Research on Contour Correction in Medical CT Image Segmentation

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Abstract—To segment the CT image with the region in which the gray changes slowly accurately, add a contour correct progress to the image segmentation after in-depth analysis of threshold based image segmentation, and a new image segmentation method based on contour correction was proposed. The results of the experiment proves that the proposed method segment the CT image with slowly transitional regions of the gray accurately.

Index Terms—CT image segmentation, threshold, contour correction, slowly transitional region

I. INTRODUCTION

Image segmentation is a crucial step from image processing to image analysis, which involving complex problem referring computer vision technology. As a crucial step of medical image processing, the medical image segmentation is further processing basis for three-dimensional reconstruction, quantitative analysis of the normal tissue and lesion tissue. Accuracy of segmentation is crucial for the doctor to assess the real situation of the disease and make the correct diagnosis. Because of its non-invasive, non-damage, multi-parameter imaging, CT is widely used in medical diagnosis. However, the complexity of the human anatomy, the irregular nature of tissues and organs, as well as the individual differences, together with the image quality constrained by multiple factors, image segmentation becomes difficult. Regional gray inconsistency, artifacts, weak borders, border breaks, which often happen in CT image, could not be solved by traditional method ideally.

II. ANALYSIS OF THRESHOLD BASED IMAGE SEGMENTATION METHOD

Threshold based image segmentation method utilizes the difference of the gray level between the target region and the background region, and uses one or several thresholds to divide the image into target region and background region that has different gray levels [1-3], in order to achieve the purpose of segment the image accurately. Threshold based methods of image segmentation are used widely with the characteristics that calculation simplicity and quick speed.

Implementation principle of threshold based image segmentation methods is explained as follows:

First, the method determines a threshold T(0<T<255) of the gray image with the gray levels between 0 and 255, then compares the threshold T with the gray value of every pixel of the image, and according to the comparison results, the method divides the pixels into two parts (part A and part B) : in part A, the gray level of the pixels are higher than the threshold of the gray image; in part B, the gray level of the pixels are lower than the threshold of the gray image; and the pixels with the gray level equal to the threshold can belongs to either of the two parts. Determining the threshold of the gray image is the linchpin of the above-mentioned steps. After determining an appropriate threshold, the method could segment the images accurately and expedient.

The image segmented by single threshold could be defined as:

\[
g(x, y) = \begin{cases} 
1 & f(x, y) > T \\
0 & f(x, y) < T
\end{cases} \tag{1}
\]

In this paper, we select the OTSU method which is one of the representative methods of the threshold based image segmentation to do analysis and experiment in-depth.

The implementation principle of the OTSU is explained as follows:

According to the characteristic of the gray, the method divides the image into two parts, which are named target region (part A) and background region (part B). The larger the variance between part A and part B, the more contrastive are present in the two parts. On condition that many pixels belong to part A are considered as pixels in part B or in the opposite conditions, the variance between part A and part B will be diminished. Thus, on condition that the variance between class A and class B achieves the maximum, the rate of dividing pixels in false will achieves the minimum.

The application of the OTSU is that, first, dividing the histogram of the gray image with a threshold defined by one gray level of the image into two parts (part A and part...
B), second, calculating the variance between part A and part B, on condition that the variance between part A and part B achieves the maximum, the gray level used to define the threshold in this condition will be considered as the optimal threshold. From the perspective of pattern recognition, optimal threshold value produces the best separation property of target class and background class, and this property can be expressed as category variance. In this connection, we introduce inter-class variance $\sigma_{\bar{W}}^2$, intra-class variance $\sigma_B^2$ and population variance $\sigma_T^2$, and define three equivalent standards measurements:

$$
\lambda = \frac{\sigma_B^2}{\sigma_{\bar{W}}^2} \quad (2)
$$

$$
\kappa = \frac{\sigma_T^2}{\sigma_{\bar{W}}^2} \quad (3)
$$

$$
\eta = \frac{\sigma_T^2}{\sigma_B^2} \quad (4)
$$

Considering the quantity of the calculation, in general, we could achieve the threshold by predigesting the equation 2-4. In the practical application, we generally use the predigested equation as follow:

$$
\sigma^2(T) = w_A(\mu_a - \mu)^2 + w_B(\mu_b - \mu)^2 \quad (5)
$$

In the equation 5, $\sigma^2$ is the maximum of the variance between part A and part B, $w_A$ is the rate of the pixels in part A, $\mu_a$ is the average gray of the pixels in part A, $w_B$ is the rate of the pixels in part B, $\mu_b$ is the average gray of the pixels in part B, $\mu$ is the average gray of the pixels of the whole image, namely, threshold T divides the image into two part (part A, part B), on condition that the variance between part A and part B achieves the maximum, the threshold used in this condition will be considered as the accurate threshold.

The image segmentation method based on threshold focuses on the consistency of the region internal characteristics, which can ensure the continuity of the boundary, the less inner cavity of the target region, and achieves precise segmentation effect in segment image within discernable edges. However, in the region with trifile difference in the gray, the result of the threshold based method cannot be achieved precisely. And there are many regions with trifile difference in the gray in medical CT images, in this connection, the precise result of the threshold based method cannot be achieved.

III. CONTOUR CORRECTION BASED METHOD OF IMAGE SEGMENTATION

CT images of liver cancer have background region of their own and slowly transitional region between lesions, resulting in the existence of the weak edge of focus region, and there is less likely of the existence of characteristics of complex topology. When applying threshold to do the segregate of the medical CT images, by the impact of the weak edge of focus region, it is difficult to segment focus region accurately.

Based on the above situation, this paper proposed a contour correction method for medical CT image. First of all, the threshold-based image segmentation method is applied to do initial image segmentation, to get a relatively close contour for the actual focus region. Then using the contour correction method proposed in this paper to correct the initial contour, in order to obtain a more precisely result of the medical CT image segmentation.

A. Basic principles of contour correction

While one point A, on the contour attained by medical CT image segmentation applying threshold based method, is compared with another point A', on the real edge of focus region, there are three possible situation: Firstly, point A is also on the real edge and coincides with the point A’. Secondly, point A is in the background region of focus region, being on the outside of real edge. Thirdly, A is within the focus region.

Basic principles of contour correction are: for point A, firstly to determine whether it is on the actual border of focus region. If point A is on the actual border, it remains unchanged. Otherwise point A will move to the actual border of focus region until it is on the border. To adjust every point on the contour obtained by threshold based segmentation can overcome the defect that the threshold based segmentation cannot segregate the images with the weak edge of focus region.

B. Contour correction method

According to Basic principles of contour correction, two questions should be solved in order to fulfill contour correction. The first is, for point A, to determine its position, on the actual border, in the background region or within focus region. The second is, if point A is not on the actual border of focus region, how to determine the moving direction of it.

1) To determine the position of position the contour

For any point A on the contour, the most basic and obvious prior knowledge is the gray statistics condition for every point in the neighborhood region of point A. In general conditions, the neighborhood region of point A situates on both sides of the actual border of focus region. If A in on the border, in the neighborhood region, the number of pixel points greater than average gray is almost equal to the number of pixel points which are smaller than average gray. If point A is in the background region, the number of pixel points smaller than average gray is more than the number of pixel points greater than average gray. If point A is within focus region, the number of pixel points greater than average gray is more than the number of pixel points smaller than average gray. Consequently, the gray statistic condition of pixel points in the neighborhood region of point A can be a parameter for determining the position of point A. That is to say,
introduce ballot mechanism, and then determine the position of point A according to the results of ballot.

If the weak edge of focus region exists, the contour generated by threshold based method is far from the actual border of focus region. Now, the selected neighborhood region, such as eight neighborhood region, may be all within the focus region or all in the background region, if still according to the above situation to determine the position of point, new problems will arise. However, problems can be solved by expanding the neighborhood region, such as the twenty-four neighborhood region or the thirty-five neighborhood region.

Take the twenty-four neighborhood region for instance; the method of determining the position of point A will be introduced as follow.

Firstly, the segmentation method based on threshold is introduced. That is to say, within the neighborhood region of point A limits, its average gray \( g \) is calculated by applying iteration method belong to the image segmentation method based on threshold, then regarded as a standard of ballot. For calculating the ballot results, \( w \) is used to show the gray statistic condition of pixel points in the neighborhood region of point A. Supposing \( g \) is the gray value of any pixel point \( a \), the gray condition of pixel point \( a \) can be showed as:

\[
w = \begin{cases} 
1, & g > \bar{g} \\
-1, & g < \bar{g} \\
0, & g = \bar{g} 
\end{cases}
\] (6)

If \( S \) is the gray statistics condition in the neighborhood region of point A, there is:

\[
S = \sum_{i=1}^{24} w_i
\] (7)

In general, when the value of \( S \) tends to 0, point A is at the edge of actual contour; when the value of \( S \) is greater than 0, point A is in the focus region; when the value of \( S \) is less than 0, point A is in the background region.

In actual application, according to experience, people can choose a value as the threshold of determining the position of point A. In this paper, the value is three. When the absolute value of \( S \) is less than or equal to three, point A is within the focus region; when \( S \) is less than -3, point A is in the background region.

2) To determine the moving direction of points on the contour

Within the focus region determined by traditional Snake model, a central point O can be determined through calculation, and then point is seemed as the center to define the polar coordinates, showed as Fig. 1.

![Figure 1](image)

Figure 1 the polar coordinate to determine the moving direction of point A

Thinking the direction of vector OA as the positive direction, the moving direction of A can be determined according to the ballot result. When the value of \( S \) is positive, point A will move in the positive direction of OA; when the value of \( S \) is negative, point A will move in the negative direction of OA, until the ballot result shows point A has not need to move.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

A. Results

Eight medical CT screenshots are selected to be the data resource of this experiment. The CT screenshots are provided by the Zhengzhou Fifth People's hospital.

For the selected images, following steps were taken for processing:

(1) Pre-process of medium filter is taken; images with low noise were obtained.

(2) Image segmentation by threshold method, target region was obtained, which are showed as fig.2-2, 3-2,4-2,5-2,6-2,7-2,8-2,9-2.

(3) Extracting the contour of the target region obtained in step 2, which would be used as initial contour of contour correction, and the results are showed as fig.2-3,3-3,4-3,5-3,6-3,7-3,8-3,9-3.

(4) Contour correction proposed in this paper was taken to obtain the lesion contour, which are showed as fig.2-4,3-4,4-4,5-4,6-4,7-4,8-4,9-4.

![Figure 2](image)

Figure 2: 2-1 CT screenshots, 2-2 binary image obtained by threshold based method, 2-3 contour of binary image, 2-4 contour curves obtained by contour correction

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Figure 3: 3-1 CT screenshots, 3-2 binary image obtained by threshold based method, 3-3 contour of binary image, 3-4 contour curves obtained by contour correction.

Figure 4: 4-1 CT screenshots, 4-2 binary image obtained by threshold based method, 4-3 contour of binary image, 4-4 contour curves obtained by contour correction.

Figure 5: 5-1 CT screenshots, 5-2 binary image obtained by threshold based method, 5-3 contour of binary image, 5-4 contour curves obtained by contour correction.

Figure 6: 6-1 CT screenshots, 6-2 binary image obtained by threshold based method, 6-3 contour of binary image, 6-4 contour curves obtained by contour correction.

Figure 7: 7-1 CT screenshots, 7-2 binary image obtained by threshold based method, 7-3 contour of binary image, 7-4 contour curves obtained by contour correction.
B. Analysis

The above-mentioned figures show that, there are two kinds of results in the experiments of this paper:

(1) There are obvious improvements in the images after contour correction;
As the fig.2, 4, 5, 9 shows, there’s obviously slowly transitional region between the background regions and the focus regions, and the results of the threshold based method are not precisely enough. The contour correction improved the accuracy of the image segmentation.

(2) There are almost no improvement in the images after contour correction;
As the fig.3, 6, 7, 8 shows, there’s few slowly transitional regions between the background regions and the focus regions, and the results of the threshold based method are precisely enough. The contour correction only makes small alterations to the threshold based image segmentation.

V. CONCLUSIONS

Based on in-depth study of the principle of threshold based image segmentation, this paper analyzes problems encountered in applying threshold method to medical image segmentation, and also introduces a contour correction process, suggests a new contour correction image segmentation method based on threshold method, which has a good result in medical CT image segmentation. The contour correction principle and methods suggested by this paper has a certain reference meaning to other segmentation methods also. Because the contour correction process need to calculate all the contour point after segmenting the image, which takes a relatively long time than threshold based method, further improvements are necessary.

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