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Survey Report

A Survey on Neural Network based Automatic Segmentation of Brain Magnetic Resonance Images

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ABSTRACT

Medical Images are used as an important tool for determination of Pathological condition of the vital organs of the body like brain, lungs, liver, etc. Segmentation is the first step towards automatic processing for analysis and evaluation of medical images. Especially, image segmentation is a prerequisite process for image content understanding in brain MRI for the development of a computer aided diagnosis (CAD) system. It is a technique, which partitions an image into units, which are homogeneous with respect to one or more characteristics. Automatic Segmentation of brain MRI is used as a diagnostic tool in neuro medicine. Abnormal growth of brain tissues can be detected with the help of segmentation techniques. Changes in volumetric growth of brain tissues such as White Matter (WM), Gray Matter (GM) and Cerebrospinal fluid (CSF) can help in the early detection of neural disorders like epilepsy Alzheimer's disease, parenchymal bleeds, etc. Even though several automated methods are available for segmentation of Brain MRI, there is no clear differentiation between these techniques about the suitability for various neural disorders. We presented a review of the methods used in brain segmentation. The review covers imaging techniques, magnetic resonance imaging and methods for segmentation and how a known Neural Network with fixed structure and training procedure could be applied to resolve medical imaging problem pertaining to Brain image segmentation.

Keywords: Brain, Segmentation, Medical Imaging, CAD, MRI and Neural Networks.

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C O M P U T E R S   **S U R V E Y   R E P O R T**

A Survey on Neural Network based Automatic Segmentation of Brain Magnetic Resonance Images

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ABSTRACT

Medical Images are used as an important tool for determination of Pathological condition of the vital organs of the body like brain, lungs, liver, etc. Segmentation is the first step towards automatic processing for analysis and evaluation of medical images. Especially, image segmentation is a prerequisite process for image content understanding in brain MRI for the development of a computer aided diagnosis (CAD) system. It is a technique, which partitions an image into units, which are homogeneous with respect to one or more characteristics. Automatic Segmentation of brain MRI is used as a diagnostic tool in neuro medicine. Abnormal growth of brain tissues can be detected with the help of segmentation techniques. Changes in volumetric growth of brain tissues such as White Matter (WM), Gray Matter (GM) and Cerebrospinal fluid (CSF) can help in the early detection of neural disorders like epilepsy Alzheimer's disease, parenchymal bleeds, etc. Even though several automated methods are available for segmentation of Brain MRI, there is no clear differentiation between these techniques about the suitability for various neural disorders. We presented a review of the methods used in brain segmentation. The review covers imaging techniques, magnetic resonance imaging and methods for segmentation and how a known Neural Network with fixed structure and training procedure could be applied to resolve medical imaging problem pertaining to Brain image segmentation.

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1.   INTRODUCTION

Diagnostic imaging becomes more and more invaluable in medicine area today. Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Positron Emission Tomography (PET), provide a convenient and effective way for non-invasively detecting the anatomical structure of a subject.

These imaging techniques have been opening many medical frontiers by enabling physicians to Study the internal activities of human body visually. With the Knowledge of normal and diseased anatomy for medical research, medical imaging has been a critical component in diagnosis and treatment planning.

Computational applications are gaining significant importance in the day-to-day life. Specifically, the usage of the computer aided systems for computational biomedical applications has been explored to a higher extent. It is necessary to use computers to perform medical image processing and analysis. Especially for high-resolution images and full scan case, the image size and number are very large. Generally, there are two goals for computer based medical image analysis. The first is to enhance (or complement) the image quality, by making detailed quantitative data accessible which would be unobtainable in a routine clinical setting using manual methods. This makes it possible to delineate the

anatomical structures of images. The second is to fully automating the process of abnormality detection, which involves identifying structures such as tumor and lesion by segmentation method.

Magnetic Resonance Imaging (MRI) is a widely used approach to obtain high quality clinical images. Automated brain disorder diagnosis with MR images is one of the specific medical image analysis methodologies. The automated diagnosis involves two important steps: (a) Image classification and (b) Image segmentation. Image classification involves the process of categorizing the abnormal input images into different categories i.e., brain tumors, brain hemorrhages and many other types. Image segmentation is used to extract the abnormal portion (tumor / hemorrhage) which is used for volumetric analysis. This volumetric analysis determines the treatment plan that should be followed by the physician for a particular patient. Post-processing the image data with segmentation methods can further aid in the visualization and recognition of soft tissues and lesions in brain [1]. The paper is segmented into many sub-divisions which deal with various computing techniques for image analysis. Many research papers with different approaches for image analysis are reported in the literature.

2. LITERATURE SURVEY

The two goals that stand before the field of medical image processing are:

1. To develop computational methods and algorithms those are capable of analyzing and quantifying the biomedical data.
2. To develop tools that to enable one to support the diagnosis and advancement of interpretation of biomedical of observation.

In the past twenty years, different brain MR image segmentation algorithms have been developed, but the accuracy is not satisfying and most of them are sensitive to noise. In addition, only few of them can perform segmentation that is highly desirable for MR image quantitative analysis. Moreover due to the complexity of MR imaging process and brain anatomical structure,

conventional segmentation algorithms based on distance measurement are not able to distinguish areas corrupted by in homogeneity effect, especially putamen, which is believed to be one of the hardest tasks in the segmentation area.

Different segmentation algorithms have been developed to delineate the anatomical structures and other regions of interest (ROI) to assist radiologist and scientist in both clinical and research area. Quantitative analysis, often combined with segmentation algorithms is important in medical image analysis. It refers to the problem of estimating tissue quantities from a given image, and segmenting of the image into contiguous regions of interest to describe the anatomical structures. Image segmentation and quantitative analysis algorithms are important components in medical research and visualization applications, such as the quantification of tissue volumes in normal and diseased population [2-3], diagnosis [4], morphological analysis, study of anatomical structure [5], and computer integrated surgery [6].

2.1 Imaging modalities
The important modalities used for imaging are the x—ray, computed tomography (CT), positron emission tomography (PET), single-photon emission computed tomography (SPECT), ultrasound and magnetic resonance imaging (MRI) [7]. Most of the Radiologists identify abnormalities from the data of medical images obtained from Bio-medical Devices which use popular imaging techniques like Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) [8]. The images indicate the presence or absence of a lesion along with the patient's history. As such, they provide information of vital factors in the process of Medical Diagnosis. Analysis of this wide gamut of diversified types of images requires sophisticated and powerful computer techniques for their quantification and visualization. Thus, a scrupulous and meticulous exploitation of CT, MRI or PET images from machines if manipulated through mathematical logic and powerful computers is tantamount to render the field of Medical Imaging immensely popular.

2.2 MR imaging (MRI)

MR imaging (MRI) which was invented in the year 1970 is a popular method in medical imaging because of its safe scanning and lesser side effects. It can be used as often as necessary. MRI is a widely used computed imaging especially for brain imaging in which MRI's soft tissue contrast and non-invasiveness are very important. Since it can provide rich biomedical information and it has great potential clinical usage [9], MR imaging attracted much attention in daily clinical and research areas. Besides the usage in human brain, MRI is also used for human body studies because of its ability to provide detailed images of living tissues. In addition, MR imaging raised rapid interesting in image processing field, because it presents new challenges for the development of theory and techniques to perform sophisticated visual information processing. Fig. 1.1 shows the general functional chart of MR image processing procedure.
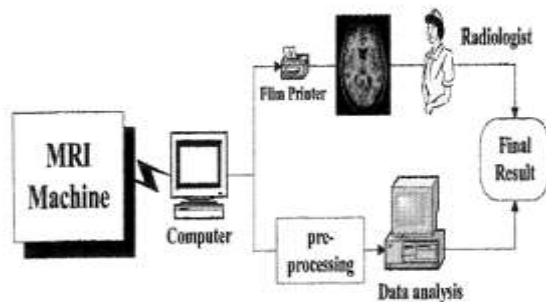

Fig. 1.1 General MR image processing flowchart.

2.3 Brain MRI Segmentation Methods

Brain MRI segmentation methods can be classified into various types based on different principles. In the clinic, brain tumor segmentation methods are usually classified into three main categories including manual, semi-automatic, and fully automatic segmentations based on the degree of required human interaction [10-12].

In manual brain tumor segmentation, the experts of brain tumor are believed to have some prior knowledge of brain such as its anatomy because manual brain tumor segmentation aims to manually draw the boundaries of the brain tumor and identify the regions which are different in anatomic structures as comparable to a normal brain image [10].

Manual segmentation is applied to clinical trial. Since manual segmentation of the different regions of brain tumor is based on human expert it may be error-prone and time-consuming task for the experts and yield poor results in a way. Therefore, more advanced segmentation methods such as semi-automatic and fully automatic segmentation methods are required to address this problem. The semi-automatic brain tumor segmentation is mainly based on user interaction and software computing. In the semi-automatic brain tumor methods, the user needs to give some input parameters to the computing machine and is responsible for analyzing the visual information and providing feedback response for the software computing.

A semi-automatic segmentation method is better compared to manual segmentation. But it is mainly based on the user who gives the parameters to the computing machine. It gives different results for different experts or if the same user uses the software at different intervals of time. Hence, fully automatic brain tumor segmentation methods were proposed.

In fully automatic brain tumor segmentation, the computer automatically does the job of segmentation of a brain image without a human interaction. The fully automatic segmentation of a brain image is accomplished by an algorithm which combines artificial intelligence and prior knowledge of the problem and its characteristics. With the development the artificial intelligence which can simulate the intelligence of humans to learn effectively, the study of fully automatic brain tumor segmentation has become a popular research issue [13].

2.4 Neural networks for medical image
    Segmentation

Image segmentation is a process of dividing a given image into meaningful regions with

homogeneous properties. Medical Image segmentation is an indispensable process in outlining boundaries of organs and tumors and in the visualization of human tissues during clinical analysis. Therefore segmentation of medical images is very important for clinical research and diagnosis [14].

Through recent years Artificial Neural Networks (ANN) have proven to be a useful technique in the interpretation of high-dimensional data such as images. However, an adequate application of neural networks is often plagued by a lack of systematic methodology.

Automatic Segmentation of brain [15] is used as a diagnostic tool in neuro medicine. Abnormal growth of brain tissues such as changes in volumetric growth of brain tissues such as White Matter (WM), Gray Matter (GM) and Cerebrospinal fluid (CSF) can help in the early detection of neural disorders like epilepsy, Alzhemeir's disease etc.

A number of approaches to segmentation of head or brain images have been presented in past years: pattern recognition techniques, rule based systems, and knowledge- based approach are some of them.

Artificial neural networks or neural networks, for short are a popular approach to information processing in computer science and artificial intelligence. Their name is derived from the fact that some basic ideas of processing were adapted from our knowledge about the function of groups of nerve cells in the brain. The main features are massively parallel processing in a large group of relatively simple but highly interconnected processors (or `units'), and self-organization or adaptation through so-called learning algorithms that change the connectivity between the units.

Neural networks can be trained by samples from a specific domain and thus obtain their "knowledge" about appropriate processing through extracting important information from those samples. Among others, supervised and unsupervised learning schemes can be distinguished depending on the role and

specificity of a "teacher" (or feedback). In the domain of diagnosis the most typical form of neural networks consists of several layers of units, each unit in a layer being connected to each unit in the next one. Such networks among others known as multilayer perceptrons or feed forward associative networks can be trained to implement mappings from input.

Neural networks have been widely used as tools for prediction and classification in the field medicine. We can see even more applications of neural networks for medical diagnosis in the future. Neural network rule extraction algorithms make the work easier for the decision process of a trained network. These rules are more logical to a human user than the classification process of the networks [16].

Artificial Neural Networks (ANN) is currently believed as a 'hot' research area in medicine and it is believed that they will receive extensive application to biomedical systems in the next few years. At the moment, the research is mostly on modeling parts of the human body and recognizing diseases from various scans (e.g. cardiograms, CAT scans, ultrasonic scans, etc.).

Neural networks are perfect in recognizing diseases using image scans since it is not necessary to provide a specific algorithm on how to identify the abnormality in the image. Neural networks learn by a set of training samples that are representative of all the variations of the disease given to the network during the training phase. Hence the details of how to recognize the disease are not needed. What is needed is that the training samples are need to be selected very carefully for achieving better results.

Researchers depend on Artificial Intelligence (AI) techniques for brain image segmentation. Among the AI techniques, ANN and Fuzzy theory are the predominantly used methodologies for segmentation. ANN is preferred by the researchers because of its adaptive nature, accuracy, etc.

The feed-forward neural network is the most used neural network for medical image segmentation. Among our reviewed papers, 6 of

17 papers employed the feed forward neural network for medical image segmentation [17]. Compared with Traditional Maximum Likelihood Classifier (MLC) based segmentation method, the feed forward neural network based segmented images are less noisy. However most feed forward neural network based methods have a slow convergence rate and require a priori learning parameters.

Hopfield neural networks were introduced as a tool for finding solutions to complex optimization problems. Among our reviewed literature, 4 of 17 papers used Hopfield neural network to segment some organs from a medical image [18].

Other neural networks used for medical image segmentation are Gaussian based neural networks [19], contextual neural network [20], probabilistic neural network [21], hybrid neural network [22 – [25].

The application of Linear Vector Quantization (LVQ) for brain image segmentation is demonstrated by [26]. A comparative analysis is performed with the Back Propagation neural network (BPN) and the experimental results proved the superior nature of LVQ. The report also concluded that the ANN is faster than the conventional classifiers.

Self-Organizing Map based segmentation techniques are used for MR brain images. Reyes-Aldasoro et al used self organizing map technique for brain mri segmentation. [27]. the proposed system was faster but the segmentation efficiency is comparatively low since it employs unsupervised mode of training. Automatic brain image segmentation using conventional LVQ is proposed by [28]. The convergence rate of this approach is high but this system failed to distinguish the outer layers of brain which is normally seen in MR brain images.

A combined radial basis function neural network (RBF) and contour model based MR image segmentation technique is used by [29]. A modified version of SOM with Markov random field model is suggested by [30]. But this method is highly prone to noise and applicable for only noise-free images. Back propagation neural network based tumor segmentation is performed by Martin [31]. A comparative analysis is done with the Inverse Laplace Transform based technique. The report concluded that BPN is superior in terms of processing time and accuracy over the conventional algorithm.

A fast neural network suitable for real time applications is implemented by [90]. An iterative-free training approach is followed in this network using the Huang's neural network. A comparative study between the neural classifiers and another AI technique such as fuzzy classifier is presented by [91]. SOM is used as a neural representative and fuzzy n-means algorithm is used as the fuzzy representative. Experimental results revealed the inability of SOM to detect small tumor areas.

A novel neural network such as Incremental Supervised Neural Network (ISNN) is proposed by [96]. This method depends on Continuous Wavelet Transform (CWT) and Zernike moments for the analysis of six different types of brain tissues. The architecture of the proposed neural network is adaptive in nature and the number of neurons is added incrementally. Experimental results suggested the applicability of this network for noisy environment.

3. CONCLUSION

Image segmentation has been an active research area in the field of medical imaging for the last few decades. Moreover, it is a most challenging field since its results help physicians in diagnosing various pathologies. Therefore development of novel techniques in this field with accuracy, precision, speed and reliability are still challenging to the researchers. In this work, we have discussed various segmentation techniques for identifying brain abnormalities. With a comprehensive survey over neural networks in the field of medical imaging especially for brain pathology identification, several novel hybrid approaches may be developed which are advanced in terms of accuracy, speed and robustness.

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