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MRI Brain Image Segmentation based on Thresholding

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Abstract

Medical Image processing is one of the most challenging topics in research field. The main objective of image segmentation is to extract various features of the image that are used for analysing, interpretation and understanding of images. Medical Resonance Image plays a major role in Medical diagnostics. Image processing in MRI of brain is highly essential due to accurate detection of the type of brain abnormality which can reduce the chance of fatal result. This paper outlines an efficient image segmentation technique that can distinguish the pathological tissues such as edema and tumour from the normal tissues such as White Matter (WM), Grey Matter (GM), and Cerebrospinal Fluid (CSF). Thresholding is simpler and most commonly used techniques in image segmentation. This technique can be used to detect the contour of the tumour in brain.

Keywords

Abnormality, accurate, segmentation, thresholding, tissues, tumour

1. Introduction

Image segmentation subdivides an image into its constituent regions or objects. The level to which the subdivision is carried depends on the problem being solved. Segmentation of nontrivial images is one of the most difficult tasks in image processing. Segmentation accuracy determines the eventual success or failure of the computerized analysis procedures [1]. Segmentation algorithms are area oriented instead of pixel-oriented. The result of segmentation is the splitting up of the image into connected areas.

Image segmentation is the fundamental step in image analysis, understanding, and interpretation and recognition tasks. Segmentation is the most important step in automated recognition system which has numerous applications in the field of medical imaging, satellite imaging, movement detection, security, surveillance etc [2].

2. Segmentation Techniques

Image Segmentation partitions an image into set of regions. The region represents meaningful areas in an image or be the set of border pixels grouped into structures such as line segments, edges etc. The segmentation has two objectives: (i) to decompose an image into regions for further analysis, (ii) to perform a change of representation of an image for faster analysis [2]. Different types of segmentation techniques are used for segmentation. Based on the application, a single or a combination of segmentation techniques can be applied to solve the problem effectively.

Segmentation algorithm is based on the properties of gray level values of pixels. The different types of segmentation techniques are: (a) Edge based segmentation (b) Threshold Based Segmentation (c) Region Based Segmentation (d) Clustering (e) Matching.

In this paper, we discuss about the different types of threshold based segmentation Techniques.

3. Threshold based Image Segmentation

Thresholding techniques identify a region based on the pixels with similar intensity values. This technique provides boundaries in images that contain solid objects on a contrast background [3]. Thresholding technique gives a binary output image from a gray scale image. This method of segmentation applies a single fixed criterion to all pixels in the image simultaneously [3].

3.1 Global Thresholding

Suppose the histogram of an image f (x, y) is composed of light objects on a dark background. The pixel intensity levels of the object and the background are grouped into two dominant modes. In global thresholding, a threshold value T is selected in such a way that it separates the object and the background. The condition for selecting T is given as follows:

$$g(x, y) = \begin{cases} 1 & \text{if } f(x, y) > T \\ 0 & \text{if } f(x, y) \le T \end{cases} \quad (1)$$

Equation (1) has no indication on selecting the threshold value T. The threshold T separates the object from the dark background. Any point (x,y) for which f(x, y) $\geq$ T is called an object point. After thresholding operation, the image is segmented as follows: Pixels labeled 1 corresponds to object whereas pixels labeled 0 corresponds to the background. In global thresholding, the threshold value T depends only on gray levels of f(x, y).

Global thresholding technique will not produce the desired output when pixels from different segments overlap in terms of intensities [3]. The overlapping of intensities may be caused due to (a) noise (b) variation in illumination across the image. In the first case, minimum-error method can be used to estimate the underlying cluster parameters and the threshold is chosen to minimize the classification error. Variable thresholding technique is used for the latter case. Global thresholding is popular due to simplicity and easy implementation [5][6].

3.2 Local Thresholding

Global thresholding method is not suitable whenever the background illumination is uneven. In local thresholding technique, the threshold value T depends on gray levels of f(x, y) and some local image properties of neighboring pixels such as mean or variance [2].

The threshold operation with a locally varying threshold function T(x, y) is given by

$$g(x, y) = \begin{cases} 1 & \text{if } f(x, y) \ge T(x, y) \\ 0 & \text{if } f(x, y) < T(x, y) \end{cases} \quad (2)$$

Where

$$T(x\ y) = f_0(x, y) + T_0 \quad (3)$$

$f_0(x, y)$ is the morphological opening of f, and the constant T_0 is the result of function *graythresh* applied to f_0 [1]. Local thresholding is superior to the global threshold method in the case of poorly illuminated images.

3.3 Adaptive Thresholding

Adaptive thresholding technique is used when images are captured under unknown lightning condition and it is required to segment a lighter foreground object from its background or whenever the background gray level is not constant and object contrast varies within an image. This technique allows the threshold value T to change based on the slowly varying function of position in the image or on local neighboring hood statistics. Threshold T depends on the spatial coordinated (x, y) themselves.

4. Threshold Selection

The key parameter in image segmentation using thresholding technique is the choice of selecting threshold value T. In case of manual thresholding method, the threshold value T can be selected by the user with the help of image histogram. This method is generally accomplished by a tool that allows the user to select the threshold value T based on choice. In case of automatic threshold selection method, the value of T can be chosen based on histogram, clustering, variance, means etc.

4.1 Histogram based Threshold Selection

An image having an object on a contrasting background has a bimodal histogram. The two peaks correspond to the relatively large number of points inside and outside the object. The valley is commonly used to select the threshold gray level. If the image containing the object is noisy and degraded due to illumination artifacts the histogram itself will be noisy and will not be sharp. This can introduce error in selecting the threshold value T. This effect can be overcome to some extent by smoothing the histogram using either a convolution filter or the curve-fitting procedure [3]. Histogram based thresholding is applied to obtain all possible uniform regions in the image [7].

Let P_1 and P_2 be the gray value of the peaks of the histogram. The threshold value T is given by

$$T = \frac{P_1 + P_2}{2} \quad (4)$$

Or T may be the gray level at the minimum between the two peaks.

$$T = \min_{u \in [P_1, P_2]} H(u) \quad (5)$$

where H(u) is the histogram value at gray level u between P_1 and P_2

4.2 Iterative based Threshold Selection

Iterative methods give better result when the histogram doesn't clearly define valley point. This method doesn't require any specific knowledge about the image. Iterative method has the ability to improve the anti-noise capability.[4]

Gonzalez and Woods [2002] describe the following iterative procedure:

1. Select an initial estimate for the threshold value (T). This can be done by selecting the midpoint between the minimum and maximum intensity values in the image.
2. Segment the image using T. This will produce two sets of pixels G_1 and G_2. G_1 contains all pixels with intensity values $\geq$ T and G_2 contains pixels values <T.
3. Compute average intensity values m_1 and m_2 for each set of pixels.

m_1 = average value of G_1
m_2 = average value of G_2

4. Compute new threshold value $T = \frac{1}{2}\left(m_1 + m_2\right)$
5. Repeat steps 2 through 4 until the difference in T in successive iteration is smaller than a predetermined parameter ΔT.

This iterative algorithm is a special one dimensional case of K-means clustering that converges at a local minimum. But the main disadvantage is, a different initial estimate for T may give a different result.

4.3 Threshold Selection based on Otsu's method

A segment is assumed to have relatively homogeneous gray level values, then a threshold value T can be selected in such a way that it minimizes the variance of the gray levels within the segment or T can be selected that minimizes the variance between objects and background or a method that attempts to optimize 'within' and 'between' segments variance [2]. This method maximizes the between-class variance and is based on computations performed on the histogram of an image.

Otsu's algorithm is as follows:

1. Compute the normalized histogram of the input image. The components of the histogram is denoted by $P_i = n_i$ / MN, where i=0, 1, 2, L-1 and $MN = n_0+n_1+n_2+\ldots+n_{L-1}$
2. Compute the cumulative sums $P_1(k)$, $P_1(k) = \sum_{i=0}^{k} P_i$, for k= 0,1,2,…, L-1
3. Compute the cumulative means, $m(k) = \sum_{i=0}^{k} i\,P_i$, for k=0,1,2,…,L-1
4. Compute the global intensity mean, m_G using $m_G = \sum_{i=0}^{L-1} i\,P_i$
5. Compute the between-class variance, $\sigma^2_B(k)$, for $k = 0,1,2,\ldots,L-1$ where

$$\sigma^2_B(k) = \frac{\left[m_G P_1(k) - m(k)\right]^2}{P_1(k)\left[1 - P_1(k)\right]}$$

6. Obtain the Otsu threshold, k*, as the value of k for which $\sigma^2_B(k)$ is maximum. If the maximum is not unique, obtain k* by averaging the values of k corresponding to the various maxima detected.
7. Obtain the separability measure, η^*

$$\eta(k^*) = \frac{\sigma^2_B(k^*)}{\sigma^2_G}$$

The main drawback of Otsu's method of threshold selection is that it assumes that the histogram is bimodal. This method fails if two classes are of different sizes and also with variable illumination.

4.4 Threshold Selection based on Clustering

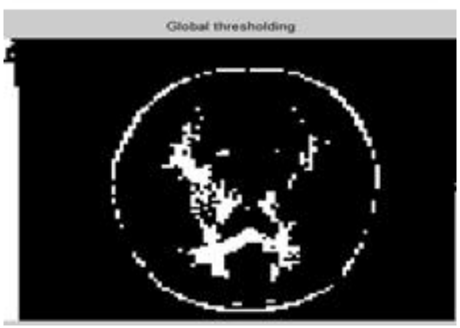
In this method, gray levels are clustered into object and background. Clustering is done to identify natural grouping of data from a large data set to produce a concise representation of system behaviour [8]. K-means clustering is an efficient method of threshold selection. Using this algorithm, the image is divided into k segments using (k-1) thresholds and minimizing the total variance within each segment. The value of k has to be selected initially. The basic algorithm is as follows:

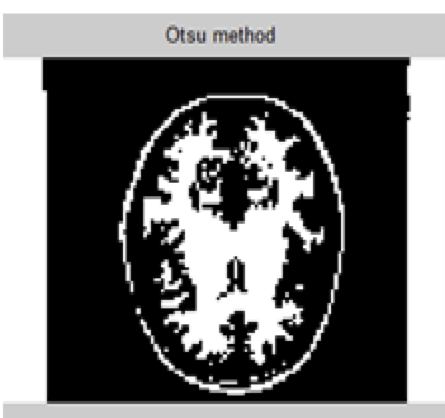
1. Choose k cluster centers, either randomly or based on some heuristics.
2. Assign each pixel in the image to the cluster that minimizes the distance between the pixel and the cluster center.
3. Compute the new cluster center by averaging all the pixels in the cluster.

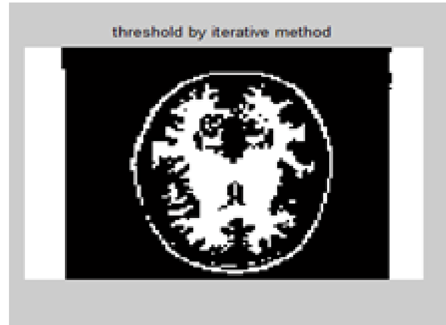
4. Repeat steps 2 and 3 until convergence is attained i.e. the cluster centers do not move significantly.

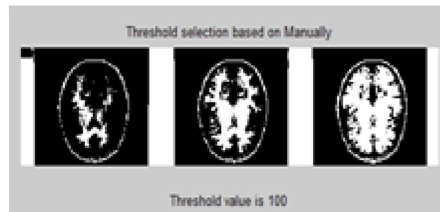
In this case, distance is calculated by squaring or finding the absolute difference between a pixel and a cluster centre. The difference is based on the properties of pixels such as colour, intensity, texture etc. This algorithm is guaranteed to converge, but it may not return the optimal solution. The quality of the solution depends on the initial set of clusters and the value of k

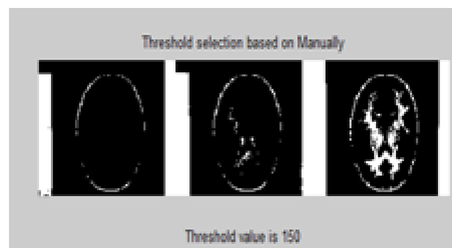
5. Experimental Results











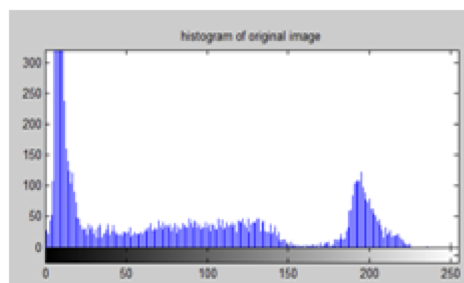


Figure 1: (Original image, Figure 2-7) Results of various segmentation Techniques

MRI brain image segmentation based on thresholding was implemented using MATLAB 7.10.0 (R2010a). Figure 2-7 show the experimental output of the given MRI input image, Figure1. The output of the segmented image using Global thresholding is shown in Figure2. Matlab built in function is used. Thresholding based on Otsu's method was implemented and its output is shown in Figure3. The inbuilt function graythreshold ( ) is used to find the threshold value. Figure 4 shows the output of segmentation using iterative method. The initial threshold is chosen as T= (max (f) + min (f))/2, where f is the input image. The new value of T is calculated by taking the average of the mean of two segments. It can be observed from Figure3 and 4 that the difference in threshold value is found to be small. Figure 5 and 6 shows the output of the segmentation in which the threshold is selected manually. This method requires prior information about the image. The user can change the value of threshold based on the output. This method requires a tool that helps the user to observe the output and alter the threshold value. Figure 7 shows the output of histogram of the original image. The image can be segmented by keeping threshold in the valley. After examining different inputs, it is observed that the threshold selection based on histogram does not work well for an image without having obvious peaks and also for the images with flat and broad valley.

6. Conclusions

An image segmentation approach based on thresholding has been discussed. This approach for segmentation of MRI brain images can help in the proper detection of the region of interest. The main limitation of this approach is that only two classes are generated and it cannot be used for multi-channel images. Thresholding approach is sensitive to noise and intensity homogeneities. Based on application we can select any one or combination of methods to get the desired segmented output

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