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Organs Extraction using three Dimensional Mathematical Morphology

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Abstract

In this paper, we propose a method to automate the extraction of organ areas from computing tomography (CT) images using three dimensional mathematical morphology. Morphological segmentation provides us the theory and tools to analyze shapes directly. This characteristic leads itself well to analyzing and extracting organ areas according to size and grey level features. After a system for three dimensional morphological processing was built, we employed a new approach, Differential Top-hats, to our new three dimensional organ extraction system. The experimental results show that organ areas can be extracted automatically with a success rate of 96%.

1 Introduction

Currently, several kinds of medical images such as CT, PET(Positron Emission Tomograph), SPECT(Single Photon Emission CT) and MRI are easily obtained under favor of rapid development of medical instruments. These kinds of medical images provide us so much physical information that make the applications of computer-supported diagnosis and medical treatment more and more popular.

Even if there exist several kinds of researches on the medical images using image processing and pattern recognition techniques, somehow the medical images are not easy to be dealt with, especially the three dimensional internal images. Although the automatic organ extraction and recognition are most important for a image generation, storage and archiving, reference and representation which are regarded as the basic techniques of construction of computer-supported diagnosis systems.

Most of the presented organ extraction and recognition approaches are not only involving many manual operations, but also using some particular algorithms, such as region growing [1] and skeleton method [2, 3], to deal with parts of special organs. In this paper, we propose a method to automate the extraction of the whole organ areas from CT images using three dimensional mathematical morphology. After a system for three dimensional morphological processing was built, we employed a new approach, Differential Top-hats Transformation(DTT), to our new three dimensional organ extraction system.

The entire procedure can be divided into two steps: segmentation processing and reconstruction processing. In the first processing, we propose a new morphological segmentation algorithm DTT which was derived from top-hats idea and morphological recursive operation. We apply it to segment original three dimensional CT data according to its size and grey information. The next processing is reconstruction processing. Its primary objective is to remove noises and reconstruct correct organ regions. In this processing, we propose a morphological filter based on conditional dilation idea.

The organization of this paper is as follows: In the section 2, after a brief overview of three dimensional morphological operations are described, the new morphological segmentation approach DTT is presented. Section 3 describes the details of our organ extraction implementation. Experimental results are discussed in section 4, and the conclusion in section 5.

2 3-Dimensional morphology

2.1 Basic definition

The three dimensional morphology is derived from two dimensional theory. It also include 3D Dilation, Erosion, Opening and Closing. If E^3 represent a 3D Euclidean space, f(x,y,z)((x,y,z)∈F, F∈ E^3) denotes a 3D grey image and k(u,v,w)((u,v,w)∈K, K∈ E^3)

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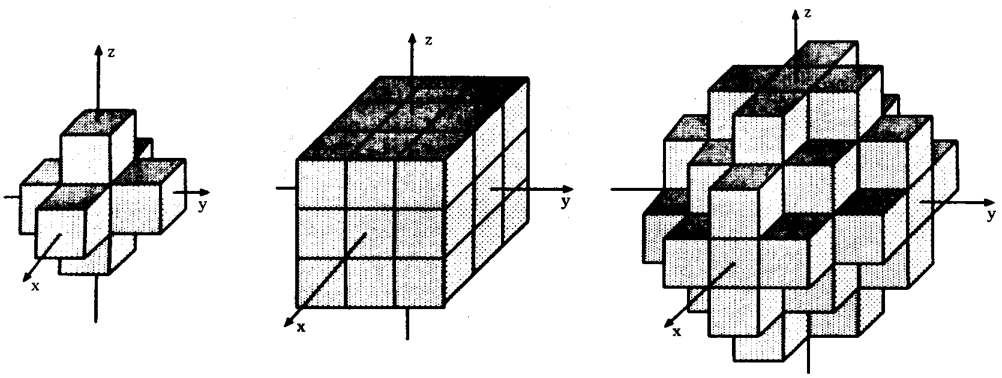

Octahedron(r=1) Cube(r=1) Sphere(r=2)

Figure 1: The composition of spheres: $r_2 K_{sphere} = r_1 K_{octahedron} \oplus r_1 K_{cube}$

denotes a 3D structure element, the four basic operations denoted as $D_k(f), E_k(f), O_k(f), C_k(f)$ are defined as following:

$$\begin{aligned} D_k(f) &= f(x,y,z) \oplus k(u,v,w) \\ &= \max_{\substack{(u,v,w)\in K \\ (x-u,y-v,z-w)\in F}} \{f(x-u, \\ &\quad y-v, z-w) + k(u,v,w)\} \end{aligned} \tag{1}$$

$$\begin{aligned} E_k(f) &= f(x,y,z) \ominus k(u,v,w) \\ &= \min_{\substack{(u,v,w)\in K \\ (x+u,y+v,z+w)\in F}} \{f(x+u, \\ &\quad y+v, z+w) - k(u,v,w)\} \end{aligned} \tag{2}$$

$$\begin{aligned} O_k(f) &= f(x,y,z) \circ k(u,v,w) \\ &= f(x,y,z) \ominus k(u,v,w) \oplus k(u,v,w) \end{aligned} \tag{3}$$

$$\begin{aligned} C_k(f) &= f(x,y,z) \bullet k(u,v,w) \\ &= f(x,y,z) \oplus k(u,v,w) \ominus k(u,v,w) \end{aligned} \tag{4}$$

Since the 3D morphological operations are distinguished into binary and grey scale operations, in this paper we employ $\oplus, \ominus, \circ, \bullet$ denoting binary operations, when $\oplus_g, \ominus_g, \circ_g, \bullet_g$ denoting grey scale operations.

2.2 Top-hats transformation(TT)

The gray-scale original image F_0 opened by a structure element $r_i K$ can remove the bright areas which cannot contain the structure element, and subtracting the opened image from the original one yields an image where the bright objects clearly stand out. The transformation described in (6) is called "white top-hat" transformation (WTT). A closed original image in gray-scale subtracting original one allows us to extract dark objects from bright background, which is called "black top-hat" transformation (BTT) and defined in (7).

$$T_i^{(i)} = \begin{cases} T_i & if\ WTT \\ T^i & if\ BTT \end{cases} \tag{5}$$

$$T_i = F_0 - F_0 \circ_g r_i K \tag{6}$$

$$T^i = F_0 \bullet_g r_i K - F_0, \tag{7}$$

2.3 Differential TT (DTT)

For some complicated images, especially those in which the target objects are combined in a nonuniform background, it's difficult to segment interested particles satisfactorily. Clues for detecting features were discovered when we applied TT with different sizes of disk structure elements. The difference between $T_i^{(i)}$ and $T_{i-1}^{(i-1)}$ includes our interested objects, and that image can be easily thresholded to make features stand out[4].

$$\begin{aligned} F_i &= |T_i^{(i)} - T_{i-1}^{(i-1)}|_B - F'_{i-1} \\ F'_i &= \bigcup_{1\le j\le i} F_j; \quad F'_1 = \emptyset \end{aligned} \tag{8}$$

where the original image is denoted by F_0, and segmented images which hold different sizes of objects are denoted by F'_i. The differences between the neighboring TT results up to i are united together in F'_i with a certain size of features

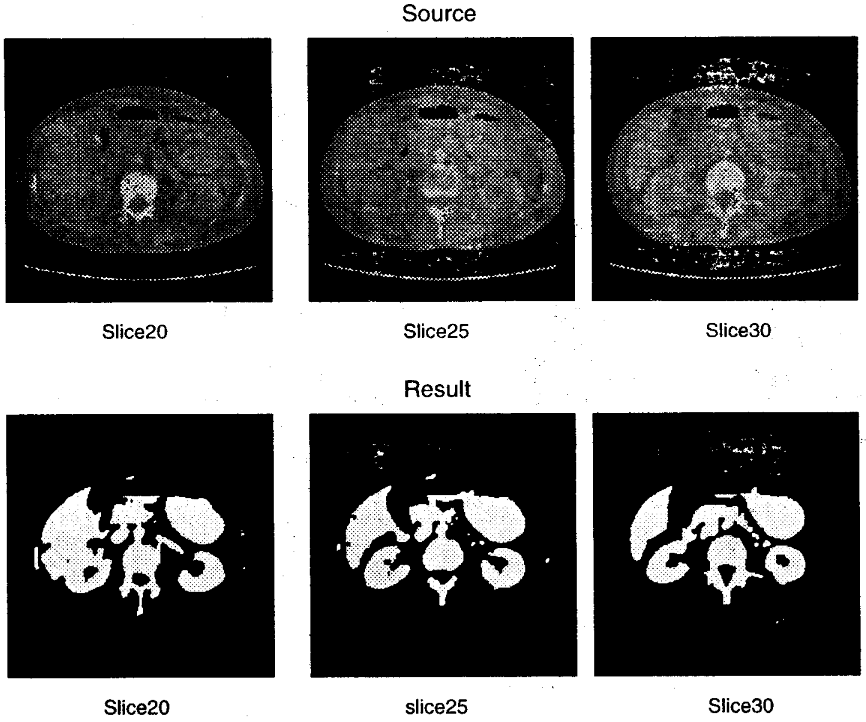

Figure 2: Examples of source and result images

2.4 Structure element

We employed a series of spheres as the structure elements in this research. Since they have not directional features, spheres should be efficient with different shapes of organs. The series of spheres can be composed by the following functions:

$$r_i K_{sphere} = r_{i-1} K_{sphere} \oplus S \ (i\ times) \qquad (9)$$

$$S = \begin{cases} r_1 K_{cube} & if\ i = 2n \\ r_1 B_{octahedron} & if\ i = 2n-1 \end{cases} \qquad (n \geq 1)$$

An example of the composition is shown in Fig.1

3 Organs extraction system

3.1 Segmentation processing

The 3D CT data F_0 was segmented by the following DTT filter where the sub-image F_i was opened by a small structure element$r_{(i-2)}K_{sphere}$ to remove small noises.

$$\begin{aligned} F_i &= |T_i - T_{i-1}|_B - F'_{i-1} \\ F'_i &= \bigcup_{1\leq j\leq i} (F_j \circ_g r_{(j-2)} K_{sphere}) \qquad (10) \\ F'_1 &= \emptyset \\ T_i &= F_0 - F_0 \circ_g r_i K_{sphere}, \end{aligned}$$

where, $|D|_B$ denotes a threshold operation by a defined grey level which is determined experimentally. The segmented results were collected into F'_i. Since the organ regions are brighter than the background, we only employed WTT in this processing.

3.2 Reconstruction processing

In this processing, the segmented sub-image F'_i were opened by a sphere structure element $r_5 K_{sphere}$ to delete separated noises, and then the same structure element was employed to reconstruct the organ regions using conditional dilation algorithm.

$$\begin{aligned} M &= F'_i \circ r_5 K_{sphere} \qquad (11) \\ R_j &= (M \oplus r_5 K_{sphere}) \cap |F_0|_B \\ if &\quad R_j = R_{j-1}\ then\ stop \end{aligned}$$

Where, the $|F_0|_B$ denotes a thresholded source 3D image by a grey level determined experimentally.

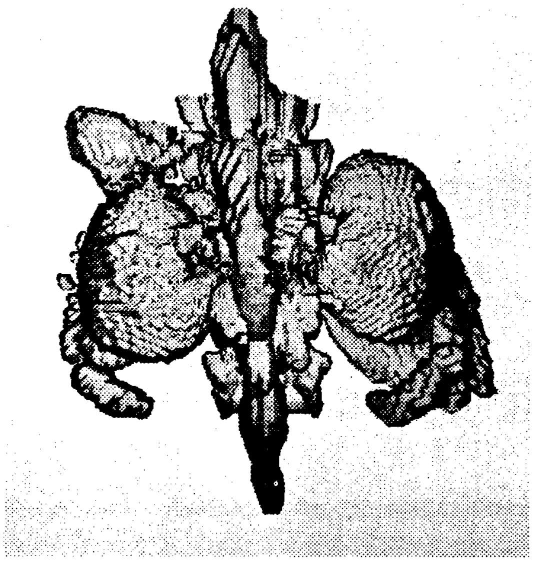

Figure 3: 3D representation image based on the binary result

4 Experimental results

we employed a 3D CT volume data with size of 256 x 256 x 100 pixels and $2mm$ slice distance in our experiment.

Preliminarily, we built a 3D morphological image processing system for the experiment. This system involve 3D morphological functions, 3D arithmetic functions, 3D logical functions and expanded I/O functions available to dealing 3D CT images. The experiments were implemented upon this system.

In the segmentation processing, We employed a series of sphere structure elements from radius 1 to 14. According to our inspection about the scale of organ regions in the CT image, we found that the largest organ region was not wider than 29 boxel (The diameter of $r_{14}K_{sphere}$). All the segmented sub-images were collected into F'_{14}. This result was pushed into the reconstruction processing to be processed by the conditional dilation filter.

The examples of three slices of 3D grey source CT image and their final results are shown in Fig.2. We want address here that the whole processing was implemented in 3D not in 2D slice images. An example of 3D represented image based on the binary result is shown in Fig.3.

After a inspection with three experimental results, we found that the average extraction rate of our system was 96% where the result was obtained by overlapping all the source slice images with their result images to estimate them by eyes. The experimental results show the effectivity of the proposed approach. There remained some problems that the system cost a long computing time (about 3 hours per process) and required a big size of memory so far.

5 Conclusion

In this paper, we proposed a new approach to automatically extract organ regions from 3D CT images using mathematical morphology. We presented a new morphological segmentation method DTT and applied it to our new organ extraction system. The proposed system was verified by our experiment showing that 96% of the organ regions were extracted correctly.

As our future work, we want to improve the system to save the computing cost and recognize the organs by labeling processing.

Acknowledgment

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