International Journal of Electronic and Electrical Engineering.
ISSN 0974-2174 Volume 6, Number 1 (2013), pp. 21-26

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Intelligent Thresholding for Medical Images Using Neural Network

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Abstract

Thresholding has to be done in medical images for various reasons. However, different images have different characteristics making the traditional process of thresholding by one algorithm a very challenging task. That is because any thresholding method may be perform well for some images but for sure it will not be suitable for all images. In this paper, intelligent thresholding by training a neural network is proposed. The neural network is trained using a set of features extracted from medical images randomly selected form a sample set and then tested using the remaining medical images. This process is repeated multiple times to verify the generalization ability of the network. The accuracy of the process is calculated by comparing every segmented image with its gold standard image.

Keywords: Neural Network,Thresholding

1 Introduction

Image segmentation, the partitioning of image data into related fragments or regions, is a major step in a number of approaches to image analysis and recognition. This can be done using many different techniques such as, thresholding or region growing. In region growing technique, a starting point (seed) is selected inside the region of interest and then the technique starts by calculating the mean of the region which firstly contains the seed point and its neighbors. In the same way, the region grows by adding similar neighbors to create a new region. This process stops when the mean of the region exceeds a certain threshold. The last calculated region is the segmented region. The problem is we get accurate segmentation for some images and low accuracy for others. This is because different images have different characteristics and every image must be processed with a suitable threshold. In this paper, intelligent threshold setting will be introduced via training with set of image features using supervised neural network. This paper is organized as: In section 2, a survey of region growing technique and neural networks is provided. In section 3, the proposed intelligent thresholding technique is introduced and discussed. In section 4, medical images are used to test the proposed technique. In section 5, the paper is summarized and concluded.

2. Background

2.1 Ostu Segmentation Techniques

There exist a vast number of methods to threshold graylevel images. The Otsu technique is considered as one of the most commonly used image thresholding techniques. The Otsu method uses the image histogram to assign a threshold to the image. It divides the image into two different classes of gray levels and assigns a threshold to the image where the variance of these two level is minimal. It leads to a comparison between Otsu segmentation technique and K-means method. The authors show that Otsu and K-means methods have the same objective function in multilevel thresholding. However, Otsu takes more time in multi level thresholding than K-means as it must evaluate a gray level histogram. Trying to reduce the high search time of 2D Otsu method by proposed a new algorithm that improves the histogram usage. Instead of dealing with the histogram of the image, the authors suggest to project the two dimensional histogram of the image onto the diagonal to form one dimensional histogram where they apply the 2D Otsu algorithm.

2.2 Region growing

Region-based methods suggest that neighboring pixels within the same region have similar intensity values. This leads to the class of algorithms known as region growing. The general procedure is to compare one pixel to its neighbors. If a criterion of similarity is satisfied, the pixel is assumed to belong to the same region. The choice of the similarity threshold is the difficult part for obtaining accurate segmentation. Region growing may also be combined with edge detection to find large and crisp segments. Segmented regions may be enlarged based on fuzzy criteria. An automatic seeded region growing algorithm for color image segmentation which firstly modifies the color images and then selects the initial seeds and segments the image into regions corresponding to the seeds and then the similar regions are merged using region-merging technique.

2.3. Neural networks and image segmentation

Self-organizing networks with competitive learning are useful for vector quantization, but are inadequate for image segmentation. The advantages of a hierarchical self-organizing neural network for image segmentation over the traditional (single-layer) selforganizing feature neural network. They combine the idea of self-organization and topographic mapping with those of multi-scale image segmentation. The another approach presents an incremental neural network for the segmentation of tissues in ultrasound images. The performance of the incremental neural network is tested for ultrasound image segmentation. They use discrete Fourier transform (DFT) and discrete cosine transform (DCT) to form elements of the feature vectors. They train the network using a training set formed from blocks of 4 × 4 pixels on five different tissues designated by an expert.

3. Intelligent Thresholding

The main problem with region growing segmentation techniques is that every image must have its own adjusted similarity threshold in order to receive good results. In other words, to obtain the maximum accuracy of segmentation for the image, one must try different thresholds for every image to find the optimum threshold. But, this operation may be very time consuming if we deal with a large set of images, as we have to process every image and try different thresholds. Besides, each result has to be somehow evaluated in order to select the best threshold.

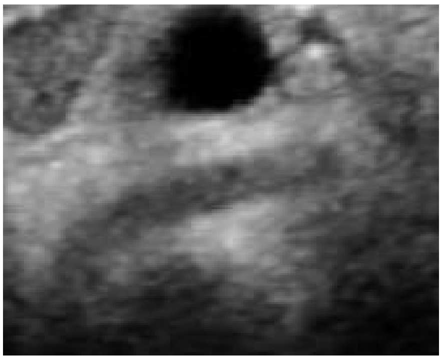

Fig. 1. The Sample Image.

However, segment validation is not an easy task either. Our proposed approach avoids dealing with every image separately, it uses a trained neural network to calculate a suitable threshold which could then be used in region growing technique. This technique consist of three steps: the first step is extracting features from a set of selected images with known optimum threshold. (e.g. through trial and error). The second step is training a neural network to obtain the optimum threshold using a multi-layer preceptron neural network. And the third step is to test the network by using region growing with the threshold generated by the neural network and calculating the average accuracies by comparing the segments with the gold standard images.

3.1 Extracting features from sample images

The first step in the proposed technique is to extract a set of features from every image and use these features as training parameters for the neural network. A general problem is that we usually do not have enough images as training images, so we use multiple points in every image as different seeds such that every sample image can be used multiple times. The algorithm continues and randomly selects multiple points within the region and for every point calculates the feature. The algorithm then proceeds by finding a region around every point as this region starts with a small window region around each initial seed (e.g 10*10) and enlarges the window (e.g to 20*20)

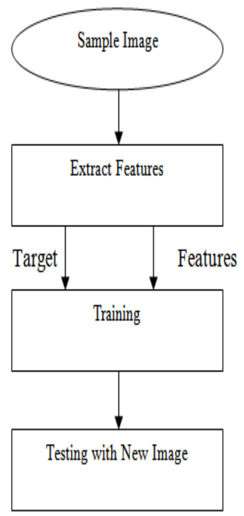

Fig. 2. The proposed training approach.

and this process stops when the standard deviation of one region becomes grater than or less than the standard deviation of the previous region by a certain limit (e.g. 20%) and the last calculated region is considered the region around the point. As we have multiple points inside every image (e.g. 250 points), we will have as many regions around every point as well. The next step is to extract the features which are 1) the mean gray level, 2) standard deviation, and 3) thedistance between the maximum and the minimum point of the region around the point. By this way, we have 250 points in every image, we will have 750 features from every image (250 point times 3 features). For every image, we treat the five points which are the point and its four neighbors as one training set, so the number of training sets from every image is 15 × 50 = 750. We have five images for training and so we get a 15 × 250 training feature matrix.

3.2 Training the neural network

A feed forward backpropagation neural network is used to learn the set of sample images. The network consists of one input layer of ten nodes and one hidden layer of 20 nodes and output layer with one output. For every training set, five different sample images each with 15 × 50 feature matrix randomly selected to train the neural network. The optimum thresholds for these five images are assigned as the target of the neural network. The network is trained using Matlab trainrp function with error goal set to 0.00005 for about 10000 epochs.

3.3 Recall Phase: Testing with new images

After being trained, the neural network is now ready to process new images. In this step any new image is processed by the algorithm which starts by calculating the features for this image by asking the user to click inside the regionof interest. The algorithm takes this point and its four neighboring points and calculates the features for them which are the mean, the standard deviation and the distance as mentioned before. The extracted features are now the inputs of the neural network which assigns to each input image a suitable threshold based on its characteristics. The image is then segmented using region growing technique using the threshold assigned by the neural network.

Experiments and Results

In this section a set of 20 medical images are used to test the proposed technique. The algorithm randomly selects five of the images as a training set and the remaining 15 images are used for testing the proposed system. This process is repeated four times to generate different training sets and investigate the generalization ability of the network. For each training set, five images are selected randomly to train the neural network and the remaining 15 images are used to test the proposed system.

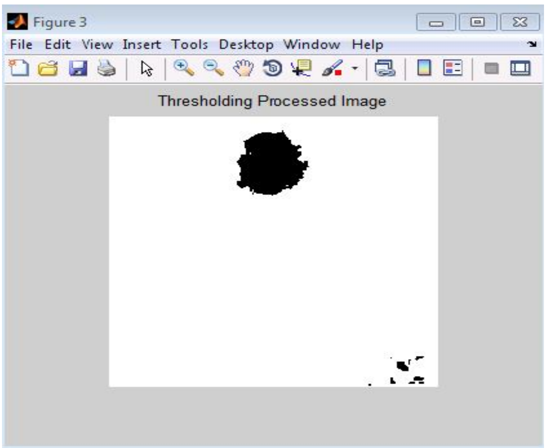

Fig. 3. Thresholding Processed Image.

Conclusions

Image thresholding is a critical process in image analysis. Different images have different properties making a dynamic adjustment of thresholds inevitable. Intelligent segmentation by training a neural network seems to be a potential solution. This solution starts by extracting different features from each image, trains a multi-layer preceptron neural network with those extracted features and their optimum thresholds as targets of the network. This solution seems to improve the average accuracy of segmentation and improves the confidence interval which means that the segmentation process is more consistent.

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