SEGMENTATION AND EXTRACTION OF TEETH FROM 3D CT IMAGES

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ABSTRACT

This paper describes an automatic 3-dimensional (3D) segmentation method for 3D CT (Computed Tomography) images using region growing (RG) and edge detection techniques.

Specifically, an augmented RG method in which the contours of regions are extracted by a 3D digital edge detection filter is presented. The feature of this method is the capability of preventing the leakage of regions which is a defect of conventional RG method.

Experimental results applied to the extraction of teeth from 3D CT data of jaw bones show that teeth are correctly extracted by the proposed method.

Keywords: 3D-CT image recognition, Region Growing method, Teeth extraction

1. INTRODUCTION

CT or MRI (Magnetic Resonance Imaging) is an effective tool for medical diagnosis because it enables us to observe internal organs without dissecting bodies. In the progress of CT, 3 dimensional CT (3D CT) such as a helical scanning CT and a multi-detector raw CT have been developed. With the use of 3D CT, 3D shapes of organs can be observed from several viewing directions. Then, physicians can easily grasp the 3 dimensional shapes of internal organs by changing his viewing directions. However, the quantity of 3D CT data is much larger than that of 2D CT data. Then, highly automated and effective 3D extracting and reconstruction techniques of internal organs are required.

To extract 3D shapes of internal organs from 3D CT images, several image processing techniques have been developed. Regions growing method is one of the effective segmentation techniques. But conventional RG method has the following defects.

(1) Extracted regions are strongly affected by the threshold value for segmentation.

(2) A break point on a region contour yields a leakage of region (unfavorable conjunction of inner and outer regions).

To overcome these defects of conventional RG method, we proposed an augmented region growing method (ARG) which combines a region growing technique and an edge detection technique. Namely, the shapes of internal organs are extracted by 3D RG method. At the same time, the contour of region is determined by the edge information of regions. Experimental results show that 3D shapes of organs have been extracted precisely (without unfavorable leakage of regions) by this method.

2. 3D IMAGE PROCESSISNG FOR 3D CT DATA

2.1 Acquisition of 3D CT data

In general, 3D CT data are expressed by orthogonal XYZ coordinates. Object images are given by the brightness values of pixels defined on the XYZ coordinates. In order to express the shape of objects with high fidelity, pixels in XYZ coordinates are equally spaced along the 3 axes.

On the other hand, there are two methods to get 3D CT data.

(1) Axial piling up of 2D CT images

(2) Helical scanning by 3D CT

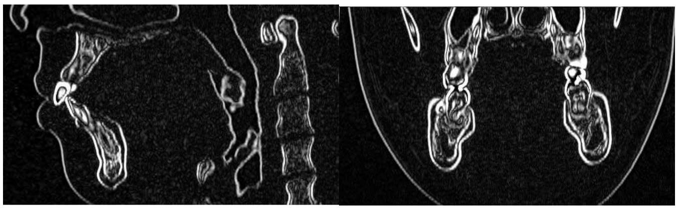
In method (1), adjacent two 2D CT planes are required to be placed with a unit interval each other along the piling axis. If the adjacent two 2D CT planes are not equally spaced with a unit interval of other axes, the interpolations techniques are applied to their planes.

In method (2), pixel values defined by the cylindrical coordinates of helical scanning are transformed to the pixel values defined by orthogonal XYZ coordinates.

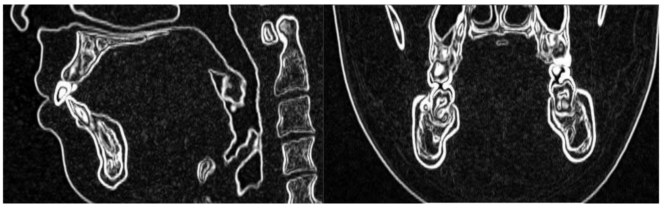
2.2 3D digital filters

In most of the conventional region extraction methods from 3D CT data, object regions are extracted from 2D CT planes as 2D regions by 2D digital filters. And they are piled up three-dimensionally. In this method, however, the region edge planes perpendicular to the piling axis can not be extracted correctly. Figure 1 (a) shows the defect of this process. Namely, the region edges in vertical direction are insufficiently extracted.

On the other hand, region extraction by 3D digital filters can extract the region edges of all directions correctly. Figure 1(b) shows the region extraction result by 3D digital filters. The region edges in vertical directions are extracted correctly. Then 3D digital filters were used to extract the region edges in our method.



(a) By 2D filters



(b) By 3D filters

Fig. 1: Edge extraction by digital filters

As 3D digital filter, 3D Sobel filter is effective. Figure 2 shows the weight patterns for 3 directions of Sobel filer.

Figure 2 3D Sobel filter

-1	0	1		-2	0	2		-1	0	1
-2	0	2		-3	0	3		-2	0	2
-1	0	1		-2	0	2		-1	0	1

(a) X-axis

1	2	1		2	3	2		1	2	1
0	0	0		0	0	0		0	0	0
1	-2	-1		-2	-3	-2		-1	-2	-1

(b) Y-axis

1	2	1		0	0	0		-1	-2	-1
2	3	2		0	0	0		-2	-3	-2
1	2	1		0	0	0		-1	-2	-1

(c) Z-axis

3. REGION GROWING METHOD USING EDGE INFORMATION

3.1. Augmented Region Growing method

In general, region is composed with the following pixels.

(1) They are adjacent each other.

(2) Their pixel values (CT values) or textures are similar.

Using these characters, the following methods can be considered.

(a) Region growing method: Comparing the pixel value of an object pixel with those of adjacent pixels, the pixels are merged into one region when the differences between their values are within a threshold.

(b) Edge extraction method: Comparing the pixel value of an object pixel with those of adjacent pixels, the pixels are extracted as edge pixels when the differences between their values exceed a threshold.

Method (a) can extract relatively large regions because small fluctuations of pixel value are ignored. On the other hand, relatively small regions are also merged into one region.

Method (b) can extract relatively small regions because the local difference of adjacent pixel values is detected. However, this method is vulnerable to noise and extracted edges have often many break points.

As mentioned above, method (a) and (b) have complementary characters. Then, we propose an augmented region growing method (ARG) which combines these two methods. Namely, pixels with similar pixel values are merged into one region by “region growing method” and the edges of regions are extracted by “edge extraction method”. Specifically, the following criteria are applied in our method.

(i) Adjacent pixels are redeemed as merging candidates when their pixel values satisfy the inequality (1).

$$\left| f_x - f_0 \right| < a \quad (1)$$

where f_x, f_0 : pixel values of adjacent pixels and that of object pixel, respectively.

(ii) Zero cross point pixels of the output images by 3D differential filter are redeemed as edge pixels.

By this method, adjacent pixels with similar pixel value are merged into one region and the pixels with large difference values are extracted as edge pixels.

3.2 Features of ARG

We examined the efficacy and precision of ARG method by a simple artificial 3D model (Figure 3). This model is composed of 3 co-centric spherical zones R_1, R_2 and R_3 which have different CT values and different thicknesses. Each zone is separated by gaps with different thicknesses. It can be useful for testing the region extraction capabilities of segmentation methods. Furthermore, Gaussian noise (the mean: 0, standard deviation: 20.0) was added to this model in order to test the robustness of extraction methods to noise.

The purpose of this experiment was to extract region R_1 correctly. Here, we compared the segmentation capabilities of the following three methods (b) -(d) for this artificial 3D CT image (a). Figure 3 (a) – (d) show the sliced images of artificial model and images processed by three methods.

(a) Original image with Gaussian noise

(b) Region growing method

(c) Edge extraction method

(d) Augmented region growing method.

The same parameters were employed for all of these experiments.

In case of method (b), both R_1 and R_2 regions were extracted as one region because of the noises between R_1 and R_2 regions. The leak of the processing may be avoided by how to choose processing parameters. But, it is necessary to set a parameter extremely closely. In case of method (c), R_2 and R_3 were merged because of the crack in the contour of R_2. However, in case of method (d), target region R_1 was extracted correctly. Namely, ARG method can extract R_1 precisely by complementary use of region and edge information.

The extracted volume of R_1 was 24,200 against the correct volume 24,113 of original image. Then the extraction error about region volume was about 0.36%.

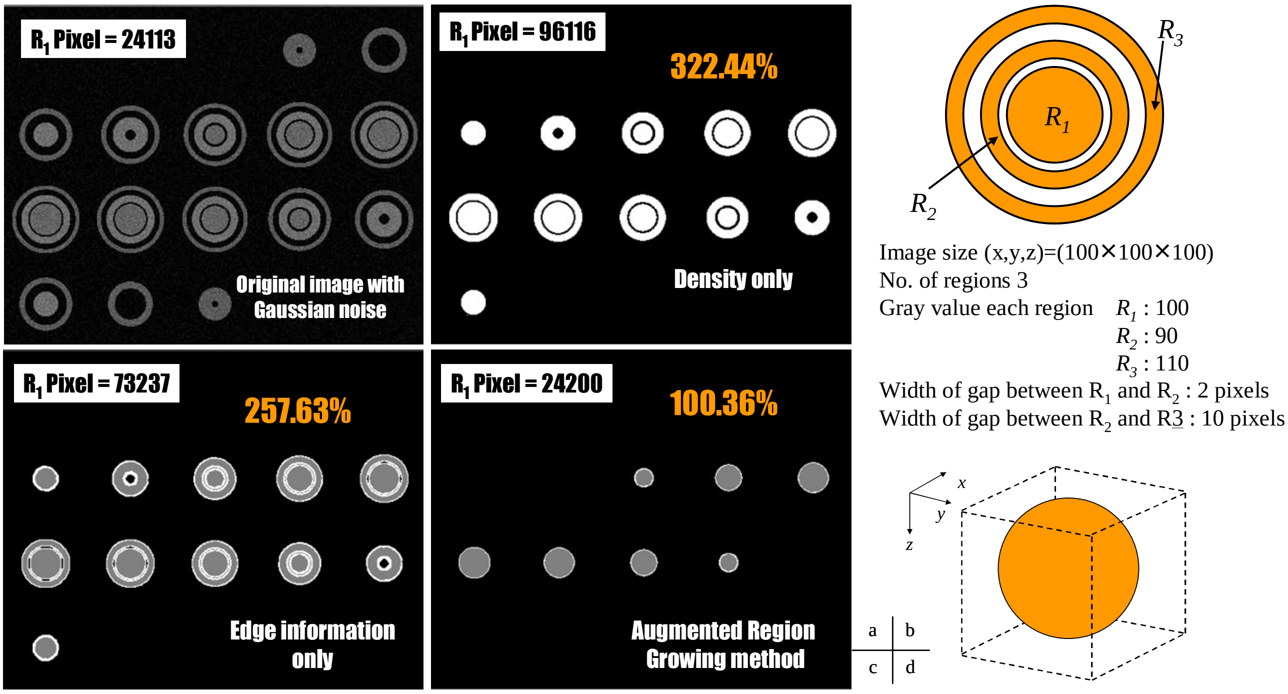


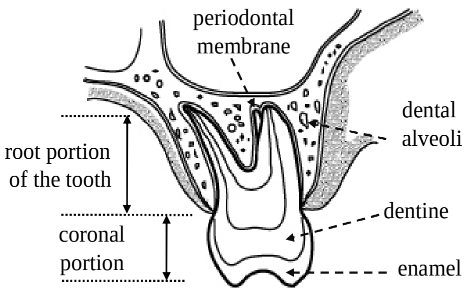
Fig. 3: Artificial 3D CT image

4. SEGMENTATION EXPERIMENT OF TEETH

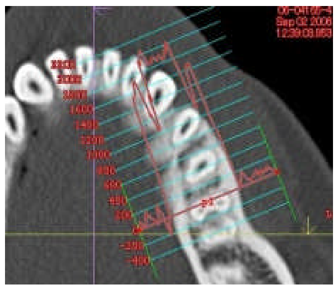
Proposed ARG method was applied to the segmentation and extraction of teeth from 3D CT data of jaw bones. A tooth is composed with coronal portion which is often called as a tooth crown and root portion (Figure 4(a)). Tooth crown is covered with tooth enamel which has higher CT values than 2500HU. Therefore, a tooth crown can be extracted only by a threshold processing. Tooth enamel is contact with air and mucous membrane of oral cavity but it does not contact with other osseous tissues. In our ARG method, a pixel on the tooth enamel was adopted as the starting point of region expansion process.

ARG method can detect a periodontal membrane which separates a dentin and an alveolar bone by the difference of CT values between them. Namely, a dentin and an alveolar bone have relatively high CT values, but CT values of an alveolar bone are lower than that of a dentin. The red line in Figure 4(b) shows the variation of CT values on the cross section of dentine and alveolar bone. As shown in Figure 4(b), a periodontal membrane between a dentin and an alveolar has a very low CT value because a periodontal membrane is composed of a ligament which contains much water. Then, a periodontal membrane can be detected by comparing the CT values. Namely, a large density difference occurs between ligament and bones. In order to get a correct edge between ligament and bones, 3D filters are applied. Finally, employing the edge information of a periodontal membrane, we can extract a region of teeth precisely.

Figure 5 shows the comparison of extracted results by ARG and that of conventional methods. In 2D method (Figure 5(b)), all tooth region are not necessarily extracted. In conventional 3D method, some ligament regions are also extracted. But in ARG method (Figure 5 (c)), only tooth crowns are extracted correctly.



(a)anatomical chart of tooth

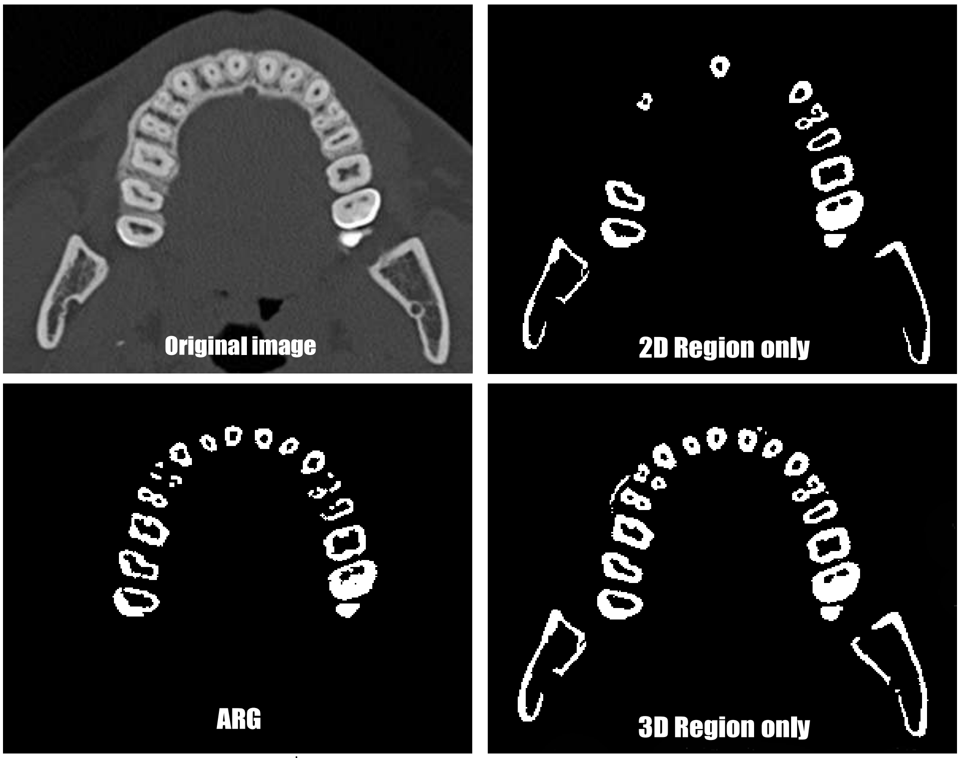


(b)CT value of tooth and alveolar

Figure 4 Extraction of teeth

Figure 6 shows the 3D images of teeth from frontal view point, which were obtained by two methods: conventional RG and ARG methods. Dental roots were not extracted correctly by conventional RG method because of remarkable changes of pixel values. Furthermore, the pixel values of internal organs may not be uniform. Then, partial volume effect also may affect the results. In case of no use of edge information, even a lower jaw was also extracted because of a leakage of regions (Figure 6 (a)).

On the other hand, tooth crown and dental roots were extracted correctly by ARG because of leakage prevention ability (Figure 6 (b)).



a	b
c	d

(a) Original image (b) 2D RG method
(c) ARG (d) conventional methods.

While structures in dentistry field are quite small and complex, the spatial resolution of CT image is not high. This is one of main factors which make the segmentation of dentistry CT images difficult. The early appearance of high-resolution CT for dentistry field is expected.

5. CONCLUSION

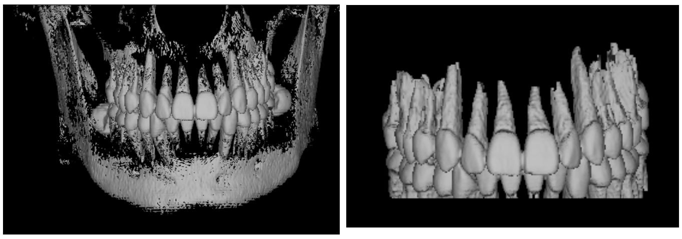
This paper proposed a 3D segmentation method of 3D CT images using region growing and edge detection techniques. As a fully 3D process was adopted in this method, the problems of data transfer between sliced CT planes have been solved.

Our technique can extract plural teeth of complicated shape at a time. Because our technique employ both region and edge information, it can extract a narrow region. Therefore it can detect periodontal membrane which is a narrow region between teeth and alveolar bones.

The features of this method are summarized as follows.

(1) Relatively precise segmentation result can be obtained.
(2) Determination of threshold parameter for RG method is relatively easy because of the usage of edge information.
(3) Algorithm is comparatively simple.
(4) Employing the anatomical knowledge for tooth, precise segmentation is attained.

We are going to apply the proposed method to clinical tests hereafter.



(a) Conventional RG method (b) ARG method

Fig. 6 Front image of teeth extraction

REFERENCES

[1] Mehnert and P. Jackway: “An improved seeded region growing algorithm”, Pattern Recogn. Lett., vol. 18, pp. 1065.1071, 1997.

[2] Hao JIANG at el: “A Segmentation Method Based on Region Information and Edge Information” IEICE 91/12Vol.J74-D-II No.12

[3] Hao JIANG at el: “Automated segmentation of MRI head images by 3-D region growing method which utilizes edge information“, Bio Medical Engineering, 29, 3, pp.170-177 (1991.9)

[4] KANDA Ken-ichi at el:, ”Extraction of organs using region-growing method with knowledge of opposed domains and its application”, IEICE, Vol.101, No.434(20011109) pp. 45-52

[5] Yan Kang; Engelke, K.; Kalender, W.A.: “A new accurate and precise 3-D segmentation method for skeletal struCTures in volumetric CT data”, Medical Imaging, IEEE TransaCTions onVolume 22, Issue 5, May 2003 Page(s): 586 – 598

[6] M. Aizawa and S. Murakami at el: “Teeth on CT images by Region Growing Method using Combination of Region and Edge Information“ JSOMR,49th academic conference