Different Segmentation Methods to Detect Multiple Sclerosis Lesion In Brain MR Images

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ABSTRACT

In supporting and relieving clinical information in the diagnosis of multiple sclerosis (MS) disease, magnetic resonance images (MRI) play an important role by presenting lesion in brain MR images. In this study, we compared different types of algorithms for MS lesion segmentation from Brain MR Images. We compared Marker-Controlled Watershed, k-means, fuzzy -c means, global image threshold, multilevel threshold, global histogram threshold, adaptive image threshold, Otsu threshold, Canny edge detection, Prewitt, and Sobel segmentation algorithms.

By applying all these algorithms, we understood that with the fuzzy c-means (FCM) algorithm, we could detect MS lesions parts accurately.

Problem Statement

Finding an optimal and accurate method for diagnosing diseases is important. Over time, the importance of finding an accurate and efficient way for diagnosing diseases is increased. Multiple sclerosis is known as an autoimmune disease, also known as MS, that is a long-lasting disease that attacks the central nervous system (CNS) and disturbs white matter by the person's own immune system. A nerve fiber is bounded by myelin, which is vital to the normal functioning of the nervous system. Mylin protects the nerves and helps them to conduct electrical Signals (Impulse) between each other. Myelin helps to and increases electrical resistance when a nerve carries electrical impulses from one end to the other by stopping the impulse from leaving the axon, so, it can enhance signal conduction. When Demyelination happens, the myelin is disappeared, can cause neurological disease, and a variety of cognitive, motor and sensory deficits appears. One of the most famous demyelinating diseases is MS. MS is a largely unknown disease these days and diagnosis it correctly and early, has a significant impact on disease progression.[1]

Approach

Here different methods of segmentation are explained and we focused on Adaptive thresholding and Fuzzy c-means clustering which are two effective methods in brain lesion segmentation.

1. Thresholding

This technique is based on a threshold value to turn a gray-scale image into a binary image [2]. In this technique image is segmented by comparing pixel values with the predefined threshold limit [3].

There are different types of threshold methods. We can have global or local threshold values. There are two types of thresholding-based methods : 1) Fixed Thresholding and 2) Adaptive Thresholding (see *Figure 1*).

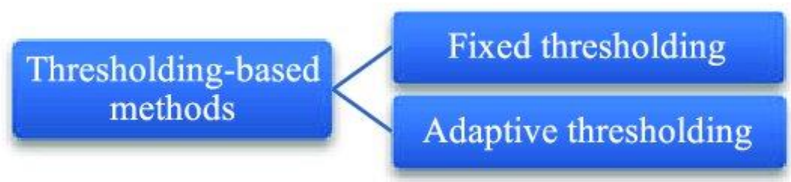

Figure 1. Thresholding Techniques[4]

1.1. Fixed Thresholding

In fixed thresholding, pixels above the threshold level are to a group and below the threshold are counted as background. However, the object of interest in MRI suffers from many objects. Therfore, to detect the object of interest in fixed thresholding-based methods we should consider some criterias like entropy, between-class variance, etc.

The equation to define the threshold level here is given by:

$$x(i,j) = \begin{Bmatrix} 0, f(i,j) \leq L \\ 1, f(i,j) \leq L \end{Bmatrix}$$

1.2. Adaptive Thresholding

When a single threshold value is unable to segment, or a threshold value cannot attain from histogram of an image, Adaptive thresholding method is preferred. So, this is an efficient means of segmenting multiple objects from intensity histogram. But, the performance of these methods is sensitive to the gray scale distribution, noise, multichannel images, and images with multimodal regions.[4]

Otsu’s method, and evolutionary-based methods are popular and efficient thresholding-based methods used for brain tissue segmentation of MRI which are entropy-based. To obtain the optimal threshold values from the histogram, Kapur et al. [5] proposed maximization of entropy. Otsu’s method which Otsu [6] proposed is a nonparametric approach to find optimal threshold automatically by maximizing the variance of grey levels between classes. In both methods, due to the extensive search strategy with the increase in the number of thresholds, computational time increases.

2. Clustering

There are two different types of clistering as showed in Figure 2. K means and Fuzzy C Means are examples of each type respectively hard and soft clustering methods.

2.1. K means Clustering

One of the simplest unsupervised learning algorithms is K-means. This algorithm is easy to solve the well-known clustering problem. To classify a given data set through a different number of clusters, this method follows an easy way, but, is sensitive to noise, intensity inhomogeneity (IIH), and images with heterogeneous regions .

2.2. Fuzzy C-Means Clustering

Fuzzy c-means (FCM) is a technique of clustering which allows one part of data to belong to two or more clusters. This method which is commonly used in pattern recognition is established by Dunn in 1973 and improved by Bezdek in 1981. FCM is popularly used for soft segmentations like brain tissue model. And also FCM can provide better results than other clustering algorithms like KM, EM, and KNN [7]. In FCM, data points can possibly belong to several clusters. Membership grades are assigned to each of the data points (tags). The membership grades in FCM indicate the degree to which data points belong to each cluster. Thus, points on the edge of a cluster, with lower membership grades, may be in the cluster to a lesser degree than points in the center of cluster.

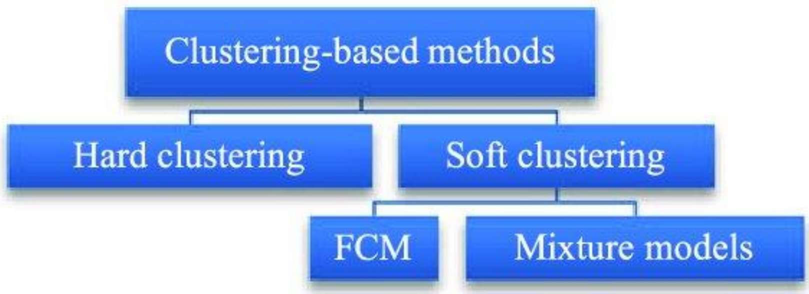

Figure 2. Clustering-methods-in-brain-tissue-segmentation

3.Edge Detection

The most familiar approach for detecting significant discontinuities in intensity values is edge detection approach.

3.1. Canny edge detection

The canny method is a better method without disturbing the features of the edges in the image afterward it is applying the tendency to find the edges and the serious value for threshold [8]. The algorithmic steps are as follows:

- Convolve image with a Gaussian function to get smooth image.
- Apply first difference gradient operator to compute edge strength then edge magnitude and direction are obtained as before.
- Apply non-maximal or critical suppression to the gradient magnitude.
- Apply threshold to the non-maximal suppression image.

3.2. Sobel edge detection

The Sobel method is using the Sobel approximation to the derivative of edge detection for image segmentation to finds edges. Those points where have the highest gradient are defined as edges. A 2-D spatial gradient quantity on an image is performed in the Sobel technique and so highlights regions that correspond to edges or regions with high spatial frequency. In general, at each point in n input grayscale image, it is used to find the estimated absolute gradient magnitude.

3.3. Prewitt Edge Detection

The Prewitt edge detection is used to estimate the magnitude and orientation of an edge. Even though different gradient edge detection wants a quiet time-consuming calculation to estimate the direction from the magnitudes in the x and y-directions, the compass edge detection obtains the direction directly from the kernel with the highest response. It is limited to 8 possible directions; however, knowledge shows that most direct direction estimates are not much more perfect. This gradient based edge detector is estimated in the 3x3 neighborhood for eight directions. All the eight convolution masks are calculated. One complication mask is then selected, namely with the purpose of the largest module.

4. Region Based Methods

Depend on the homogeneity of intensity in the image there are different types of region-based segmentation methods to detect the object boundary (Figure 3). Popular techniques under this method are as follows:

1. contour- and shape-based method
2. region growing
3. region-based level set method
4. graph-based method

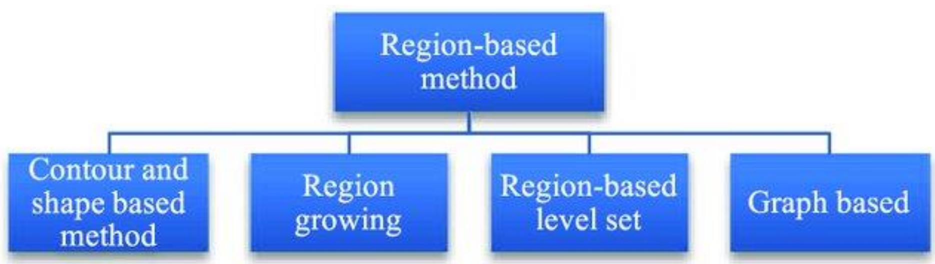

Figure 3. Region-based methods

Results

Based on our result here we can see that adaptive threshold method and Fuzzy C means method are two accurate methods to detect brain lesion Figure 4.

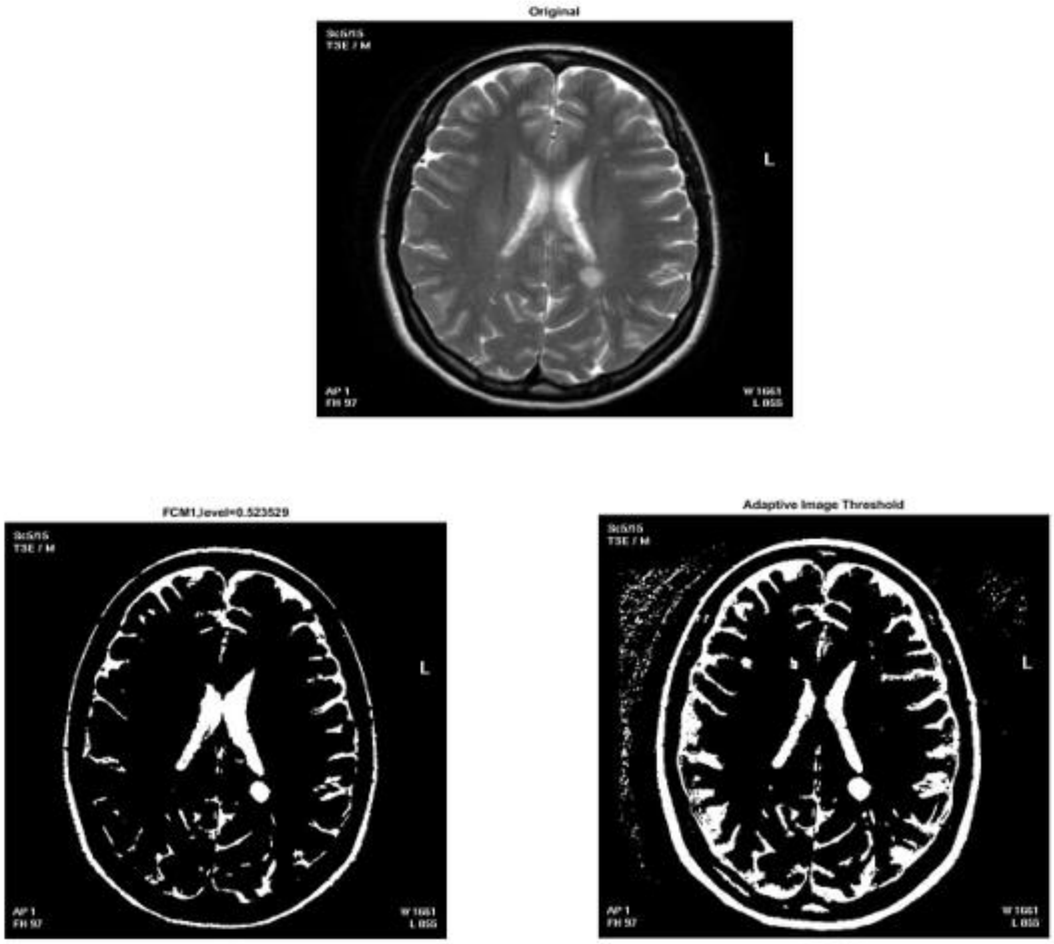

Figure 4.Original, FCM, Adaptive Thresholding

As we can see, there are more noises in adaptive thresholding method and we need an accurate filtering part to extract the lesion part.

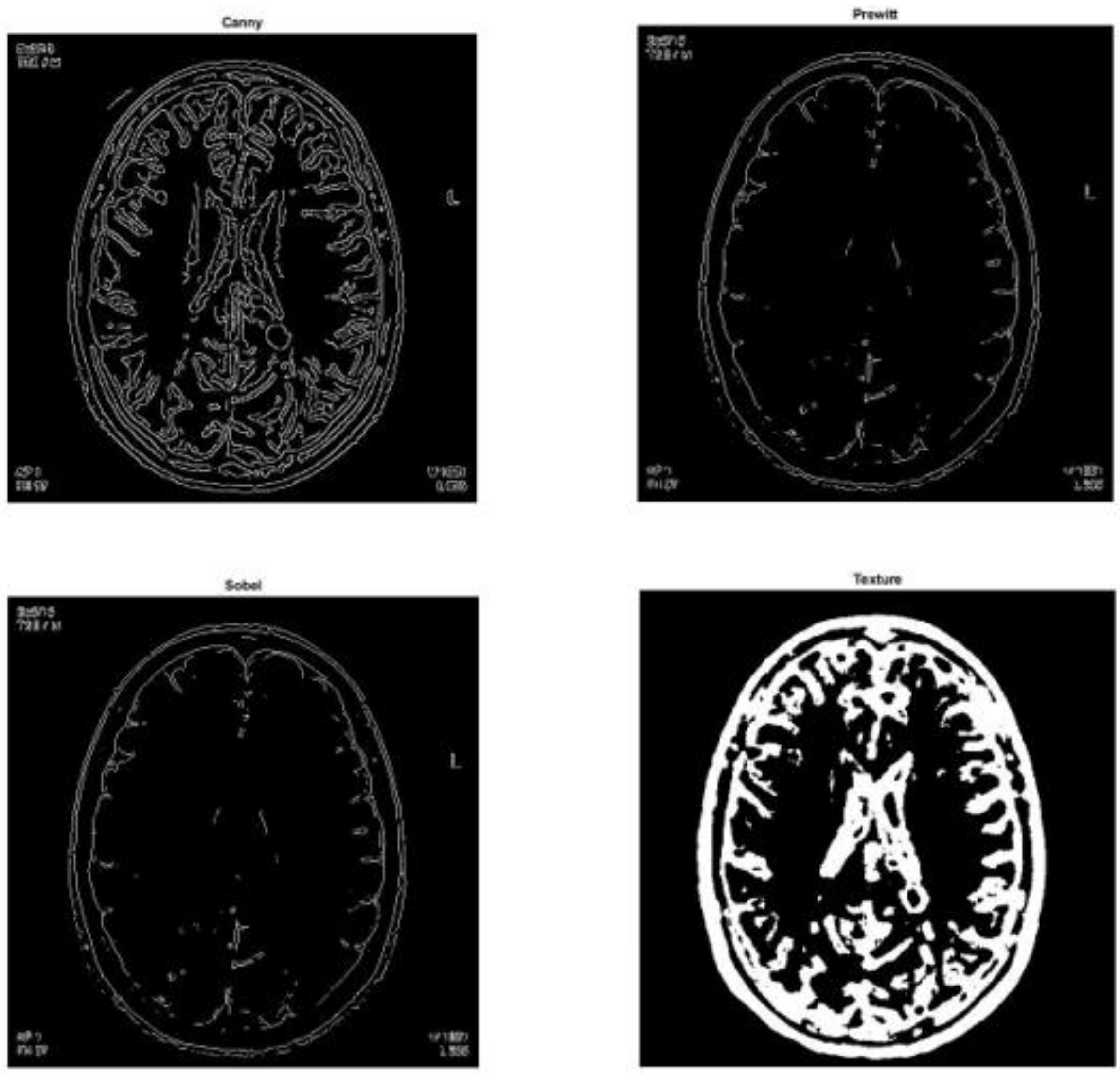

Figure 5. Canny, Prewitt, Sobel, and Texture edge detection

Results show that Canny edge detection method can be an effective technique, but we need to use that with another technique to have an acceptable result.

Source code Link

https://www.dropbox.com/home/Computer%20Vision%20Project/MS_BrainLesionSegmentation/Code

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