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A Study of Segmentation Methods for Detection of Diseases from Brain MRI

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Abstract: ***This paper introduces study of segmentation methods which are used to locate volumetric objects such as brain tumor in Magnetic Resonance Imaging (MRI) images. The methods studied are Thresholding, Region – growing, Clustering techniques, K-means Clustering, Fuzzy C– means Clustering, an Automated Medical Image Segmentation Using a New Deformable Surface Model, Brain Tumor Detection Using Segmentation Based on Neuro Fuzzy Technique, An Image Segmentation Method Based on a Discrete Version of the Topological Derivative, Atlas-guided approaches, Morphological methods, Classifiers.***

Keywords: MRI of Brain; Segmentation; Automated segmentation Methods.

1. Introduction

Image processing plays vital role in today's world. Now a day the applications of image processing can be found in areas like electronics, remote sensing, bio-medical and so on. If we focus bio-medical applications, image processing is widely used for diagnosis of different tissues purpose[1]. Use of accurate input image is very important and use of appropriate image segmentation method too. With the increased size and number of medical images, the use of computers in facilitating their processing and analysis has become necessary. Computer algorithms for the delineation of anatomical structures and other regions of interest are a key component in assisting and automating specific radiological tasks. These algorithms, called *image segmentation* algorithms, play an important role in numerous biomedical imaging applications such as the quantification of tissue volumes, diagnosis,localization of pathology, study of anatomical structure, treatment planning, partial volume correction of functional imaging data, and computer integrated surgery. Each method adds an additional level of algorithmic complexity. Some methods are the simplest forms of image analysis, some are characterized by the application of uncertainty models and optimization methods.

Image segmentation is the fundamental step in image analysis, understanding, and interpretation and recognition tasks. Image Segmentation partitions an image into set of regions. The segmentation decomposes an image into regions for further analysis and performs a change of representation of an image for faster analysis. 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.

Performance of segmentation methods vary widely depending on the specific application, imaging modality, and other factors. For example, the segmentation of brain tissue has different requirements from the segmentation of the liver. General imaging artifacts such as noise, partial volume effects, and motion may also have significant consequences on the performance of segmentation algorithms. There are some methods that are more general and can be applied to a variety of data. Methods that are specialized to particular applications can often achieve better performance by taking into account prior knowledge. So, selection of an appropriate approach to a segmentation problem can be a difficult task.

2. 2. MRI (Magnetic Resonance Imaging)

MRI is a diagnostic technique that provides high-quality cross-sectional or three dimensional images of organs. It also provides structures within the body without using X rays or other radiation. During the imaging, the patient lies inside a massive hollow cylindrical magnet. The nuclei of the body's hydrogen atoms normally point in random directions. In a magnetic field these atoms line up parallel to each other. If the hydrogen nuclei are knocked out of alignment by a strong pulse of radio waves, they produce a detectable radio signal as they fall back into alignment.

Magnetic field gradient is required to translate the signals into separate spatial locations. Magnetic coils in the machine detect these signals and a computer changes them into a cross-sectional or three dimensional image based on the strength of signal produced by different types of tissue. Tissues that contain a lot of hydrogen (such as fat) produce a bright image; those that contain little or no hydrogen (such as bone) appear dark. MRI provides clear images of tumors of the brain and spinal cord. Also shown clearly by MRI is the internal structure of the eye and ear. MRI can produces detailed images of the heart and major blood vessels, provides images of blood flow, and is useful for examining joints and soft tissues.

3. Segmentation Methods

3.1 Thresholding

Thresholding creates a binary partitioning of the image intensities and approaches segment scalar images with it. A thresholding procedure determines an intensity value, called the threshold, which separates the desired classes[3]. Then the segmentation is achieved by grouping all pixels with intensity greater than the threshold into one class, and all other pixels into another class.

Thresholding is a simple method for obtaining a segmentation in images where different structures have contrasting intensities or other quantifiable features.The partition is generated interactively. As the thresholding operation is implementable in real-time, interactive methods can be based on an operator's visual assessment of the resulting segmentation. Generally, thresholding is used as an initial step in a sequence of image processing operations.

Its main drawbacks are that in its simplest form only two classes are generated and it can't be applied to multi-channel images. In addition, thresholding does not take into account the spatial characteristics of an image. This results it to be sensitive to noise and intensity inhomogeneities, which can occur in magnetic resonance images. Both these limitations essentially corrupt the histogram of the image, making separation more difficult. Because of these reasons, variations on classical thresholding have been proposed for medical image segmentation that incorporate information based on local intensities.

3.2 Region Growing

Region growing is a technique that extracts a region of the image that is connected based on some predefined criteria. This criteria can be based on intensity information and edges in the image. Region growing operates with a seed point that is manually selected by an operator, and extracts all pixels connected to the initial seed with the same intensity value. Like thresholding, region growing is not generally used alone but within a set of image processing operations, particularly for the delineation of small, simple structures such as tumors and lesions. Its main disadvantage is that it requires manual interaction to obtain the seed point. So, for each region that needs to be extracted, a seed must be planted. Split and merge algorithms are related with region growing but do not require a seed point. Region growing can also be sensitive to noise, resulting extracted regions to have holes or even become disconnected.

3.3 Clustering

Clustering algorithms do not need training data for performing operations. This is the reason why they are called as unsupervised methods. Instead of training data, clustering methods iterate between segmenting the image and characterizing the properties of the each class. Clustering methods train themselves using the available data. Most commonly used clustering algorithms are the K-means or ISODATA algorithm, the fuzzy K-means algorithm, and the expectation-maximization (EM) algorithm.

The K -means performs by 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. The EM algorithm applies the same clustering principles with the underlying assumption that the data follows a Gaussian mixture model. It iterates between computing the posterior probabilities and computing maximum likelihood estimates of the means, covariance, and mixing coefficients of the mixture model.

Clustering algorithms require an initial segmentation or initial parameters. The EM algorithm has shown greater sensitivity to initialization than the K -means or fuzzy –C means algorithms. Clustering algorithms do not directly incorporate spatial modeling and so can be sensitive to noise. This lack of spatial modeling, can provide significant advantages for fast computation.

3.3.1 K-means Clustering

K mean is the unsupervised algorithms that solution to the clustering clustering problem. K mean clustering algorithm is simple and easy way to segment the image using basic knowledge of cluster value. In K mean initially K centroids are defined randomly. The selection of this K centroid is placed in cunning way because different location makes different clustering. Its better to place centroid valueas much as far away from each other. Secondly distance between each pixel to selected cluster centroid is calculated. Each pixel compares with K clusters centroids and finding distance using distance formula. If the pixel has shortest distance among all, then it is moved to particular cluster. This process is repeated until all pixels are compared to cluster. The process continues until some convergence criteria are met.

3.3.2 Fuzzy C-means Clustering

Fuzzy C-mean clustering is also called as soft clustering method. Fuzzy C-means is an overlapping clustering technique. One pixel value depends on two or more clusters centers. One of the most widely used clustering algorithms is the Fuzzy C-means (FCM) algorithm.

Fuzzy C-means is a popular method for medical image Segmentation. Its drawback is it only considers image intensity thereby producing unsatisfactory results in noisy images. A bunch of algorithms are proposed to make FCM robust against noise and in homogeneity.

3.4 Mean Shift

This is a non-parametric clustering technique. It is used for cluster analysis in computer vision and image processing. Mean shift algorithm for clusters uses an n- dimensional data set first defining spherical window of radius r in data points and calculate the mean of points which located within the window [1]. Each point's algorithm computes its peak. Further, the spherical window is moved to the next means and repeated until convergence. At the each iteration, the spherical window moves dense portion of data set until maximum peak is reached.

3.5 Automated Medical Image Segmentation Using a New Deformable Surface Model

In this method, a new deformable surface model is been proposed for automated segmentation [13]. It can segment objects from medical images like MRI. Considering the algorithm development, emphasis is put on considering the whole MRI data set as a 3D entity. So, all the processes of segmentation are done in 3D space[14]. Two main steps are developed to segment 3D object. Firstly, it removes noisy voxels with 3D nonlinear anisotropic filtering. The filtering well preserves the intensity distribution continuity in all three directions and also gets rid of noisy voxels. Secondly, it uses a deformable surface model to segment an object from the MRI. A dynamic gradient vector flow is used in forming the surface model. The segmentation method with a new deformable surface can segment objects from medical images such as MRI. As the emphasis was put on considering the whole MRI data set as a 3D entity, all the processes of segmentation are done in 3D space.

Real MRI data are used to evaluate the segmentation performance. Especially, brain tumor segmentation from MRI images is tested. The experiments have demonstrated the potential of proposed approach. This proposed segmentation method is also applicable to other applications such as blood vessel segmentation. It seems that much computation is needed because the data is huge with three dimensions.

3.6 Brain Tumor Detection Using Segmentation Based on Neuro Fuzzy Technique

This method proposes a hybrid technique combining the advantages of HSOM and FCM and implements for the MRI image segmentation process to detect various tissues like white matter, gray matter and tumor [17]. FCM (fuzzy C means) algorithm is also called as a soft clustering algorithm. FCM finds a soft partition of a given data set by which an element in the data set may partially belong to multiple clusters. HSOM combines the idea of regarding the image segmentation process as one of data abstraction where the segmented image is the final domain independent abstraction of the input image. The hierarchical segmentation process for a hierarchical structure is called abstraction tree.

The HSOM is organized in a pyramidal mannered structure consisting of multiple layers where each layer resembles the single layer SOM. Learning process has sequential corrections of the vectors representing neurons. With every step of the learning process a random vector is chosen from the initial data set and then the best-matching neuron coefficient vector is identified. The most similar vector to the input vector is selected as a winner.

In neuro fuzzy based segmentation process, the performance of the MRI image in terms of weight vector is studied, execution time and tumor pixels are detected and the results with the existing ones are compared. A layer by layer abstraction level with fuzzy clustering technique is implemented to detect tissues like white matter, gray matter, and tumor. A higher value of detected tumor pixels is achieved.

3.7 An Image Segmentation Method Based on a Discrete Version of the Topological Derivative:

In this method, the topological derivative for an appropriate functional associated to the image indicating the *cost* endowed to specific image segmentation is computed. The topological derivative gives an easy to quantify the sensitivity of the problem when the domain under consideration is perturbed by the introduction of a hole[18].

This algorithm is straight-forward to be implemented. It produces good quality segmentations with very little additional information and almost no user interaction. Also, image segmentation method based on a discrete version of the topological derivative needs no additional information (like seed points), besides the set of classes *C*, to start the segmentation algorithm.

3.8 Atlas-Guided Approaches

Atlas-guided approaches are a powerful tool for medical image segmentation if a standard atlas or template is available. The atlas is generated by compiling information on the anatomy and that is required for segmenting medical images obtained from MRIs. This atlas is then used as a reference frame for new image segmentation. Atlas-guided approaches are similar to classifiers except they are implemented in the spatial domain of the image rather than in a feature space.

The standard atlas-guided approach treats segmentation as a registration problem. It finds a one-to-one transformation that maps a pre-segmented atlas image to the target image that requires segmenting. This process is generally called as atlas warping. The warping can be performed using linear transformations. But as the anatomical variability exists, a sequential application of linear and non-linear transformations is used.

Atlas-guided approaches are generally applied in MR brain imaging. Atlas-guided approaches are advantageous as the labels are transferred as well as the segmentation. They also provide a standard system for studying morphometric properties. Even with non-linear registration methods accurate segmentations of complex structures is difficult due to anatomical variability.

3.9 Morphological Methods

The watershed algorithm uses concepts from mathematical morphology to partition images into homogeneous regions. This method may suffer from over segmentation. Over segmentation occurs when the image is segmented into an unnecessarily large number of regions. As a result, watershed algorithms in medical imaging are usually followed by a post processing step to merge separate regions that belong to the same structure.

3.10 Classifiers

Classifiers need training data. As these require training data classifiers are known as *supervised* methods. Classifiers are manually segmented and then used as references for automatically segmenting new data. A simple classifier is the nearest-neighbor classifier, where each pixel in 2D or voxel in 3D is classified in the same class as the training data with the closest intensity. The kNN classifier is a generalization of this approach. In this classifier, the pixel is classified according to the majority vote of the closest training data. The kNN classifier is considered a nonparametric classifier as it makes no underlying assumption about the statistical structure of the data. A nonparametric classifier is the Parzen window, where the classification is made according to the majority vote within a predefined window of the feature space centered at the unlabeled pixel intensity. A maximum likelihood (ML) or Bayes classifier assumes that the pixel intensities are independent samples from a mixture of probability distributions, usually Gaussian.

Standard classifiers require structures to be segmented possessing distinct quantifiable features. As training data can be labeled, classifiers can transfer these labels to new data as long as the feature space sufficiently distinguishes each label as well. As they are non-iterative, they are relatively computationally efficient and unlike thresholding methods, they can be applied to multi-channel images.

A drawback of classifiers is that they do not perform any spatial modeling. This weakness has been pointed in recent work extending classifier methods to segmenting images as they are corrupted by intensity in homogeneities. Neighborhood and geometric information were also incorporated into a classifier approach.

Another drawback is the need of manual interaction for obtaing training data. Training sets may be acquired for each image that requires segmenting, but it is time consuming and laborious. In addition to this, use of the same training set for a large number of scans can lead to biased results which do not take into account anatomical and physiological variability between different subjects.

4. Conclusion

In this paper, various segmentation methods for brain MR image have been discussed. Accuracy and precision may be improved by incorporating prior information. For increasing computational efficiency, multiscale processing and parallelizable methods such as neuro-fuzzy technique seem to be promising approaches. Specially, Computational efficiency is also important in real-time processing applications. Computerized segmentation methods have already proved their utility in research applications and are now garnering increased use for computer aided diagnosis and radiotherapy planning. Segmentation methods are valuable in areas such as computer integrated surgery, where visualization of the anatomy is a critical component.

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