International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Various Techniques used for MRI Brain Image Segmentation

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Abstract*: Image processing methods stems from processing of images from storing, transmitting and representation for autonomous machine perception. It is widely used technique in all engineering areas including diagnosis and treatment of diseases in Medical Science. Segmentation of non trivial images is one of the most challenging task because it requires more sophisticated method to differentiate between each region. The objective of this paper is to provide comprehensive overview of various segmentation methods used for MRI brain images. Hence, study of existing algorithms is all important for achieving accuracy. First, we briefly discuss about brain tumors, imaging modalities of brain and then several segmentation algorithms surveyed in this work. Complexities of existing algorithms and the segmentation outputs and analysis has also been discussed in observations.

Keywords* : Image Processing; Magnetic Resonance Imaging (MRI); Segmentation; Machine Learning Techniques.

I. INTRODUCTION

Image processing involves the processes whose inputs and outputs are images and the processes that extract several features from images, and also recognize the individual objects [6][14]. The process of acquiring an image containing the text, preprocess that image, segment the individual characters and describing them in the form which is suitable for processing by computer.

Image segmentation is the widely used technique to subdivide an image into its constituent regions. The partitioning of the image into its sub divisions is carried out based on the intensities or the set of pixels in the digital image [7]. Accuracy of segmentation determines the success and failure of analysis procedures.

Medical imaging is the method of producing the visual description of the internal portions of human body. Knowledge related to the functions of the organs and tissues can also be gained through these images [8]. There are various methods to produce the medical brain images i) X-radiation (X-ray), ii) Magnetic Resonance Image (MRI), iii) Functional MRI (fMRI), iv) Computed Tomography (CT), v) Polyethylene Terephthalate (PET)etc [17].

Revised Manuscript Received on December 30, 2019.
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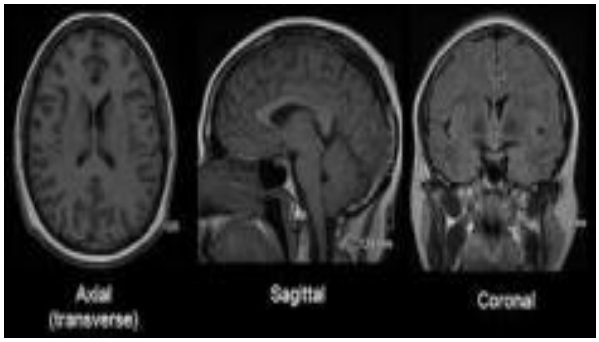
Most complicated structure in human body is the human brain, so the segmentation of brain images must be accurate for further analysis of Edema, tumors, necrotic tissues inorder to get proper treatment. Mainly, the brain structures are mainly described by the boundaries of tissue classes, so the segmentation technique based on these categories is important [4]. There are different matters present in brain, normally categorized as i) White matter, ii) Gray matter, iii) Cerebrospinal Fluid (also known as Vasculature). These matters have been extracted using various segmentation techniques [18]. Fig.1 shows the different views of Brain MRI Images. The Axial View is the images from chin to the top of the head, Sagittal View MRI images are taken from one side ear to the another ear. Coronal view of MRI is the image which will be taken from back of the head [11].



A B C

Figure 1. A) Axial View, B) Sagittal View, C) Coronal View.

MRI is the imaging technique which generates several images and each image provide a different and important characteristics in the same human body with various modalities.

Section II represents the various Machine Learning techniques classification, Section III represents the Machine Learning techniques used for image segmentation. Section IV shows the related work done in this field, Section V represents the observations and at the last section VI represent the conclusion followed by references.

II. MACHINE LEARNING CLASSIFICATION

Machine Learning provide systems the ability to learn and improve from experience without being explicitly programmed. It focuses on computer program development. Machine Learning Algorithms is generally categorized as shown in Fig.2. i). Supervised Machine Learning Algorithms in which the model is going to get trained on a labeled dataset, and ii). Unsupervised Machine Learning Algorithms in which training of machine is done using information that is neither classified nor labeled.

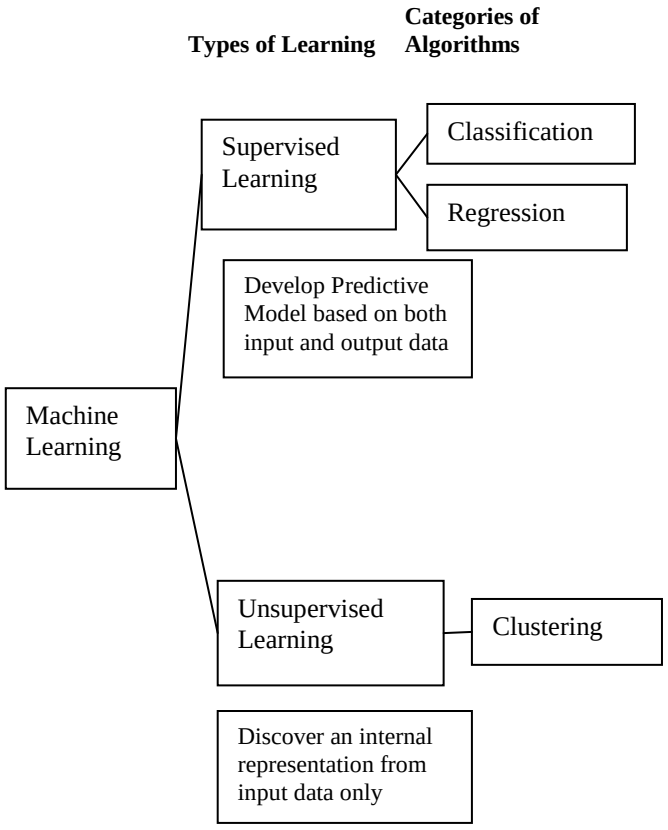


Figure 2. Machine Learning Techniques

Several approaches based on Supervised learning are Decision Trees, Linear Regression, Guassian Naïve Bayes, Support Vector Machine(SVM), Nearest Neighbour etc.. and the algorithms based on Unsupervised learning are k- means, Fuzzy c-means, Guassian mixture, Neural Network etc..

III. MACHINE LEARNING APPROACHES USED FOR BRAIN IMAGE SEGMENTATION

Modern image segmentation techniques are powered by machine learning technology. Here several machine learning architectures are discussed which are used for segmentation purpose.

A. Neural Network

Neural network is designed as a set of input and output units where each connection is assigned with a associated weight. These weights are then adjusted for learning of network and predicting the class label correctly. They are designed to recognize patterns. Properties of neural network make them popular for clustering. Image segmentation with Convolutional Neural Network (CNN) involves feeding segments of an image as input to CNN, which labels the pixels. The CNN cannot process the whole image at once. It scan small filter of several pixels each time, until it has mapped the entire image.

Advantage:

- Convolutional Neural network is an automatic feature extraction for any given task.

B. K-means

K-means clustering algorithm is an unsupervised algorithm which is basically used to segment the required interested area from the background. It partitions the given data into k clusters. This algorithm is useful for unlabelled data and its objective is to find various groups based on some kind of similarity.

The objective of k means clustering algorithm is to minimize the sum of squared distances between all point and the cluster center.

$$J = \sum_{J=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2$$

where J denotes Objective function; k shows number of clusters, n is no. of cases; $x_i^{(j)}$ denotes case i; c_j denotes centroid of cluster; $x_i^{(j)} - c_j$ denotes the Distance function.

Advantage:

- On huge variables, k means is faster than hierarchical clustering.
- They produce tighter clusters.

C. Support Vector Machine

Support vector machine is used as a discriminative classifier for both linear and non linear classification defined by a separating hyperplane. It transform the original training data into a higher dimension through mapping process. A separating hyperplane between two groups can be written as

$$X,Y + b = 0$$

where X denotes weight vector namely X = {X1,X2, X3,……Xn}; n shows the number of attributes; b is the scalar referred as bias and Y is the vector representing the values of attributes. In Image Segmentation, Support Vector Machine is used to reduce error which is caused by motion of the objects. It act as a classifier that partitions a vector space into two separate zones.

Advantages:

- SVM works effective when clear margins of separation will be present between classes.
- It is more effective in high dimensional space.
- It also provides memory efficiency.

D. Self Organizing Map

Self Organizing Map (SOM) is one of the widely used artificial neural network, sometimes also known as Kohonen Self Organizing Feature maps. They differ from the other neural network as they used to apply competitive learning such as backpropagation with gradient descent and it uses the neighbourhood function to preserve input space properties.

Advantage:

- It conserves the original distance and niosy data can be accurately clustered.

E. Fuzzy C Means

It is one of the common and widely used algorithm that is used for image segmentation by dividing the space into various clusters with similar image pixel values. It is simply a version of k means algorithm.

It produces C partitions by minimizing the weights within group sum of squared error function. It randomly choose centroid and computer membership matrix as

$$U_{ik} = [(d_{ik} / d_{jk}) ^{2/(m-1)}]$$

and then check for the convergence.

Advantage:

- It gives best result for overlapped dataset.

F. Expectation Maximization (EM) Algorithm

An Expectation Maximization Algorithm is developed to estimate parameters of the Guassian Mixtures. It tends to find the maximum likelihood parameters of probabilistic models where the model depends on unobserved variables.

Advantages:

- It guarantees the increase of likelihood with each iteration.

G. Level Set Method

This method provide the framework which uses level sets as a tool for numerical analysis of surfaces and shapes containing in an image. It is used for active contour image segmentation. The user specifies an initial contour, which is then moved to the boundaries due to image drives forces. Parametric deformable form is robust to image noise as well as boundary gaps and get boundaries to be smooth whereas Implicit Deformable Models are designed to naturally handle topological changes.

Advantage:

- Computations related to curves and surfaces can be efficiently performed.

IV. RELATED WORK

G M Wells et al. [1] proposed a technique of adaptive segmentation. They uses the expectation maximization (EM) algorithm for accurate segmentation and their results are obtained and analyzed on coronal axial view of MRI brain images.

She Juan He et al. [2] presents an automatic segmentation algorithm which is based on Fuzzy C means (FCM) method and it also uses the multiscale segmentation algorithm for segmenting the various matters of brain.

She Juan He et al. [3] presents a systematic method for finding brain end contours and real calculation models are constructed using Multiscale Wavelet Transform (MVT) for image denoising of EEG and MEG research. This process is dedicated for magnetic and electrical source images and the result is used in forward and inverse problem of biomagnetism.

S. Javeed et al. [4] proposed an image segmentation technique using Fuzzy Inference System and FFBNN. Using extracted features of images, the classification process is achieved by generating the fuzzy rules.

Antonios Makropoulos et al. [5] proposes an intensity based segmentation for any Neonatal brain. Author proposed the segmentation technique which models the intensities of whole brain using structural hierarchy. The result is compared with atlas based technique. It gives the better result across the wide range of gestational ages.

Lahouaoui Lalaoui et al. [8] also uses the Expectation Maximization Algorithm (modified) based on likelihood and it also reduces the number of iterations, due to which the computational cost also get decreases with maintained accuracy.

Pim Moeskops et al. [9] proposes a method using CNN which segment the image into number of tissue classes. Authors use the multiple convolutional kernel sizes and acquire the information of each voxel. They applied the proposed method on 5 datasets of different ages and get different dice coefficients on each data set.

Ishman Zabir et al. [10] uses the traditional region growing approach for selecting the segmented area as initial contour to iterative Distance Regularized level Set Evolution method (DRLSE). They proposed a technique for automatic Glioma detection. Authors uses the BRATS 2012 dataset for detecting and analyzing tumor for various Glioma cases.

Sudipta Roy et al. [12] uses a new concept of level set methodology for segmenting white matter(WM), gray matter(GM) and cerebrospinal fluid(CSF) from other parts of the head of human like skull, mascular skin, and marrow. For correct tissue segmentation, hierarchical structure is generated by segmented component.

Sergio Pereira et al. [13] also uses CNN of 3*3 kernels. It gives positive effect against overfitting. Before applying segmentation, it uses intensity normalization as a preprocessing. Proposal was validated for BRATS 2013 data set and provide a good Dice similarity coefficient matrix.

Vishnumurthy TD et al. [14] implements the automatic segmentation by morphological operations. Jaccard Distance, False Positive/negative Ratio, and Dice coefficients are used for comparison. Quality and accuracy of segmentation is maintained by using this segmentation technique in minimal computation time.

Swapnil R. Telrandhe et al. [15] proposed an adaptive tumor detection technique using k means segmentation. Authors also uses SVM to make the proposed system adaptive inorder to create patterns. They focus to find texture and color features in their work.

Weihua Zhu et al. [17] use global Entropy Minimization for the segmentation purpose.
They uses two times segmentation approach for better performance and accuracy.

Qingneng Li et al. [19] proposed an algorithm using spatial fuzzy c- means clustering and improved Distance Regularization Level Set method for better segmentation performance. They apply their method on BRATS 2015 dataset. The proposed method was effective for multimodal and flair images.

Wassim El Hajj Chehade et al. [20] enhances Li's method which is used for segmenting images. They use Between-class variance with Gamma Distributions, and experiments on this method provide a good result.

Segmentation methods are analyzed and summary of used methodologies and presentation is illustrated in below table I.

TABLE I. SUMMARY OF SEGMENTATION METHODS

Segmentation Methods	Authors Reference	Methodology Used	Presentation
Convolutional Neural Netwok	Pim Moeskops et al. [9]	Use multiple patch sizes as well as multiple convolutional kernel sizes	Accurate and robustness to differences in ages
	Sergio Pereira et al. [13]	Use intensity normalization as pre processing step	Positive effects against overfitting
	C. Anitha et al. [16]	Use 3*3 kernel sizes and intensity normalization	Validated for the 2013 database (BRATS 2013)
	S.Javeed Hussain et al. [4]	Fuzzy Inference system (FIS), Feed Forward back neural network (FFBNN)	Efficient in segmenting WM, GM and CSF
Level set models	Ishman Zabir et al. [10]	Use Distance Regularized Level Set Evolution method	Improve performance of overall detection of tumor present in brain
	Sudipta Roy et al. [12]	Use repeated level set method to generate hierarchical structure of segmented component.	Robust to noise, decreases error rate and provide high accuracy.
K- means + SVM	Swapnil R. Telrandhe et al. [15]	Denoising of median filter and skull masking is used	Improves performance to detect and identify the brain tumor as compared to existing algorithms
Global Entropy Minimization	Weihua Zhu [17]	Based on the cluster area, apply segmentation approach two times	Overcome the negativity of shifted segmentation, and provide high accuracy
Expectation Maximization Algorithm	Lahouaoui Lalaoui et al. [8]	Use Region based modified Expectation of Maximization (MEM) based on the properties of likelihood	Minimizing number of iterations and the Execution time
	W. M. Wells et al. [1]	Adaptive segmentation using knowledge of tissue intensity and intensity inhomogeneities	More powerful than HMF followed by intensity-based segmentation
Fuzzy C-Means (FCM)	Qingneng Li et al. [19]	Extracting seed points, merge the regions and use improved DRLSE method	Effective in segmenting Gliomas in multimodal images
	Shi Juan He et al. [2]	Fuzzy C-Means algorithm (histogram based), and multi-scale connectivity clustering algorithm	Segment WM, GM, and CSF of the brain effectively
Gaussian Distribution + Gamma Distribution	Wassim El Hajj Chehade et al. [20]	Uses Between-Class Variance	Provide efficiency when compared with the original Li's method.

V. OBSERVATIONS

- White matter, Gray matter and Cerebrospinal Fluids Segmentation has been done in most of the papers.
- The hybrid technique can be used for partitioning brain image into more than 3 regions and further the lot of work to be done on 3D MRI brain image segmentation.
- Region based Expectation Maximization algorithm will not work well for color images in RGB and YUV spaces.
- The intensity difference between different regions of brain are very less, so segmenting them is a difficult process.
- Some algorithms work well only with a specific dataset but reduce accuracy when applied on other dataset or real time data.

VI. CONCLUSION

This paper conveys the survey on various MRI brain image segmentation techniques. There are various methods present which will efficiently used for segmentation purpose. The study of various techniques and their comparative study is also done in this paper. The work will be extended for constructing new technique which will be more efficient for brain image segmentation inorder analyze and detecting tumors. The further work will be done to minimize computational time with accurate results.

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