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Automatic Segmentation of Skin and Bone in CT Images using Iterative Thresholding and Morphological Image Processing

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** Short Paper*

***Abstract*: This paper proposes a fast and efficient method to extract the skin and bone automatically in CT images. First, the images were smoothed by applying an anisotropic diffusion filter to remove noise. The whole body was then detected by thresholding, which was set automatically. In addition, the contour of the skin was segmented using morphological operators and connected component labeling (CCL). Finally, the bone was extracted by iterative thresholding.

Keywords: Image segmentation, Iterative thresholding, Morphological operation

1. Introduction

Medical imaging technology is one of the most important fields in computer aided diagnosis. Medical image segmentation aims to extract a specific organ from various imaging modalities. The density from computed tomography (CT) images is used for image segmentation [1]. Although there have been few studies of skin segmentation from CT images, it can be used as a preprocess to segment the other organs, e.g. bone, liver, heart, lung, etc. The skin contour was extracted to segment the bone area. Jeff et al. [2] proposed bone segmentation using a variational method based on a level set. This approach is weak for image noise because of local minima, and is computationally expensive. Ying et al. [3] proposed a hip bone segmentation from magnetic resonance imaging (MRI). It is necessary for this method to model the atlas that incorporates the locations and shapes of the anatomical structures, as well as the relationships between them.

The remainder of the paper is organized as follows. Section II outlines the proposed method of automatic segmentation of the skin and bone in CT images. This procedure consists of four processing steps. Section III presents the results of the application of the proposed method to clinical dataset. Section IV summarizes the results and discussion.

2. Proposed Method

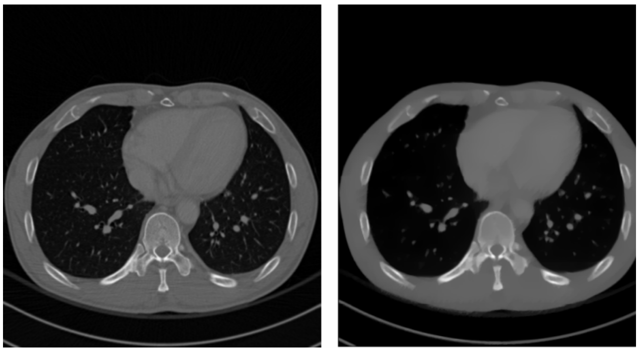
This section proposes the method of segmentation that incorporates four main steps. First, the image is smoothed with an anisotropic diffusion filter. The whole body is segmented from CT, and the contour of skin is extracted. Finally, bone is segmented by iterative thresholding.

2.1 Smooth Image with Anisotropic Diffusion Filter

This step involves smoothing the input images using an anisotropic diffusion filter [4], which minimizes the total variation (TV).

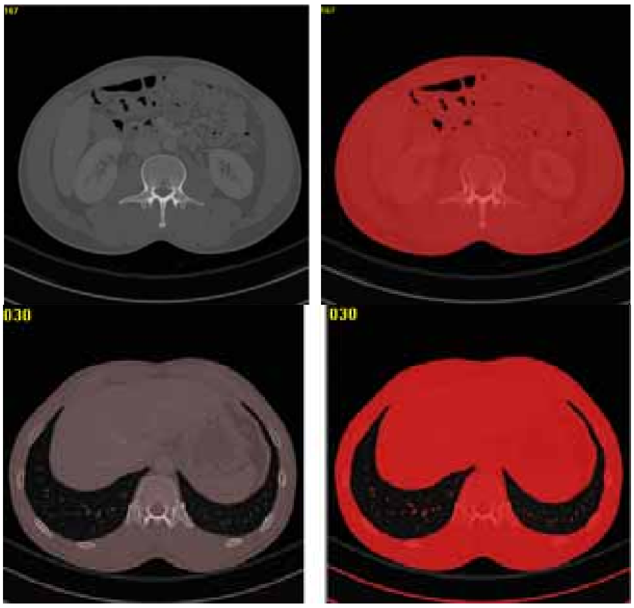
$$\min TV = \int_{\Omega} \sqrt{u_x^2 + u_y^2}\, dxdy \qquad (1)$$

where u is an image, u_x and u_y are the derivatives of u with respect to x and y, respectively. This method reduces the image noise without removing the important parts, such as edges or features compared to isotropic filters, e.g. Gaussian filter [see Fig. 1]. To minimize Eq. (1), the Euler-Lagrange equations were used as follows:



(a) (b)

Fig. 1. Smoothed CT image (a) Original image, (b) Filtered image.



(a) (b)

Fig. 2. Extraction of the whole body (a) Original image, (b) Mask of the whole body.

$$\frac{\partial}{\partial x}\left(\frac{u_x}{\sqrt{u_x^2+u_y^2}}\right)+\frac{\partial}{\partial y}\left(\frac{u_y}{\sqrt{u_x^2+u_y^2}}\right)-\lambda_1-\lambda_2(u-u_0)=0,\ in\,\Omega \quad (2)$$

A parabolic equation with the gradient descent method and the numerical method were used to solve Eq. (2).

2.2 Extract the Whole Body

To segment the skin and the bone, it is necessary to extract the whole body, which includes the hard and soft tissues, such as skin, bone, muscle, and other organs. The whole body was extracted using Otsu's thresholding method [5] [see Fig. 2]. Otsu's method is the most popular method for automatic thresholding. This method finds the threshold that minimizes the variance within the class, i.e., maximizes the variance between classes.

$$\sigma^2_{\omega}(t)=\omega_1(t)\sigma^2_1(t)+\omega_2(t)\sigma^2_2(t) \quad (3)$$

where ω_i are the weights separated by a threshold, t, and σ^2_i is the variances of these classes. This is computed iteratively until the variance is minimized. Fig. 2 shows that the body is extracted using Otsu's method. Because the body including many soft tissues has higher intensity (gray color) than the background or lung (black color), it assumes that there are only two classes in the image, i.e. the body and background.

2.3 Segment and Extract Contour of Skin

In this step, the skin was segmented and the contour of the skin was extracted with morphological operators and CCL [6]. CCL is a method based on graph theory and a heuristic approach. This method detects the connected regions in the binary image and gives labels to the objects (i.e. components) in the image. A two-pass algorithm was used for CCL. In the first pass, temporary labels were assigned and equivalences to the components were recorded. In the second pass, they were replaced with the smallest label of its equivalence class. The components, i.e. organ and background, were distinguished by CCL.

The mask still has an unnecessary region, such as the pad of the CT device. This region was removed by an opening operation and CCL, and the hole, which represents lung, was filled using the growing region [7]. Region growing is a region-based image segmentation method; it has a point, line or region for the seed. To fill the hole, i.e. lung, a seed point was set and expand the region was expanded from the seed. The contour of the skin was extracted with a Prewitt filter [6] [see Fig. 3].

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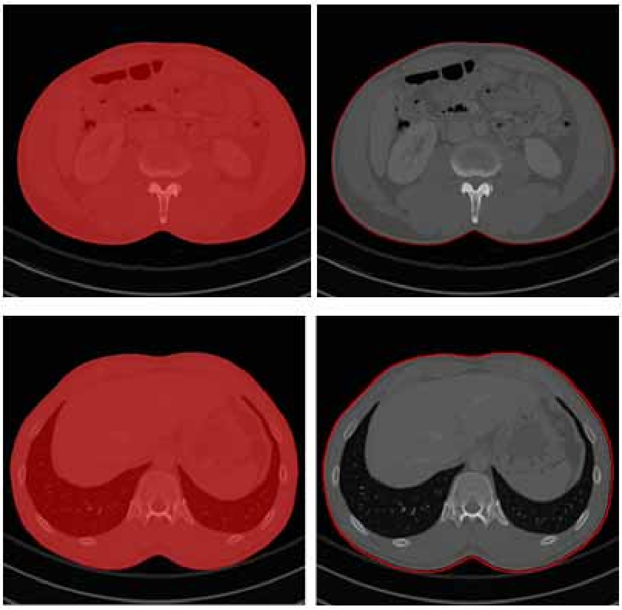
Seeded region growing algorithm

 Label seed points with initial label
 Put neighbors of seed points to the queue

 While the queue is not empty
   Take first data x from queue
   Remove x
   Check the neighbors of x
       If all neighbors of x have labels and
       they are all same :
          Set x to this label
          Change the mean of current region
          Add unlabeled neighbors of x to
           the queue
       Otherwise :
          Flag x with the boundary label
 End while
```

2.4 Segment Bone with Iterative Thresholding

In this step, the bone was segmented from the CT images using an iterative thresholding method. Otsu's thresholding, which is similar to the previous step, was applied twice in this step. The first thresholding step extracts the whole body, and second involves thresholding within this whole body segment bone region [see Fig. 4].



(a) (b)

Fig. 3. Extraction of the contour of the skin (a) Hole filled mask of the whole body, (b) Contour of the skin.

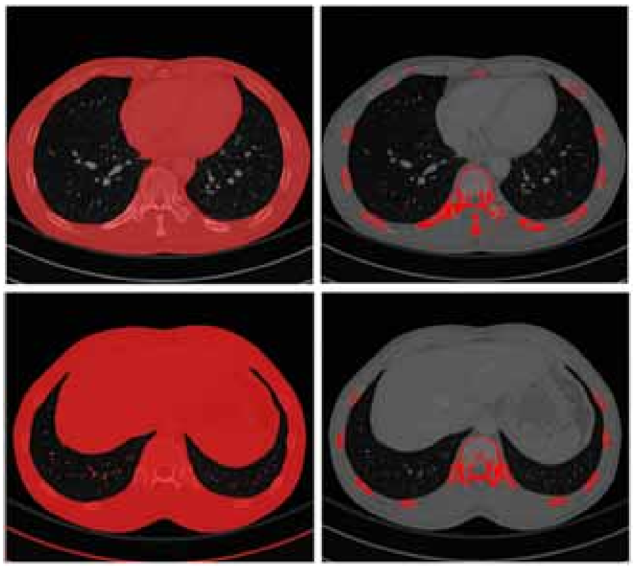


Fig. 4. Extraction of the bone (a) Mask with first thresholding, (b) Mask with second thresholding.

3. Experimental Results

The proposed method was tested using an Intel® Core™2 Quad 3.4 GHz processor with 16 GB of main memory. This method was implemented using Microsoft Visual Studio 2008 without the help of other open-source libraries. The skin and bone were segmented from twenty clinical CT images, each acquired from a different patient. All the test datasets were obtained using a CT scanner by Siemens. Each image had a matrix size of 512 x 512, and the number of images per scan ranged from 222 to 275. The voxel size was 0.66 x 0.66 x 1.51 mm. To represent the results in more detail, the iso-surface was extracted using a marching cube algorithm [8] and 3D mesh data was rendered [see Fig. 5].

Table 1. Computational Time.

Data	Time for each step (sec)			
	Smoothing	Skin seg.	Bone seg.	Total
1	4.868	0.624	0.513	6.005
2	5.647	0.656	0.554	6.857
3	4.968	0.630	0.521	6.119
4	6.088	0.663	0.575	7.326
5	3.852	0.585	0.463	4.900
6	7.078	0.743	0.652	8.473
7	6.519	0.689	0.567	7.775
8	6.331	0.670	0.551	7.552
9	6.403	0.674	0.563	7.640
10	4.419	0.609	0.517	5.545
11	4.949	0.626	0.524	6.099
12	6.411	0.686	0.575	7.672
13	6.762	0.722	0.623	8.107
14	7.215	0.759	0.646	8.620
15	5.558	0.641	0.533	6.732
16	6.403	0.674	0.552	7.629
17	7.317	0.763	0.621	8.701
18	6.748	0.716	0.614	8.078
19	6.776	0.733	0.622	8.131
20	6.147	0.669	0.555	7.371

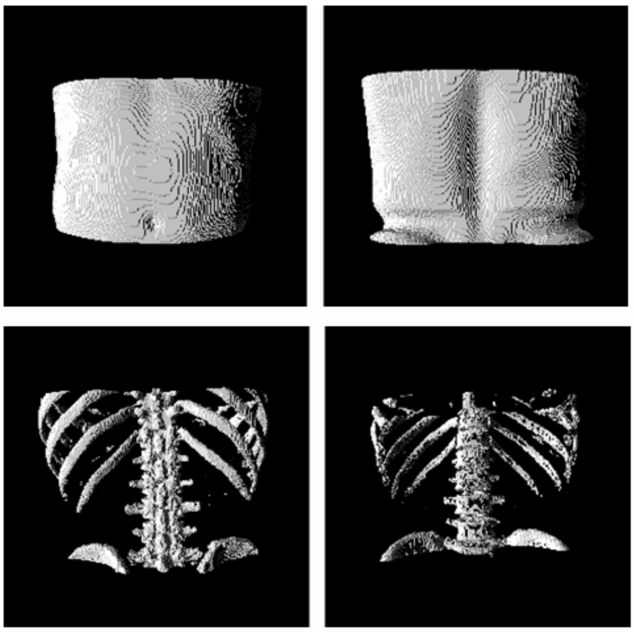


Fig. 5. Results of the iso-surface extraction from skin and bone mask (a) Results of the extraction of the skin, (b) Results of the extraction of the bone.

4. Conclusion

This paper presented a segmentation method of skin and bone using morphological operations and iterative thresholding. In the first step, the images were smoothed by applying an anisotropic diffusion filter to remove noise. In the second step, the whole body was detected by thresholding, which was set automatically. In the third step, the contour of the skin was segmented using morphological operators, seeded region growing and connected component labeling (CCL). Finally, the bone was extracted by iterative thresholding. These results were confirmed by extracting the iso-surface. Future studies will aim to improve this segmentation method to make it more robust in the images with considerable noise and distortion.

This method is expected to be used the preprocess in the others organ segmentation.

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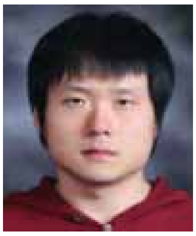

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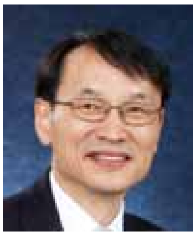

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