ISSN: 2321-7782 (Online)
Volume 1, Issue 7, December 2013
International Journal of Advance Research in Computer Science and Management Studies
Research Paper
Available online at: www.ijarcsms.com

A Review on Current Methods in MR Image Segmentation

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Abstract: Automatedbrain tumor detection from MRI images is one of the most challenging tasks in today's modern Medical imaging research. Magnetic Resonance Images are used to produce images of soft tissue of human body. It is used to analyze the human organs without the need for surgery. The first important step in image analysis is image segmentation. Here we describe different methods of MR Segmentation which are categories into three classes, traditional image processing method and statistical-based segmentation method and partition technique with bias field estimation.

Keywords: MRI; image ayalysis; image segmentation; Bias field.

I. INTRODUCTION

Image segmentation is often required as a preliminary and indispensable stage in the computer aided medical image process, particularly during the clinical analysis of magnetic resonance (MR) brain images. They can noninvasively provide high resolution two dimensional or three-dimensional (3-D) images for the structures. Researchers always study and analyze the structures from magnetic resonance imaging (MRI) in order to facilitate and improve diagnosis and patient treatment, treat medical conditions and improve clinical studies. It is necessary to segment various parts of the structures in a magnetic resonance (MR) image sequence first and this could involve organ detection or tissue characterization. There are many applications such as in neuroscience, which studies the development of brain, the mapping of functional activation onto brain anatomy, and analyze the neuro anatomical variability among normal brains [25]. The segmentation of brain tumor from magnetic resonance (MR) images is a vital process for treatment planning, monitoring of therapy, examining efficacy of radiation and drug treatments, and studying the differences of healthy subjects and subjects with tumor.

Traditional image processing techniques are playing important role in image segmentation and have been widely used for MRI analysis in recent years, for example: thresholding method, region based, k-means clustering, some fuzziness- based methods [1] [3] [4] and the algorithms based on statistical classification are another important branch of segmentation for MRI. 1988, M. Kass et al. utilized parametric active contour methods for medical image segmentation. Many active-models-based methods, containing contour-based or shape-based, have been extensively studied and widely applied in medical image segmentation [23]. While advances in MR imaging technology have allowed for greater precision in the assessment of morphometric properties of the structures as automated segmentation and delineation of detailed the structures remains a difficult task[25].Some segmentation algorithms based on statistical classification are methods assuming that mixed voxel (pixel) intensities reflect distinct tissue groups, and individual voxels are assigned to different groups through modelling the intensity histogram as a mixture of probability distributions. The result of these algorithms had shown their success in MRI segmentation.

Unfortunately, the above numerical techniques are going to be problematic due to the image noise and bias fields. (Bias fields are also called intensity inhomogeneity),

Bias field [5] is low frequency smooth undesirable signal that corrupts MRI images, blurs it and reduces the high frequency contents of images and changes the intensity value of image pixel which degrades performance of image processing algorithms. A pre-processing step is needed to correct effect of bias field [7] [1] before performing image processing through segmentation and classification algorithms. It can be modeled as a multiplicative component of an image as shown:

$$I = bJ + n$$

Where *I* is the observed image, *J* is the true image to be restored, *b* is an unknown bias field, and *n* is the additive zero-mean Gaussian noise [1]. For this reason, a great deal of intensity inhomogeneity correction/removal methods has been introduced into the studies on the segmentation in MRI in last decade[2][1][5][6].The present review is primarily focused on the segmentation methods for MRI and perform a qualitative discussion in term of three categories[25]. The rest of the paper is organized as follows. Section II presents the most common and current models of MRI. The last section is concluding remarks.

II. Literature Review

Basic Segmentation Strategies Generally, automated segmentation and delineation of detailed structures remains a difficult task in MRI segmentation. There has been a wide range of segmentation methods proposed in the latest literatures. According to the research sort the segmentation methods into three classes.

A. *Traditional image processing method.*

B. *Segmentation techniques, based on statistical theory*.

C. *The partition method considering bias field effects.*

A. *Traditional Image Processing Methods Review*

1. *Thresolding:* Its presents an automatic image segmentation method using thresholding technique [3] [13]. This is based on the assumption that adjacent pixels whose value (grey level, color value, texture, etc) lies within a certain range belong to the same class and thus, good segmentation of images that include only two opposite components can be obtained. Threshold based image segmentation are Global Thresholding, Local Thresholding, and Adaptive Thresholding**.** The key parameter in image segmentation using thresholding technique is the choice of selecting threshold value T. 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.

2. *Region Growing: For image segmentation region growing method is a well developed technique. Based on some predefined criteria this method extracts image region. This is based on intensity information or edges in the image. The region growing starts with a seed, which is selected in the centre region of interest. During the region growing phase, pixels in the neighbor of seed are added to region based on homogeneity criteria thereby resulting in a connected region. Region growing can also be sensitive to noise, causing extracted regions to have holes or even become disconnected. These problems can be removed using a homotopic region-growing algorithm [22].*

3. *Kmeans:* The K-means clustering algorithm clusters data by iteratively computing a mean intensity for each class and segmenting the image by classifying each pixel in the class with the closest mean. This is also called as hard segmentation. A hard segmentation forces a decision of whether a pixel is inside or outside the object.

4. *Fuzzy C –Mean:* Segmentations that allow regions or classes to overlap are called soft segmentations. Soft segmentations are important in medical imaging because of partial volume effects, where multiple tissues contribute to a single pixel or voxel resulting in a blurring of intensity across boundaries. The main objective is to develop an FCM algorithm [1][7][12] for distributing the clusters in such a way that obtained group of clusters minimizes the dissimilar elements in each cluster .It classifies pixels of an image data set into clusters based on Euclidean distance of a pixel from the center of the least distant cluster. For a given image data set X = (x1, x2, x3, .., xn) with n pixels, to be partitioned into c clusters based on pixels characteristics. The objective cost function is given by

$$J=\sum_{j=1}^{n}\sum_{i=1}^{c} U_{ij}^{m}\,|x_j-c_i|^2 \qquad (1)$$

Where in equation (1), U_{ij} represents the membership of an image pixel xj in the ith cluster, c_i is the ith cluster center. ||.|| is a norm metric, and m is a constant that usually equals to 2 and controls the fuzziness of the partitioned clusters

5. *Classifier methods:* supervised methods [26] are pattern recognition techniques that partition a feature space derived from the image by using data with known labels. A simple classifier is the nearest-neighbor classifier, in which each pixel is classified in the same class as the training datum with the closest intensity. The k-nearest-neighbor classifier is a generalization of this approach.

B. Segmentation Method Based On Statistical Theory

The base theory of these methods is that mixed pixel intensities reflect distinct tissue groups, and individual pixels are assigned to different groups through modeling the intensity histogram as a mixture of probability distributions. In recent years, the active-models-based segmentation methods have been widely used in MRI segmentation and have achieved considerable success. 1988, M. Kass et al. utilized parametric active contour methods for medical image segmentation, and then many contour-based and shape-based methods studied more and greatly employed in medical image segmentation..As compared with traditional methods, model-based segmentation methods seem s appropriate for 3D MR image segmentation since such a strategy employs a predefined shape model to seek interested features within the image data [25].

For medical image segmentation, level set method is a powerful method. It can handle any of the cavities, concavities, convolution, splitting, or merging. This method needs to specify initial curves. If these curves are placed near symmetrically with respect to the object boundary, can only give good outcomes.

1. *Guassian Mixture Model:* L.Gupta and T.Sortrakul and H. Permuter, J. Francos, and I. Jermyn proposed Brain MR images can be segmented by using the guassian mixture model, where the voxels intensity in each target region are modelled by a Guassian distribution and the GMM parameters are usually estimated by maximizing the likelihood of the observed image via the EM algorithm [2]. On the other hand, statistical methods often relied on Gaussian assumptions in most cases, using which for modelling the underlying distributions. Because of these are histogram based and, therefore, need an accurate parametrical estimation or nonparametric modeling of involved probability density functions. Bayesian inference has been commonly applied to classify the tissue with MRI. Bayesian estimation theory allows the probability map for each pixel via the conditional PDF (probability density function) learned from a limited training data set. Considering the spatial relation and a priori knowledge of the image.Many modified version of the mixture model algorithms had been proposed [25] [1]. There are also many literatures using statistical mixture modelling with expectation-maximization algorithm includes.

2. *Finite Mixture Model:* FMMs are necessary tool for unsupervised classification, and minimizing the difference between observed data and the finite mixture model (FMM) with respect to the unknown parameter values is essential to a statistically based method for unsupervised classification. This unsupervised method usually involves solving a complex FMM parameter estimation optimization problem and it is difficult to solve by standard local optimization

methods, such as the expectation-maximization (EM) algorithm, if a principled initialization is not available. They proposed a global optimization algorithm for the FMM parameter estimation problem, which is based on real coded genetic algorithms.

3. *Markov random field Method:* An additional conventional method to improve segmentation smoothness and immunity to noise is to model neighbouring vowels interactions using a Markov random field (MRF) statistical spatial model [26][17][24]Smoother structures are obtained in the presence of moderate noise as long as the MRF parameters controlling the strength of the spatial interactions are properly selected.

4. *Artificial Neural Network:* Pham, Chenyang Xu, L. Prince stated that ANNs show a paradigm for machine learning and can be used in variety of ways for image segmentation [27].The most widely applied use in medical imaging is as a classifier where the weights are determined using training data, and the ANN is then used to segment new data. They can also be used in an unsupervised fashion as a clustering method as well as for deformable models.

5. *Deformable Model:* Deformable models are physically motivated, model-based techniques for delineating region boundaries using closed parametric curves or surfaces that deform under the influence of internal and external forces. To delineate an object boundary in an image [8] [22], a closed curve or surface must first be placed near the desired boundary and then allowed to undergo an iterative relaxation process. Internal forces are computed from within the curve or surface to keep it smooth throughout the deformation. External forces are usually derived from the image to drive the curve or surface towards the desired feature of interest.

The statistical atlas provides the prior probability for each pixel to originate from a particular tissue class. Algorithms that are based on while, all statistical image segmentation methods have their own advantages and disadvantages. For MR image, all these statistical segment methods may be problematic due to existing within/between slice bias fields.

C. The Partition Methods Review Considering Bias Field Effects

Two main common methods have been applied to minimize the intensity inhomogeneity in MR images,

- Prospective approach
- Retrospective approach

The prospective approach which based on phantoms, multicoils, and special sequences, and the retrospective approach as filtering, surface fitting, segmentation, and histogram based. The prospective approach aims at calibration and improvement of the image acquisition process, and the latter relies exclusively on the information of the acquired image and some a priori knowledge [25]. Retrospective approaches are given below.

1. *Filtering Methods:* Filtering methods assume that intensity inhomogeneity is low-frequency artifact that can be separated from the high-frequency signal of the imaged anatomical structures by low-pass filtering [6], but sometimes this assumption is not valid because For most of the anatomical structures imaged by MR this assumption does not come true which results in overlap of anatomy and inhomogeneity frequency spectra.

2. *Surface Fitting Methods:* These methods fit a parametric surface to a set of image features that contain information on intensity inhomogeneity. The resulting surface, which is usually polynomial or spline based, represents the multiplicative inhomogeneity field that is used to correct the input image [5][6]. A common practice for images is to divide the corrupted image by a background image represents an estimate of the variation in the illumination across the image. The same can be done for MRI images corrupted by bias field signal. The background image is normally estimated from the corrupted image by low pass filtering operation. Since it is very difficult to design an optimal low-pass filter that has sharp cut-off frequency and at the same time has no ripples in the pass-band and stop-band regions,

the background image estimated this way has some noise introduced such as ripples in the image and ringing around the edges[5].To improve the quality of the background image, a two-dimensional surface equation is fitted to data points selected from the background image and then the fitted equation is used to generate the bias field signal. The bias field signal obtained this way is much smoother than the background image obtained using a low-pass filtering operation alone.

3. *Segmentation Based Methods:* In segmentation based intensity in homogeneity correction methods these two procedures are merged so that they benefit from each other, simultaneously giving better segmentation and inhomogeneity correction [5].for example Finite mixture and more frequently Fuzzy C mean[4] ,finite Gaussian mixture models [1] are used and modified to incorporate intensity inhomogeneity.

4. *Histogram Based Methods:* These methods apply directly on image intensity histograms and need little or no initialization and/or a priori knowledge on the intensity probability distribution of the imaged structures [6] and make these methods fully automatic and highly general so that they can usually be applied to various images with or without pathology. Although a number of segmentation based methods also operate on image intensity histograms, the distinction between the segmentation based and histogram based methods is that the latter provide no segmentation results.

5. *High-Frequency Maximization:* A well-known intensity inhomogeneity correction method. The method [11] is fully automatic; it requires no a priori knowledge and can be applied to almost any MR image.

6. *Information Minimization:* These methods are based on the assumption that intensity inhomogeneity corruption introduces additional information to the inhomogeneity-free image. Intensity inhomogeneity removal is, therefore, based on constrained minimization of image information, which is estimated by image entropy. Image entropy is a quantity which is used to describe the `business' of an image, i.e. the amount of information Image entropy [12] [6] can be computed from the original intensity distributions or from the log-transformed distributions. Numerical computation of entropy becomes far more difficult due to the nonlinear log-transformation of image intensities.

III. CONCLUSION

This paper describes the study of various methods for medical image segmentation. Several segmentation methods for MR image have been reviewed in this paper. We examine the different methods considering three categories, i.e. traditional image processing method, statistical-based segmentation method and partition technique with bias field estimation. As we know ongoing research in biological world, increasing new knowledge about different disorders is rapidly coming up before us. Future work in the segmentation of medical images is to work towards improving the accuracy, precision, and computational speed of segmentation methods, as well as reducing the amount of manual interaction to improve of clinical studies as computerized segmentation methods have shown their utility in medical research application.

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