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Automatic Segmentation of Liver Region from Non-contrast and Contrast CT images Employing Tree-structural Image Transformations

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Abstract: In the medical image processing field, segmentation from the CT image is one of the most important problems for analyzing the abnormalities and diagnosis on visual screening. Many related segmentation techniques have been developed for automatic extraction of ROI. It is however, there are still no fully automatic segmentation methods that are generally applicable to ROI based on CT image set. In this paper, we present a technique for automatic extraction of liver region on the MDCT images employing automatic construction of tree-structural image transformation (ACTIT). We propose a new technique for extraction of organs employing ACTIT with non-contrast and contrast image set in order to introduce temporal change information. We apply the proposed technique to three abdominal image set and satisfactory segmentation results are achieved.

Keywords: Segmentation, Liver region, MDCT, Tree-structural filter, ACTIT, Temporal change**.**

I. INTRODUCTION

In recent years, various imaging equipments have been introduced into medical fields. Especially, high resolution helical computed tomography (HRCT) is one of the most useful diagnosis systems because it provides a high resolution image to medical doctors as clear image. Radiologist can easily detect abnormalities by use of the image with high resolutions. Accordingly, many related image processing techniques are proposed into medical fields for extraction of abnormal area. Automatic extraction of the region of the interest (ROI) is an important theme of medical imaging and computer vision technologies.

In the medical image processing field, segmentation from the CT image is one of the most important problems for analyzing the abnormalities and diagnosis on visual screening. Many related segmentation techniques have been developed for automatic extraction of ROI before analyzing the abnormalities. Especially, in order to extract multi organs and to understand the structure of internal organ, several approaches have been developed in the past. Ney *et al.* [1] proposed a technique based on tracing the liver boundary section with a mouse. Gao *et al.* [2] applied a method of automatic segmentation of the liver region employing knowledge based and a model based boundary finding scheme. Bae *et al.* [3] devised a segmentation method of liver structures employing Gaussian smoothing and eight-point connectivity tracking. Shimizu *et al.* [4] proposed the simultaneous methods that are generally applicable to regions of interest based on CT image sets. We also have developed the segmentation technique of spleen and gallbladder region employing rib information and region growing technique [5]. Many other techniques are proposed for segmenting the organs. It is however, there are still no fully automatic and satisfactory segmentation methods that are generally applicable to ROI based on CT image set.

On the other hand, in the image analyzing fields, automatic construction of tree-structural image transformations (ACTIT) is used for constructing the filtering tree [6]. The ACTIT is the method that automatically generates image transformation process from several given examples by use of genetic algorithm. By use of the ACTIT, we can get the image transformation filtering tree as a combination of known filters, which is able to be applied to unknown image.

In this paper, we present a technique for automatic extraction of liver region on the MDCT images employing ACTIT. In our study, we propose a new technique for extraction of organs employing the ACTIT with non-contrast and contrast image set. In the past, ACTIT used only one image as tree-nodes. In this paper, we set the non-contrast image and the contrast one as tree-nodes of filtering tree. By using this method, we can introduce temporal change information between non-contrast and contrast images.

The organization of this article is as following. Firstly, we present a method for segmentation of CT image by use of ACTIT in section 2. Then we give some experimental results in section 3. Finally, in section 4, we give conclusions along with discussion of the problems obtained from experimental results.

II. METHODS

Figure 1 shows the flow of the proposed method. In the first step, we input non-contrast images, contrast images and reference images which are made manually. Non-contrast and contrast images are used as the nodes of tree-structural filter. In the second step, we apply ACTIT in order to generate tree-structural filter. Finally, we apply generated filter to unknown images.

1. ACTIT

ACTIT is the method which generates the structural filter as the combination of known filters. In order to optimize the filters, the genetic algorithm is used. Fig. 2 shows the overall scheme of the ACTIT. First, we make a lot of tree-structural filters as initial genes. Next, we calculate fitness by the following equation.

$$fitness = \frac{1}{K}\sum_{i=1}^{K}\left\{1-\frac{\sum_{x=1}^{W_x}\sum_{y=1}^{W_y} w_i(x,y)\left|O_i(x,y)-T_i(x,y)\right|}{\sum_{x=1}^{W_x}\sum_{y=1}^{W_y} w_i(x,y)\cdot V_{\max}}\right\} \quad (1)$$

Here, O_i, T_i, and K shows output image, reference image, and the number of slices respectively. W_x, W_y, V_{max} shows image width, image height, and the maximum value of image density respectively. w_i shows the weight.

Furthermore, we optimize the tree filters by genetic algorithm (elitist selection, crossover, and mutation (1%)). In the crossover step, we apply crossover between branches.

If the fitness is over 99% or does not change for 30 loops, we stop the examination and get optimized filters.

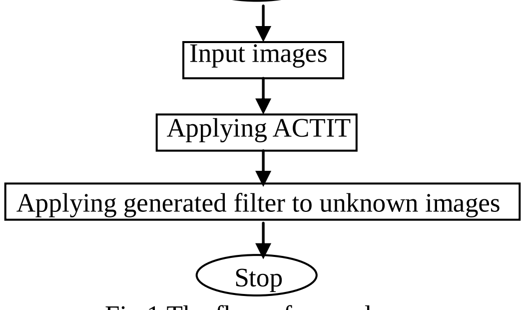


Fig.1 The flow of procedure.

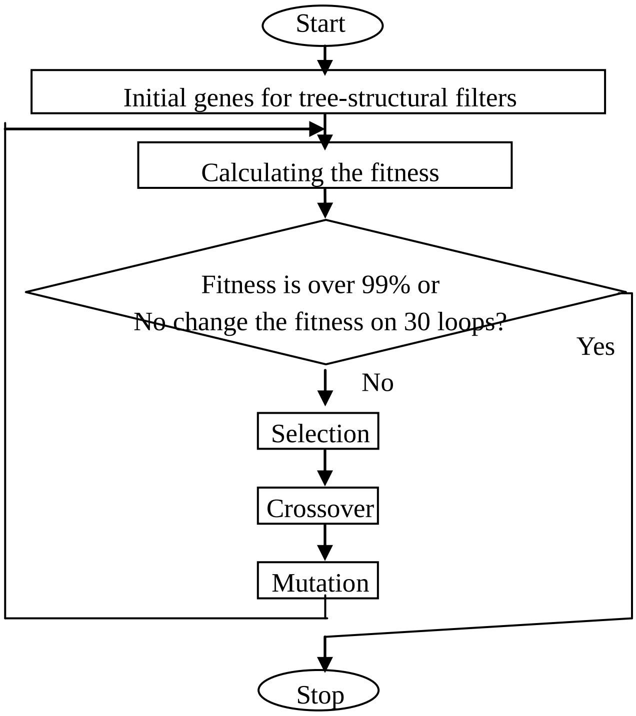


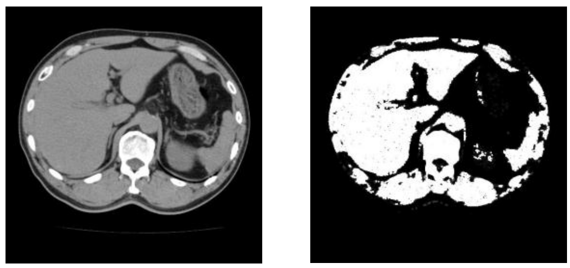
Fig.2 Overall scheme of ACTIT

2. ACTIT with temporal information

In general, ACTIT used one image as the nodes of tree. However, when we applied the ACTIT to non-contrast CT images, we could not achieve satisfactory results (Fig.3), because there are a lot of noises on the result image.

In the abdominal CT images, soft tissues such as liver, kidney and spleen are shown as 50～60[H.U.]. And the pixel value of muscles indicates 30～60[H.U.]. It is a difficult problem to separate between soft tissues and muscles.

To overcome this problem, we propose ACTIT with temporal subtraction information between the non-



(a) (b)

Fig. 3 Experimental results of ACTIT with only one image as nodes of tree filter. (a) shows original image, (b) shows the experimental result.

contrast images and the contrast one. We can introduce contrast medium information by exchanging a part of non-contrast image to the contrast one randomly. Contrast medium changes image contrast and appears around soft tissue or blood vessels with high CT values. So we can get contrast medium information by subtraction of images. Each features which is adopted are shown in Table.2

III. RESULTS

1. Experimental environments

We apply the proposed technique to three real CT cases in order to extract the liver region. The acquisition parameters and experimental environments are shown in Table 1. The images are 512×512 pixels in size with a pixel spacing of 0.616 to 0.744 mm. And we use 5 slices per case in order to construct tree filter and calculate fitness. Table 2 shows the list of filters which we used for constructing tree-structural filters. In Table 2, V_1 and V_2 show the pixel value of image 1 and image 2, respectively. Furthermore V_{max} shows the maximum pixel value of the image.

2. Results

Figure 4 shows the experimental result for extraction of liver regions by use of proposed algorithm. In Fig. 4, (a) shows the non-contrast original image, (b) shows the contrast image, (c) shows the reference image, (d) shows the experimental result which is achieved by applying generated filter to (a) and (b). (e) and (f) show other non-contrast image and the image obtained by applying tree-constructed filter generated from (a) and (b) to (e), respectively.

Table 1 Experimental environments

OS	Microsoft Windows XP
Development environment	Microsoft Visual C++
CPU	Intel Pentium 4 3[GHz]
Memory	1[GB]
CT scanner	Toshiba Aquilion 16
Image size	512×512[pixels]
Pixel spacing	0.616～0.744[mm]
Image resolution	16[bits]
Slice thickness	2[mm]

Table 2 Filters for constructing tree-structural filter

Filter	Effect
Average	3-neighbors average filter
Minimum	3-neighbors minimum filter
Maximum	3-neighbors maximum filter
Inverse	Inversion of pixel value
Erosion	Erosion
Dilation	Dilation
Binarization (discriminant analysis)	Binarization using discriminant analysis
Binarization (average)	Binarization using the average value of image
Laplacian	Laplacian filter
Laplacian + *Vmax*	Laplacian + the maximum value of image
Sobel	Sobel filter
Segmentation of Maximum area with binarization (discriminant analysis)	Segmentation of maximum area with binarization using discriminant analysis
Segmentation of Maximum area with binarization (average)	Segmentation of Maximum area with binarization using the average value of image
Elimination of symmetrical area	Elimination of symmetrical area
Elimination of non-symmetrical area	Elimination of non-symmetrical area
Subtraction	The absolute value of subtraction
Logical summation	The larger value between V_1 and V_2
Logical product	The smaller value between V_1 and V_2
Algebraic summation	$V_1+V_2-(V_1 \times V_2)/V_{max}$
Algebraic product	$(V_1 \times V_2)/V_{max}$
Bounded summation	V_1+V_2
Bounded product	$V_1+V_2-V_{max}$
Drastic summation	If V_1 and V_2 are not 0, it returns V_{max}. Else if only V_1 is 0, it returns V_2. Else if only V_2 is 0, it returns V_1.
Drastic product	If V_1 and V_2 are not V_{max}, it returns *0*. Else if only V_1 is V_{max}, it returns V_2. Else if only V_2 is V_{max}, it returns V_1.

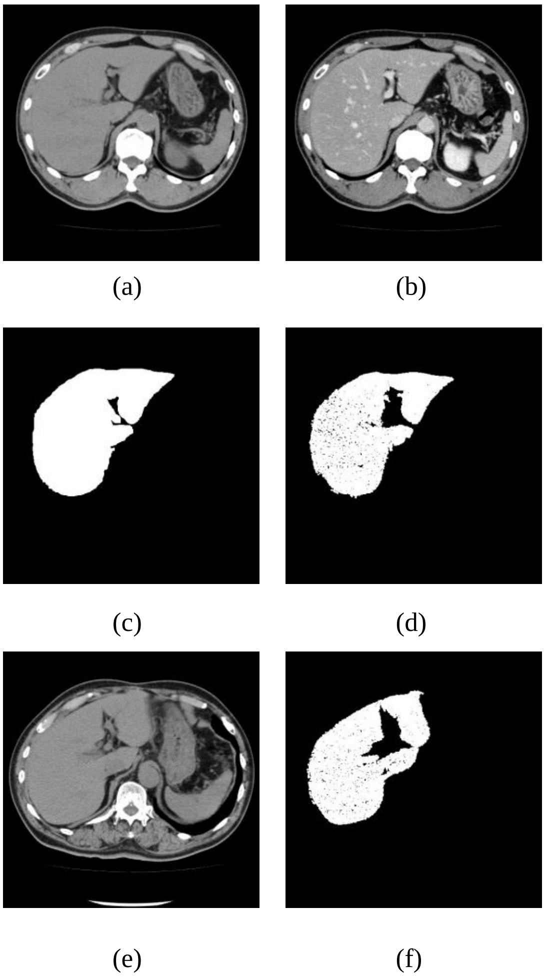


Fig. 4 Experimental results : (a) shows non-contrast image, (b) shows the contrast image, (c) shows the reference image, (d) shows extracted region by applying tree-constructed filter generated from (a) and (b). (e) and (f) show other non-contrast image and the result obtained by applying filter used for generating (d) to (e) image.

Table 3 Fitness of experimental results

Reference	Case 1	Case 2	Case 3
Case 1	(97.95)[%]	97.36[%]	97.56[%]
Case 2	97.42[%]	(97.86) [%]	97.38[%]
Case 3	97.58[%]	97.25[%]	(97.59) [%]

The fitness of experimental results by calculating equation (1) is shown in Table 3.

VI. CONCLUSION

In this paper, we proposed a segmentation technique for liver region employing ACTIT. In the experimental results, satisfactory segmentation performances are achieved. We can check that the proposed technique is useful for extraction of liver regions.

We proposed the new method for ACTIT in order to introduce temporal change information by use of non-contrast and contrast images as nodes of tree-structural filter. We can check that it is useful for eliminating the noises caused by similarity of pixel values between muscle and other soft tissues.

The proposed technique is useful for extraction of the liver regions. But it still remains miss-segmentation errors. We use the reference image including blood vessels nearby liver regions, but when we apply the obtained tree filters to other CT cases, blood vessel regions do not remain on the experimental result. It is because the fitness did not exceed 99%. We think that the combination between proposed technique as coarse segmentation and level set method [7] as fine segmentation is useful in order to improve segmentation accuracy. Furthermore improvement of algorithm is now in progress. We believe this segmentation method makes possible to improve the segmentation accuracy for analyzing the internal structure of human body before the operation.

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