An Efficient Medical Image Segmentation Using Conventional OTSU Method

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Abstract

The main objective of medical image segmentation is to extract and characterize anatomical structures with respect to some input features or expert knowledge. The Otsu method is a popular non-parametric method in medical image segmentation. Traditional Otsu method for medical image segmentation is time–consuming computation and became an obstacle in real time application systems. In the same way TSMO method also compared. This paper describes a way of medical image segmentation using optimized Otsu method based on improved thresholding algorithm. In proposed algorithm, the experimental results show that the new optimized method dramatically reduces the operating time and increases the separability factor in medical image segmentation while ensures the final image segmentation quality. However, the computation time grows exponentially with the number of thresholds when this method extended to multi-level thresholding.

Keywords: *Otsu Method, Two stage mutlti threshold otsu method, Improved Otsu method and result analysis.*

1. Introduction

Medical imaging application plays an indispensable role by automating or facilitating the delineation of anatomical structures. Medical image segmentation is a challenging task due to the various characteristics of the images, which leads to the complexity of segmentation. Threshold segmentation is wildly used in many fields because of its simplicity and efficiency.

Thresholding is a technique frequently applied to image segmentation. Its basic objective is to classify the pixels of a given image into two classes: those pertaining to an object and those pertaining to the background. For the image with clear objects in the background, the bi-level thresholding method can easily divide the object from the background. But to segment complex images, a multilevel threshold method required. The multilevel threshold segments the pixels into several distinct groups in which the pixels of the same group have gray levels within a specific range. However, when the thresholding method is extended to multi-level thresholding, the computation time grows exponentially with the number of thresholds. Many threshold methods have been proposed to solve this problem.

Single (bi-level) or multiple thresholding is a straightforward and effective technique for image segmentation and computer vision. However, it requires an adequate threshold value to extract objects of interest from their background, since the objects in an image have their own distinct gray-level distributions. Thresholding is widely used in many image processing applications.

In this paper, a hybrid algorithm based on a self-adaptive thresholding method is proposed to optimize the threshold of the Otsu's method. The work is organized as follows. In section 2, Otsu Method and TSMO method is described. In section 3, the proposed method is described. In section 4, some concluding remarks regarding the proposed method are given. Finally, the paper is concluded in section 5.

1) Otsu Method

This method, as proposed in, is based on discriminate analysis. The threshold operation is regarded as the partitioning of the pixels of an image into two classes C0 and C1 (e.g., objects and background) at grey-level t, i.e., C0 = {0, 1, 2,…, t} and C1 = {t + 1, t +2,….L-1}. As stated in [11], let σ^2_w, σ^2_B and σ^2_T be the within-class variance, between-class variance, and the total variance, respectively. An optimal threshold can be determined by minimizing one of the following (equivalent) criterion functions with respect to t:

$$\lambda = \frac{\sigma_B^2}{\sigma_W^2},\ \eta = \frac{\sigma_B^2}{\sigma_T^2},\ \kappa = \frac{\sigma_T^2}{\sigma_W^2} \tag{1}$$

The above three criterion functions, η are the simplest. Thus, the optimal threshold t is defined as

$$t = \text{Arg Min } \eta \tag{2}$$

Where

$$\sigma_T^2 = \sum_{i=0}^{L-1} [1 - \mu_T]^2 P_i\ ,\ \mu_T = \sum_{i=0}^{L-1} [iP_i] \tag{3}$$

$$\sigma_B^2 = W_0 W_1 (\mu_0 \mu_1)^2\ ,\ W_0 = \sum_{i=0}^{t} P_i\ ,\quad W_1 = 1 - W_0 \tag{4}$$

$$\mu_1 = \frac{\mu_T - \mu_t}{1 - w_0},\ \mu_0 = \frac{\mu_t}{W_0}\ ,\ \mu_t = \sum_{i=0}^{t} (iP_i) \tag{5}$$

$$P_i = \frac{n_i}{n} \tag{6}$$

Where n_i is the number of pixels with grey-level i and n is the total number of pixels in a given image defined as

$$n = \sum_{i=0}^{L-1} n_i \tag{7}$$

Moreover, Pi is the probability of occurrence of grey-level i. Otsu's method as proposed affords further means to analyze further aspects other than the selection of the optimal threshold for a given image. For a selected threshold t_ of a given image, the class probabilities w0 and w1 indicate the portions of the areas occupied by the classes C0 and C1. The class means μ0 and μ1 serve as estimates of the mean levels of the classes in the original grey-level image.

Moreover, the maximum value of η, denoted by η^*, can be used as a measure to evaluate the separability of classes C0 and C1 in the original image or the bimodality of the histogram. This is a very significant measure because it is invariant under affine transformations of the grey-level scale. It is uniquely determined within the range

$$0 \le \eta \le 1 \tag{8}$$

The lower bound (zero) is obtained when and only when a given image has a single constant grey level, and the upper bound (unity) is obtained when and only when two-valued images are given. This property is an important criterion that we will use in extending Otsu's approach.

2) Two stage Multi Threshold OTSU Method (TSMO)

Normally, Otsu's method (Otsu, 1979) found the optimal threshold in an image by maximizing the between-class variance of pixel intensity with an exhaustive search. However, with an increase of the number of classes in an image, this method becomes rather inefficient because it requires a large number of iterations to compute the cumulative probability (zeroth-order moment) and the mean (first-order moment) of a class. To significantly improve the deficiencies in Otsu's method with regard to selecting the multi-level threshold, an algorithm called the TSMO method is proposed.

The idea of the TSMO method is quite simple and straightforward: to greatly reduce the iterations required for calculating the zeroth- and first-order moments of a class. The details of the TSMO method for finding the optimal multi-level threshold in a two-stage fashion are described below.

In the first stage of the TSMO method, the histogram of an image with L (=256) gray levels is divided into Mz groups which contain Nz (=256/Mz) gray levels with a certain range. Let X denote the groups of the total image space; then, X = {X_J /j= 0,1,. . . ,Mz -1}, where j represents the group number. Hence, each group contains a certain range of gray levels as follows: X0 with gray levels {0, 1, . . . ,Nz -1}, X1 with gray levels {Nz,Nz + 1,. . .,2Nz -1}, . . . ,Xq with gray levels {qNz,qNz + 1, . . ., (q + 1)Nz -1}, . . ., and the last group XMz_1 with gray levels {(Mz -1)Nz, (Mz -1)Nz + 1, . . . , MzNz -1}. The number of cumulative pixels and the mean intensity for each group can be easily determined. For example, the number of cumulative pixels, which is also regarded as the zeroth-order cumulative moment, in the qth group denoted by gXq can be calculated as

$$g_{x_j} = \sum_{i=qXN_Z}^{(q-1)XN_Z-1} f_i \tag{9}$$

where f_i represents the number of pixels with gray level i. In this study, we adopt Mz = 16, 32, or 64 with corresponding Nz = 16, 8, or 4. The set gX={gX0 , gX1 , . . . , gXMz_1 }can then be obtained when the number of cumulative pixels for each group is statistically completed.

Since each group contains Nz gray levels, the corresponding gray level value for each group can be considered as a mean value for those Nz gray levels. Therefore, the set iX = {iX0 , iX1 , . . . ,iXMz_1} of the corresponding gray level values for all groups in an image can be easily determined. For example, the corresponding gray level value or mean intensity, which is regarded as the first-order cumulative moment, in the qth group is denoted by iXq

$$i_{x_q} = \frac{1}{g_{x_q}} \sum_{i=qXN_Z}^{(q+1)XN_Z - 1} i.f_i \tag{10}$$

Clearly, the total mean intensity µt of the whole image remains invariant. Subsequently, Otsu's method can be applied to find the optimal threshold by maximizing the between-class variance σ_B^2 with the sets of i_X and g_X. That is

$$j^* = \arg_{o \le j \le M_Z - 1} MAX \left\{ \sigma_B^2(j) \right\} \tag{11}$$

where j^* is the number of the group into which the maximum variance of the between-class, i.e., σ_B^2 max, falls with the corresponding group Xj

2. Improved OTSU Method

In the previous section we presented Otsu'S method, which performs well on medical images but very time taking process. In this section, an efficient image segmentation algorithm using histogram of an image and global thresholding method is analyzed. Thresholding is a very simple form of segmentation. A threshold is defined, and then every pixel in an image is compared with this threshold. If the pixel lies above the threshold it will be marked as foreground, and if it is below the threshold as background. The threshold will most often be intensity or colour value. Other forms of thresholding exist where the threshold is allowed to vary across the image, but thresholding is a primitive technique, and will only work for very simple segmentation tasks.

Thresholding is a non-linear operation that converts a gray-scale image into a binary image where the two levels are assigned to pixels that are below or above the specified threshold value. In this method the selection of initial threshold value is depends upon the histogram of an image and the gray scale of an image. The algorithm for the proposed method is prescribed as follows:

1. I = Input Image.
2. Obtain the histogram values (h) of the image I.
3. Set the initial Threshold value:

$$T_{in} = \frac{\sum (h * totalshades)}{\sum h} \tag{12}$$

4. Segment using T_{in}. This will produce two groups of pixels: C1 and C2.
5. Repeat step-3 to obtain the new threshold values for each class. (T_{C1} &T_{C2}).
6. Compute the new threshold value:

$$T = \frac{(T_{c1} + T_{c2})}{2} \tag{13}$$

7. Repeat the steps 3-6 until the difference in T in successive iterations is not tends to zero.

8. Now apply the Conventional Otsu method for the obtained threshold value for further segmentation process.

Finally the time (t) and η is calculated and compared with the original Otsu method and TSMO (M=32). The process is tested for different medical images.

3. Computational Results and Analysis

In this section, the performance of the proposed hybrid algorithm has been evaluated and compared with conventional Otsu method as well as TSMO method. To evaluate the practical performance of the proposed method, the algorithm has been implemented in Matlab7.9 under window XP system. Experiments are performed on nearly 20 medical MRI and CT- Scan images to compare the results of the proposed method with the existed method. The few images are given below to know how the medical image segmentation is takes place.

In the below figures (a) part indicates the original medical images and figure (b) indicates the corresponding segmented images using our method. The same segmented image obtained in both the techniques these are only differs with time (t) and η factor. In addition to that TSMO method, some of segmented details of image are missing but those are not shown here. The important point in this concept is in both the methods the obtained threshold value is nearly same, but these methods are drastically varies in terms of computational time and separability factors of an images.

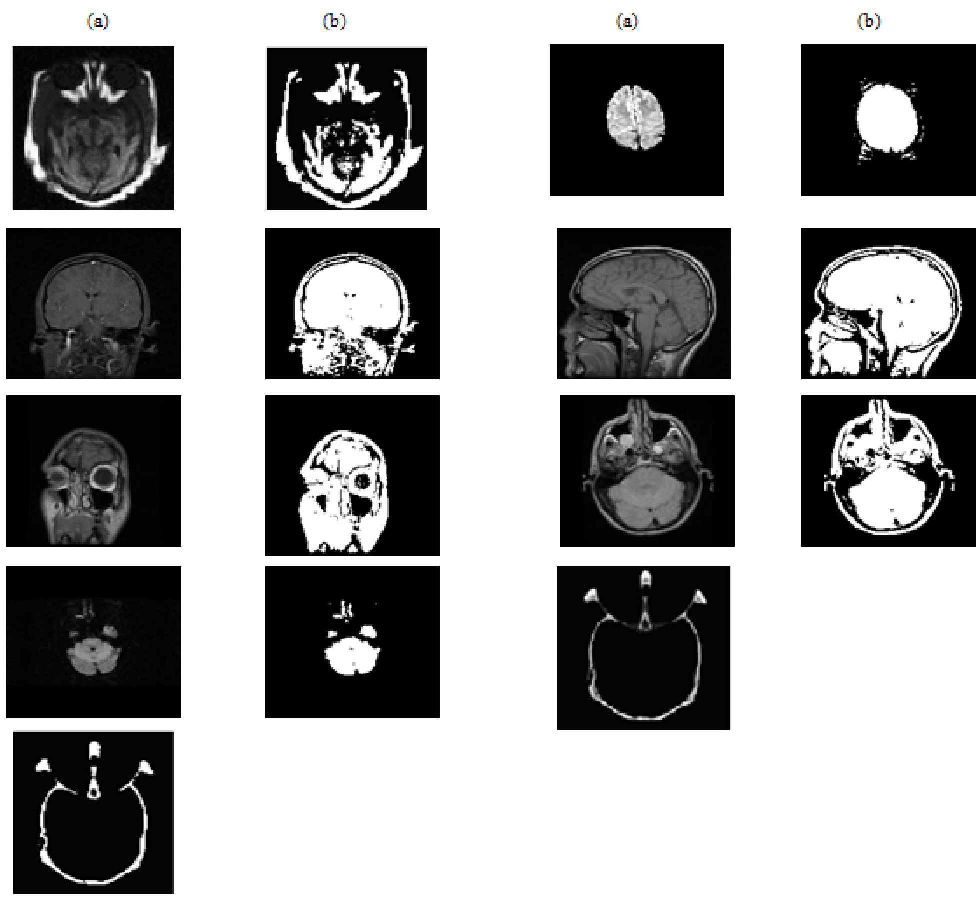

Figure: (a) Original Images (b) Segmented Images

The comparison of those factors are given in tabular form given below, in this table the methods are compared with proposed method in terms of time and separability values on same system.

Table 1. Computational Results of Medical Images

S.No	Method	Computational Time	Seperability (η)
Image1	OTSU	1.00	0.8598
	TSMO (with M=32)	0.2457	0.8923
	Proposed	**0.0089**	**0.9106**
Image2	OTSU	1.0470	0.8063
	TSMO (with M=32)	0.2349	0.6706
	Proposed	**0.0084**	**0.8483**
Image3	OTSU	1.0460	0.7260
	TSMO (with M=32)	0.2349	0.6430
	Proposed	**0.0088**	**0.7487**
Image4	OTSU	0.8910	0.6787
	TSMO (with M=32)	0.2336	0.722
	Proposed	**0.009**	**0.8046**
Image5	OTSU	0.960	0.891
	TSMO (with M=32)	0.234	0.9121
	Proposed	**0.009**	**0.9316**
Image6	OTSU	1.0780	0.8244
	TSMO (with M=32)	0.2336	0.8289
	Proposed	**0.011**	**0.8544**

The Table-1 exhibit better results for proposed method than the Otsu & TSMO method.

4. Conclusion

In this paper, the improved Otsu thrsholding method has been proposed for medical image segmentation. This method performs better than the other local and global thresholding methods and produces suitable binary images, which can be used in further processing stages. The Otsu method is one of very efficient methods to threshold the gray images. However, its computation would become more complex. The experimental results show that the proposed otsu threshold method can be obtained easily with a better result of image segmentation.

The results are also shown that the proposed method is efficient one than the existing method. Our approach requires a much simpler initialization and has a lower computational complexity than the other popular methods.

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