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Research Article

IMAGE SEGMENTATION IN MEDICAL IMAGING: STATE OF THE ART

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ABSTRACT

Today, various image segmentation techniques are used in medical imaging with intent to make the image simple and meaningful. Such as medical imaging has become an attraction for the researchers in the field of image processing and pattern recognition. This growing research interest and need of image segmentation in medical imaging, and it is mandatory to divide the research results and provide readers with an overview of the existing segmentation techniques in medical imaging. In this article,

We applied different image segmentation techniques used in reviewing magnetic resonance brain images.

INTRODUCTION

Image processing consists of various application fields like compression, enhancement, detection, feature extraction, restoration, scaling, segmentation, etc. Image segmentation is used in various applications like Medical imaging, locating objects in satellite images, face recognition, traffic control systems, fingerprint recognition and machine vision etc. Medical imaging includes locating tumors and other pathologies, measuring tissue volumes, etc.

Segmentation plays an important role in biomedical image processing. Segmentation is the starting point for other processes such as registration, shape analysis, visualization and quantitative analysis. Segmentation of an image is the division or separation of the image into disjoint regions of similar attribute. In clinical practice, Magnetic Resonance Imaging is used to distinguish pathologic tissue from normal tissue, especially for brain related disorders. Three main regions of the brain, White Matter (WM), Gray Matter (GM) and Cerebro-spinal Fluid (CSF) are the important subject of study in brain imaging. Manual segmentation by an expert is time consuming and it is very difficult to do accurate segmentation. Hence automatic segmentation algorithms are preferred in the diagnostic process.

The selection of papers includes sources from image processing journals, conferences, books, dissertations and thesis. The conceptual details of the algorithms are explained and mathematical details are avoided for simplicity. Both broad and detailed categorizations of reviewing segmentation techniques are provided. The state of art research is provided with emphasis on developmental algorithms and image properties used by them. The methods defined are not always mutually independent. Hence, their interrelationships are also stated. Finally, conclusions are drawn summarizing commonly used techniques and their complexities in the application.

Image Segmentation Methods

Image segmentation algorithms are classified into two types, supervised and unsupervised. Unsupervised algorithms are fully automatic and partition the regions in feature space with high density. The different unsupervised algorithms are Feature-Space Based Techniques, Clustering (K-means algorithm, C-means algorithm, E-means algorithm), Histogram thresholding, Image-Domain or Region Based Techniques (Split-and-merge techniques, Region growing techniques, Neural-network based techniques, Edge Detection Technique), Fuzzy Techniques, etc. It is essential to know which method is to be applicable for the segmentation of medical images. In this paper, we present a comparative study of unsupervised

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algorithms in terms of robustness, accuracy [3, 5, 8].

Clustering Methods

Clustering is a method of grouping a set of patterns into a number of clusters such that similar patterns are assigned to one cluster. Each pattern can be represented by a vector having many attributes. Clustering technique is based on the computation of a measure of similarity or distance between the respective patterns. In this paper, we are going to discuss about K-means algorithm, Fuzzy C-means algorithm.

K-Means Algorithm

K-means algorithm is under the category of Squared Error-Based Clustering (Vector Quantization) and it is also under the category of crisp clustering or hard clustering. K-means algorithm is very simple and can be easily implemented in solving many practical problems. Steps of the K-means algorithm are given below.

1. Choose k cluster centers to coincide with k randomly chosen patterns inside the hyper volume containing the pattern set.(C)
2. Assign each pattern to the closest cluster center. (C_i, i = 1,2,. . . . C)
3. Recompute the cluster centers using the current cluster memberships.(U)
4. If a convergence criterion is not met, go to step 2 with new cluster centers by the following equation, i.e., minimal decrease in square error.

$$\begin{cases} 1 \; If \left\| x_j - C_i \right\|^2 \le \left\| x_j - C_K \right\|^2 \; for \quad each\, k \ne i \\ 0 \qquad\qquad\qquad otherwise \end{cases}$$

$$C_i = \frac{1}{|G_i|} \sum_{k, x_k \in G_i} x_k$$

Where, $|G_i|$ is the size of G_i

$$\left| G_i = \sum_{j=1}^{n} U_{ij} \right|$$

The performance of the K-means algorithm depends on the initial positions of the cluster centers. This is an inherently iterative algorithm. And also there is no guarantee about the convergence towards an optimum solution. The convergence centroids vary with different initial points. It is also sensitive to noise and outliers. It is only based on numerical variables [2, 5, 7, 10].

Fuzzy C-Means Algorithm

Fuzzy C-Means clustering (FCM), also called as ISODATA, is a data clustering method in which each data point belongs to a cluster to a degree specified by a membership value. FCM is used in many applications like pattern recognition, classification, image segmentation, etc. FCM divides a collection of n vectors c fuzzy groups, and finds a cluster center in each group such that a cost function of dissimilarity measure is minimized. FCM uses fuzzy partitioning such that a given data point can belong to several groups with the degree of belongings specified by membership values between 0 and 1. This algorithm is simply an iterated procedure. The algorithm is given below.

Initialize the membership matrix **U** with random values between 0 and 1.

Calculates c fuzzy cluster center c_i,
$i = 1,\ldots c$., using the following equation,

$$C_i = \frac{\sum_{J=1}^{n} u_{ij}^m x_j}{\sum_{J=1}^{n} u_{ij}^m}$$

Compute the cost by the following equation. Stop if either it is below a certain threshold value or its improvement over the previous iteration.

$$J(U, c_1 \ldots . c_c) = \sum_{i=1}^{c} J_i = \sum_{i=1}^{n} \sum_{j}^{n} u_{ij}^m d_{ij}^2$$

Compute a new **U** by the equation. Go to step 2.

$$u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{d_{ij}}{d_{kj}} \right)^{2/(m-1)}}$$

Like K-means clustering, there is no guarantee ensures that FCM converges to an optimum solution. The performance is based on the initial cluster centers. FCM also suffers from the presence of outliers and noise and it is difficult to identify the initial partitions [2, 7, 10].

Edge Detection Methods

Edge detection is a method which is extensively used for gray level image segmentation. It is a process of finding the discontinuities of an image. Edge detection is under the category of Boundary based technique. Boundary based methods find connected regions based on finding pixel differences of the pixels within them. The objective is to find a closed boundary such that an outsider can be determined easily. The edge detection process is classified into two broad groups; (i) Derivative approach, (ii) Pattern fitting approach. Both approaches have advantages as well as disadvantages. And also a second method gives better result as compared with the first method. The pattern fitting approach uses a series of edge approximation functions over a small neighborhood and it will be analyzed. In derivative approach, edge pixels are found by taking derivatives. Here edge masks are used to find two dimensional derivatives. In this chapter, we will discuss about the Roberts, Prewitt, Sobel, Canny, Gaussian, LoG operators in detail. They are under the category of Derivative approach [4, 5, 9].

Roberts Operator

This method is based on differences between adjacent pixels. Here, +1 and -1 are explicitly used to find the edges. This difference is called as forward differences. The first order partial derivative is implemented by the cross - gradient operator.

$$d_1 = g_0 - g_2$$
$$d_2 = g_1 - g_3$$

The above two partial derivatives are implemented by approximating them into 2x2 windows. The Roberts masks are,

0	1
-1	0

-1	0
0	1

Roberts Windows

Prewitt Operator

In Prewitt operator, similar weights are assigned to all the neighbors of the chosen pixel. The first order derivative is given by,

$$d_2 = 1/3[(g_8 + g_7 + g_6) - (g_2 + g_3 + g_4)]$$

$d_1 = 1/3[(g_4 + g_5 + g_6) - (g_2 + g_1 + g_8)]$ Its masks are given below

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

Prewitt windows

Sobel Operator

In Sobel operator, higher weights are assigned to the closest neighbors of the chosen pixel. The first order derivative is given by,

$$d_1 = 1/4[(g_4 + 2g_5 + g_6) - (g_2 + 2g_1 + g_8)]$$

$d_2 = 1/4(g_8 + 2g_7 + g_6) - (g_2 + 2g_3 + g_4)]$ Sobel Masks are given below,

-1	**0**	**1**	**-1**	**-1**	**-1**
-1	0	1	0	0	0
-1	0	1	1	1	1

Sobel windows

Canny Operator

It is the most popular operator among all the edge detection algorithms. Canny algorithm mainly concentrates on three things, Maximizing Signal to Noise Ratio (SNR), localization of edges by minimizing the variance of the zero crossing position, identification of single edge rather than multiple response. The canny algorithm is given below,

1. Apply derivative of Gaussian
2. Non-maximum suppression
3. Linking and thresholding

Log Operator

Laplacian of Gaussian operator is otherwise called as Marr-Hildreth operator. It is based on the second derivative method for the detection of the zero crossing method. Here, in addition to the Laplacian operator, Gaussian smoothing is applied. Laplacian mask is given below,

0	**1**	**0**
1	-4	1
0	1	0

Laplacian Window

Log algorithm is given below.

1. Smooth the image by convolving it with a digital mask.
2. Apply the Laplacian mask.

Find the zero crossings by the Laplacian second derivative operator

Watersheds are one of the typical regions in the field of typography. A drop of the water falling it flows down until it reaches the bottom of the region. Monochrome image is considered to be a height surface in which high-altitude pixels correspond to ridges and low-altitude pixels correspond to valleys. This suggestion says if we have a minimum point, by falling water, region and the frontier can be achieved. Watershed uses an image gradient to the initial point and region can get by region growing. The accretion of water in the neighborhood of local minima is called a catchment basin. Watershed refers to a ridge that divides areas shattered by different river systems. A catchment basin is the environmental area draining into a river or reservoir. If we consider that the bright areas are high and dark areas are low, then it might look like the plane. With planes, it is natural to think in terms of catchment basins and watershed lines. Two approaches are there to find watershed of an image,

1. Rainfall approach
2. Flooding approach

In rainfall approach, local minima are found all through the image, and each local minima is assigned an exclusive tag. An intangible water drop is placed at each untagged pixel. The drop moves to a low amplitude neighbor until it reaches a tagged pixel and it assumes tag value. In flooding approach, intangible pixel holes are pierced at each local minima. The water enters the holes and tracings to fill each catchment basin. If the basin is about to overflow, a dam is built on its neighboring ridge line to the height of high altitude ridge points. These dam borders correspond to the watershed lines. The following steps are used in Watershed Algorithm:

1. Read an Image and covert it into grayscale
2. Use gradient magnitude as the segmentation function
3. Mark the foreground objects
4. Calculate the Background markers
5. Calculate the watershed transform of the segmentation function
6. Visualize the result

The main drawback of this algorithm is over segmentation, because all of edge and noise would appear in the image gradient. If the signal to noise ratio is not high enough at the contour of interest, the transform won't detect it correctly. It also failed to detect thin structures [5, 6, 9].

Regions Based Methods

Regions are group of connected pixel elements with similar properties. In this method each pixel element is assigned to a particular region. Region growing is a process that groups pixels or sub regions into larger regions. In which nearest pixel elements are examined and added to a region if no edges are detected. It starts with a set of ''seed'' points and from these produces regions by adding to each seed point those nearest pixels that have similar properties. Region splitting is another region based approach. It starts with an entire image and divides it into homogeneous regions. Splitting method alone, not sufficient for segmentation process. Therefore merging will be applied after splitting, which is called as split and merge method. Steps of Split and merge algorithm is given below.

1. If the entire region is consistent, leave it unchanged.
2. If the region is not sufficiently consistent, split it into four quadrants.
3. Merge any adjacent regions that are similar enough.
4. Repeat steps 2 and 3 repeatedly until no more splitting or merging arises [8, 9].

Thresholding Methods

Thresholding methods give segments having picture elements with similar gray levels. This technique requires that an object has homogenous gray level and a background with a different gray level. That kind of image can be segmented by two regions using thresholding. Thresholding techniques are classified into Global or fixed thresholding, adaptive thresholding and histogram based threading. In this section OTSU method which is under the category of histogram based threading is disused. This method is simple and is an outstanding method for selecting the threshold. For a grayscale image, the total number of pixels is defined as N, n_i is the number of pixels which's intensity is i. By regularizing the histogram, the following equations could be attained.

$$\sum_{i=0}^{255} n_i = N \tag{13}$$

$$p_i = \frac{n_i}{N} \tag{14}$$

Pi is the probability of the pixels which's intensity is *me*. The threshold of the image segmentation is defined as *m*, then the probability θ_o and mean value μ_o of the background can be attained through the following equations:

$$\theta_0 = \sum_{t=0}^{m} p_i$$

$$\mu_0 = \frac{\sum_{i=0}^{m} i p_i}{\theta_0}$$

Probability and typical value of the targ*et al*so can be obtained:

$$\theta_1 = \sum_{t=m+1}^{255} i p_i$$

$$\mu_1 = \frac{\sum_{t=m+1}^{255} i p_i}{\theta_1}$$

By computing all the above values, the following equation is attained,

$$\sigma_B^2 = \theta_0 \theta_1 (\mu_0 - \mu_1)^2$$

The threshold which makes the variance yields maximal is the optimal threshold [5, 6].

Other Methods

In addition to the above mentioned algorithms, Texture based methods, Wavelet based methods, Level set methods, Wavelength, based method, Genetic algorithm based method, neural network based methods, etc. also used for medical image segmentation. Each method has its own advantages as well as limitations [3].

CONCLUSIONS

The different segmentation methods have been demonstrated. From the results, the clustering algorithms are guaranteed to converge, but it may not return optimal solution. In K-Means algorithm the quality of the solution depends on the initial set of clusters and the value of K. An inapt choice of K yields very poor result. But for White matter segmentation, it gave better results. In a noisy environment FCM gave better results than KM. From the results of edge detection techniques, the canny operator performed well than all other operators. But in a noisy environment, it failed to converge. In watershed algorithms, the length of gradients is taken as elevation information. The flooding process is performed over gradient image, this leads to an over segmentation of an image, especially for noisy environment. Split and Merge technique operated well over all images. This method performs well even in noisy environment. Mainly it is suitable for detection of tumors, etc. Thresholding technique is not suited for WM, GM and CSF Segmentation. But it is giving satisfactory results for tumor affected images.

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