. On the other hand, if the predicate is satisfied for the union of two adjacent regions, then these regions are collectively homogeneous and should be merged into a single region. A method towards the satisfaction of these homogeneity criteria is the split-and-merge algorithm [5][6]. Fig. 3 shows the example image using splite and merge algorithm for brain image segmentation.

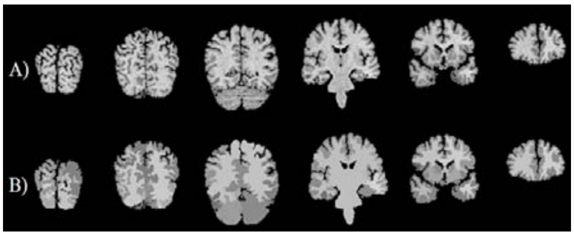

Fig. 3. Using Splite and Merge algorithm for brain image segmentation

C. Hybrid Method for Brain Image Segmentation

A hybrid method is using granular rough sets for brain image segmentation. Recently, rough set theory has become a popular mathematical framework for granular computing and is used as a mathematical tool to analyze vagueness and uncertainty inherent in making decisions. The focus of rough set theory is on the ambiguity caused by limited discernibility of objects in the domain of discourse. The primary use of rough set theory has so far mainly been in generating logical rules for classification and prediction using information granules, thereby making it a prospective tool for pattern recognition, image processing, feature selection, data mining and knowledge discovery process from large data sets [7].

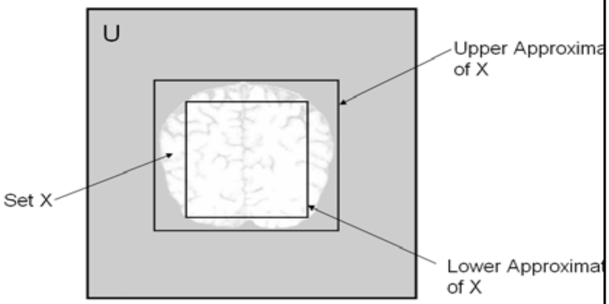

Fig. 4. Rough set for brain image segmentation

The advantages of rough set theory is that it does not need any preliminary or additional information about data, such as probability distribution in statistics, basic probability assignment in the Dempster-Shafer theory, or grade of membership or the value of possibility in fuzzy set theory [8].

A rough set is an approximate representation of a crisp set. A rough set is represented by a pair of crisp sets. The pair of crisp sets are a lower approximation and an upper approximation.

Fig 4 shows an example of approximating a brain image using rough set. The outer square which include the object and some other granules not belonging to the objects forms upper approximation. The inner square which include only the granules of the object and it does not fully represent the object, form the lower approximation. Fig 5 shows the steps of hybrid method for brain image segmentation.

The first phasein this process is preprocessing the image using thresholding and eroding methods. The second phase makes use of granular rough sets for brain image separation and the third phase makes use of fuzzy thresholding to separate white matter. The results show the effectiveness of the method. Fig. 6 shows the comparison results for selected MRI slices.

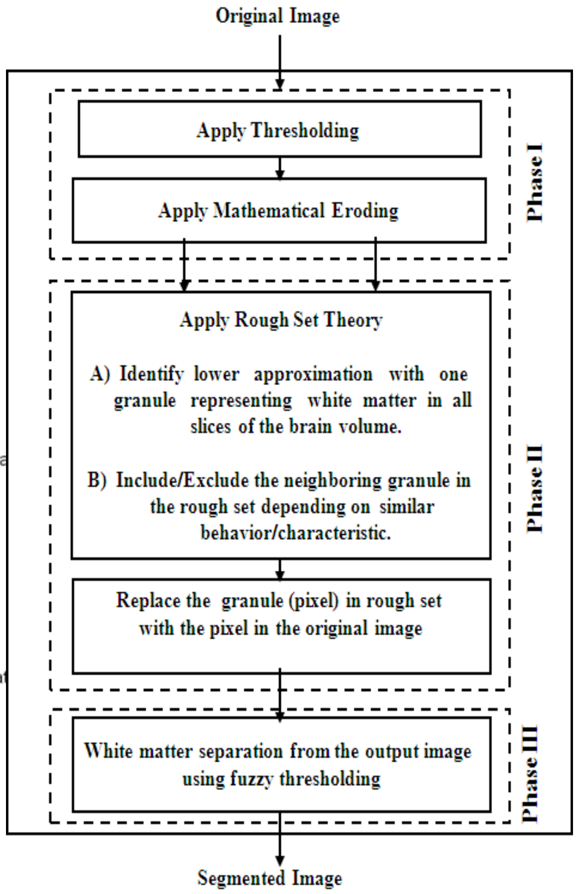

Fig. 5. Steps of hybrid method for brain image segmentation

D. Fuzzy Thresholding Method for Brain Image Segmentation

The result of image thresholding is not always satisfactory due to the disturbing factors like vagueness, non-uniform illumination, etc. More over the linear index of fuzziness for type-1 fuzzy sets by Zenzo et. al. and measure of ultra-fuzziness for type-2 fuzzy sets by Tizhoosh have difficulties in handling MRI brain images with one level of gray value as background and other two levels of grayness as white matter and gray matter [5]. Hence this paper proposes a new modified thresholding measures for MRI brain images using type-1 and type-2 fuzzy sets. The results show the effectiveness of the proposed modified thresholding measures [7],[8]. Fig. 7 shows the comparison results of fuzzy thresholding method.

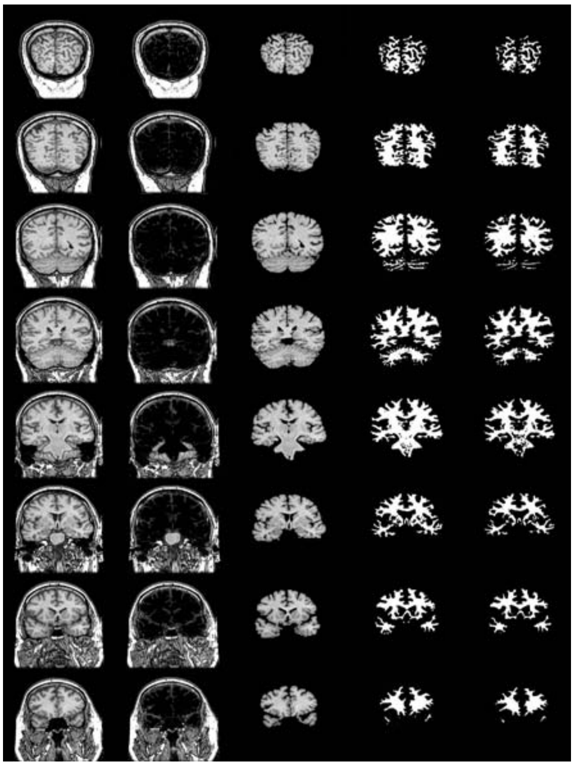

Fig. 6. Comparison results for selected slices (a) original images (b) background images using granular rough set (c) output brain images using granular rough set (d) white matter separation using mean shift algorithm (e) white matter separation using our hybrid method

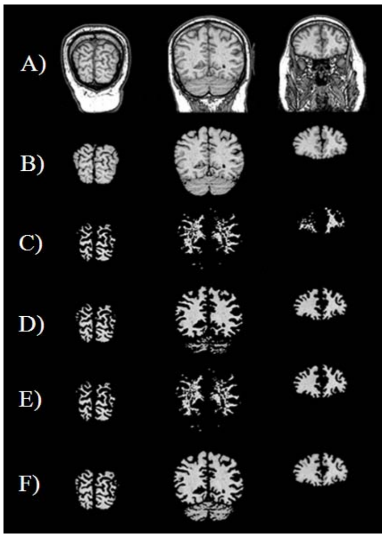

Fig. 7. Fuzzy thresholding method, a) Original MRI brain images, b) Preprocessed images corresponding to a, c) Thresholded images with threshold obtained from fuzziness index of type1. Thresholded with T=176, T=199, and T=199, d) Thresholded with T=166, T=165, and T=147, e) Thresholded images with threshold obtained from ultrafuzziness of type2. Thresholded with T=176, T=199, and T=150, f) Thresholded with T=156, T=150, and T=133

IV. CONCLUSION

This paper mainly focus on the study of different approaches to brain image segmentation. The edge based approachs, prewitt, sobal, roberts, ACO, fuzzy based approach, Genetic algorithm based approach and Neural network based approach is applied on a MRI brain images. The splite and merge technique is applied on a MRI brain images. Hybrid method is applied for brain image segmentation. Fuzzy threshold technique is applied for MRi brain images. Example images of MRI results show the efficiency of brain image segmentation.

REFERENCES

[1] Dao Qiang Zhanga and Song Can Chena, ”A novel kernelized fuzzy C-means algorithm with application in medical image segmentation”, *Artificial Intelligence in Medicine*, vol. 32, 2004, pp.37-50.

[2] Bouchet A, Pastore J and Ballarin V, ”Segmentation of Medical Images using Fuzzy Mathematical Morphology”, *JCS and T*, Vol.7, No.3, October 2007, pp.256-262.

[3] Ian Middleton and Robert I. Damper, ”Segmentation of magnetic resonance images using a combination of neural networks and active contour models”, *Medical Engineering and Physics*, vol.26, 2004, pp.71-86.

[4] George Karkavitsas and Maria Rangoussi,”Object Localization in Medical Images Using Genetic Algorithms”, *International Journal of Signal Processing*, 2005, pp.204-207.

[5] Wei Sun and Yaonan Wang, ”Segmentation Method of MRI Using Fuzzy Gaussian Basis Neural Network Neural Information Processing”, *Letters and Reviews*, Vol.8, No.2, August 2005, pp.19-24.

[6] N. Senthilkumaran and R. Rajesh, ”Edge Detection Techniques for Image Segmentation - A Survey of Soft Computing Approaches”, *International Journal of Recent Trends in Engineering*, Vol.1, No.2, May 2009, pp.250-254.

[7] N. Senthilkumaran and R. Rajesh, “Brain Image Segmentation using Granular Rough Sets”, *International Journal of Arts and Sciences*, U.S.A., Vol.3, No.1, ISSN: 1944-6934, 2009, pp: 6978.

[8] N. Senthilkumaran and R. Rajesh, C. Thilagavathy ,“Hybrid Method for White Matter Separation in Brain Images using Granular Rough Sets and Fuzzy Thresholding”,*Proceedings of 2010 IEEE 17th International Conference on Image Processing (ICIP 2010)*, IEEE Signal Processing Society, Hong Kong, 26-29, September 2010, pp.3037-3040.