35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

Automatic Dental Arch Detection and Panoramic Image Synthesis from CT Images

Vera Sa-ing, Kongyot Wangkaoom, and Saowapak S. Thongvigitmanee

Abstract— **Due to accurate 3D information, computed tomography (CT), especially cone-beam CT or dental CT, has been widely used for diagnosis and treatment planning in dentistry. Axial images acquired from both medical and dental CT scanners can generate synthetic panoramic images similar to typical 2D panoramic radiographs. However, the conventional way to reconstruct the simulated panoramic images is to manually draw the dental arch on axial images. In this paper, we propose a new fast algorithm for automatic detection of the dental arch. Once the dental arch is computed, a series of synthetic panoramic images as well as a ray-sum panoramic image can be automatically generated. We have tested the proposed algorithm on 120 CT axial images and all of them can provide the decent estimate of the dental arch. The results show that our proposed algorithm can mostly detect the correct dental arch.**

I. Introduction

In general, X-ray panoramic and intraoral radiographs are commonly used in dental applications; however, they contain only 2D information and superimposition of anatomic structures. Due to accurate 3D information of inner structures, cone-beam computed tomography (CBCT) becomes popular in dental imaging. Although conventional medical CT can be used in this application, its radiation dose to patients is much higher [1]. A CBCT scanner uses a cone-shaped X-ray beam and an area detector. This technology has been widely used in dental applications such as treatment planning and diagnosis in dental implants, jaw reconstruction, and maxillofacial surgery [2].

In fact, 3D images acquired from any CT scanner can create simulated panoramic images similar to actual X-ray panoramic radiographs by using software. Typically, manual drawing of a dental arch to create simulated panoramic images is commonly used. To accommodate this task, several papers have researched on automatic dental arch detection. G. Hui and C. Oksam [3] proposed the automatic dental arch fitting; however, it cannot really detect a connection line between the teeth and the jaw. Han B. et al. [4] presented the fully automatic algorithm to produce the panoramic image from CT images; however, their results depended on the curve angle defined in the algorithm. T. Chanwimaluang et al. [5] presented the automated approach in the dental arch detection. Their algorithm cannot detect the dental arch when the image contains an empty space between teeth.

This work is supported by the National Science and Technology Development Agency (NSTDA).

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To overcome the previous problems, in this paper, we propose the automatic panoramic extraction algorithm to detect the dental arch from CT images. Our algorithm is based on downsampling, thresholding, and image morphology techniques. Once a single dental arch is achieved, other offset panoramic curves can be automatically generated to reconstruct a series of simulated panoramic images as well as a ray-sum panoramic image. As most dentists are familiar with X-ray panoramic radiographs, those simulated panoramic images acquired from CT data are usually required in clinical diagnosis. Moreover, they can provide a good overview of the inferior alveolar nerve canal in the mandible.

II. The Proposed Algorithm

The overall proposed system for automatic detection of a dental arch is illustrated in Fig. 1. First, we select a CT axial image in the mandible or maxilla areas and resize it to reduce the processing time of the detection. In the second step, the proposed algorithm uses the morphological closing to connect the neighboring components. Then thresholding and hole filling are applied to separate the object of interest from the background. After that, we employ the morphological thinning algorithm to compute the object of interest in one pixel wide. In addition, a curve line that has the maximum number of pixels is expected to be a curve. The curve fitting algorithm is applied to smoothen the curve. Finally, we create a panoramic image set and a ray-sum panoramic image from the result of curve fitting. The detail of the proposed algorithms will be explained below.

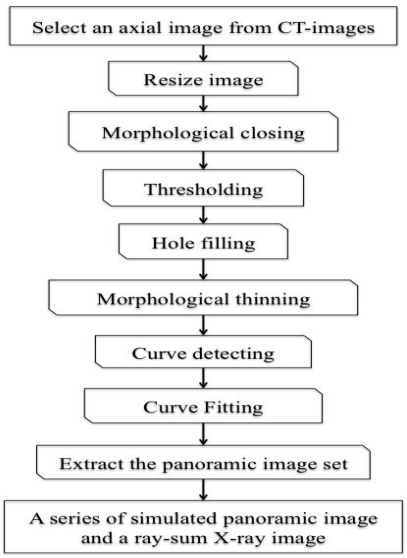


Figure 1. The overall process of the proposed algorithm

A. *Downsampling and Morphological Closing*

From the original CT image, as shown in Fig. 2(a), we resize this image by downsampling by 4 to reduce the processing time. The result of this process is shown in Fig. 2(b). Then, we apply the morphological closing operation [6] to close some opening elements in the resized CT image as shown in Fig. 2(c). For morphological closing, we used the circular-shaped structuring element to preserve the circular nature of the object. In addition, this process will also smooth the image.

B. *Thresholding and Hole Filling*

From the result of morphological closing, we apply a simple thresholding technique [7] according to the bone and teeth intensity to extract the object of interest, which is the teeth and jaw bone area (representing in the white color in Fig. 3(a).) Then we fill the holes that may exist in the binary image.

C. *Morphological Thinning and Selected the Curve*

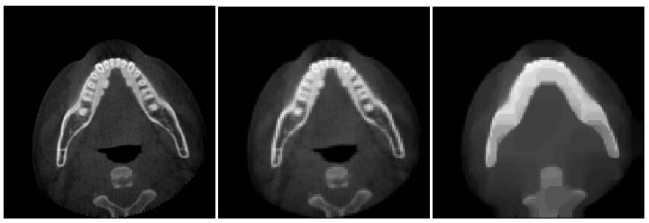
In this step, we apply the morphological thinning operation to obtain a one-pixel curve, as shown in Fig. 3(b). Since there might exist more than one curve, we need to determine only a curve that fits the dental arch the most. The selected curve should have the maximum number of pixels and a curve-like shape. The result of this step is shown in Fig. 3(c).

D. *Curve Fitting*

A curve of the dental arch we obtain from the previous step may not smooth enough, thus we apply the piecewise cubic curve fitting algorithm [8] to smoothen the curve as shown in Fig. 4(a). The resulting dental arch after curve fitting is plotted on the original CT image as shown in Fig.5.

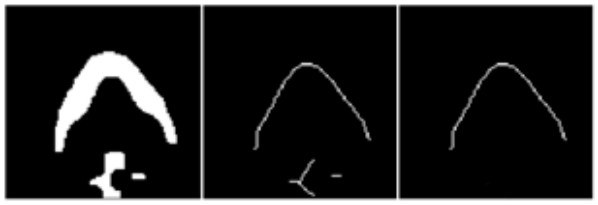
E. *Panoramic Image Set*

A series of simulated panoramic images consisting of based and offset curve can be generated from one dental arch. The panoramic based curve is in fact the dental arch we detect. The panoramic offset curves are generated by finding all points that are perpendicular to the points on the dental arch (Fig. 6). Then we can generate a series of simulated panoramic images from those curves as shown in Fig.7. A ray-sum panoramic image which resembles a 2D panoramic radiograph is computed by averaging over a set of panoramic images (Fig. 7).



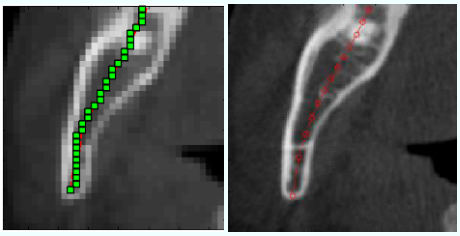
(a) (b) (c)

Figure 2. (a) The original image, (b) the resized image, (c) the image after morphological closing



(a) (b) (c)

Figure 3. The resulting images after (a) thresholding and hole filling (b) morphological thinning, and (c) curve detecting



(a) (b)

Figure 4.The results of the curves (a) before and (b) after curve fitting

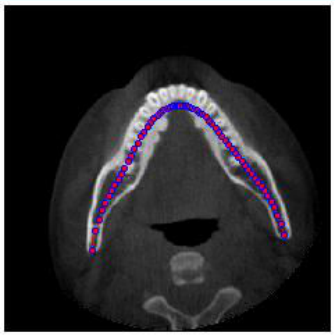


Figure 5. The curve fitting

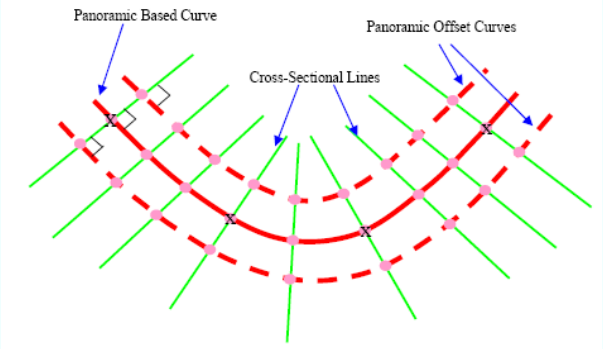
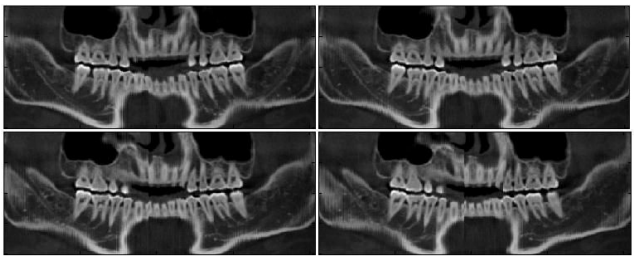
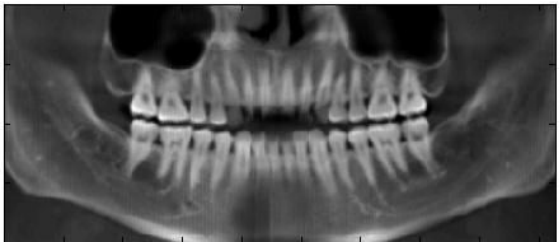


Figure 6. Panoramic based and offset curves



(a)



(b)

Figure 7. (a) A sample of panoramic images, and (b) a ray-sum panoramic image

III. Experimental Results

In this section, we test our proposed algorithms on the CT images. About 120 CT images have been tested and all of them can get good estimates of the dental arch. Some sample images for dental arch detection are illustrated as follows.

A. *Sample #1*

The first sample is to illustrate an axial slice that has linkage between jawbones and teeth in the image. This problem is easy to achieve. The process of the automatic extract dental arch is shown in Fig.8. Our proposed algorithm can detect the dental arch and extract the panoramic images set in the case that has no the space between components.

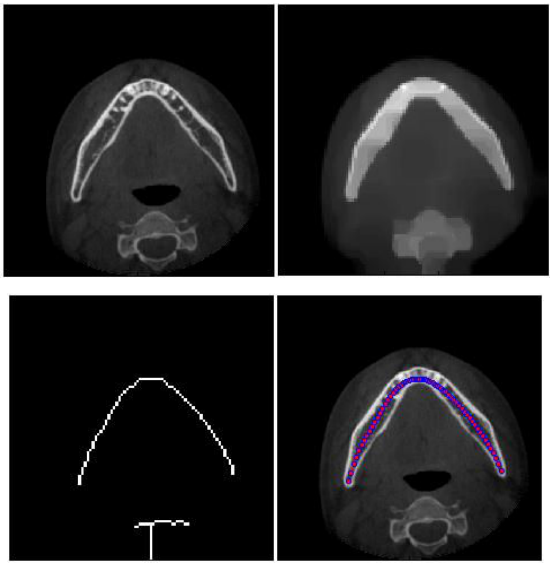


Figure 8. The dental arch detection of Sample #1

B. *Sample #2*

The second case is when the object of interest contains some small spaces between the teeth and jaw. These spaces separate the object as small fragments. With the morphological closing and hole filling techniques, we can successfully detect the correct dental arch. The process and the results of the dental arch detection in this situation are shown in Fig.9.

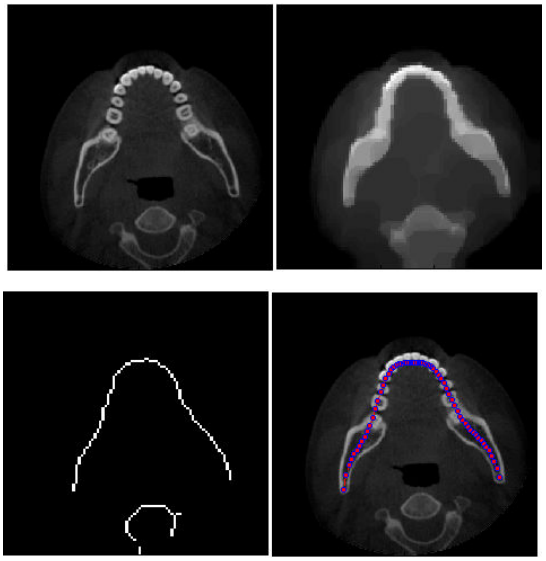


Figure 9. The dental arch detection of Sample #2

C. *Sample #3*

This sample is more difficult to extract the connected dental arch because it contains a large space between the teeth and the jawbone area in the image. Due to downsampling and morphological closing techniques, our proposed algorithm can obtain the correct dental arch. The results of each process in this experiment are shown in Fig. 10.

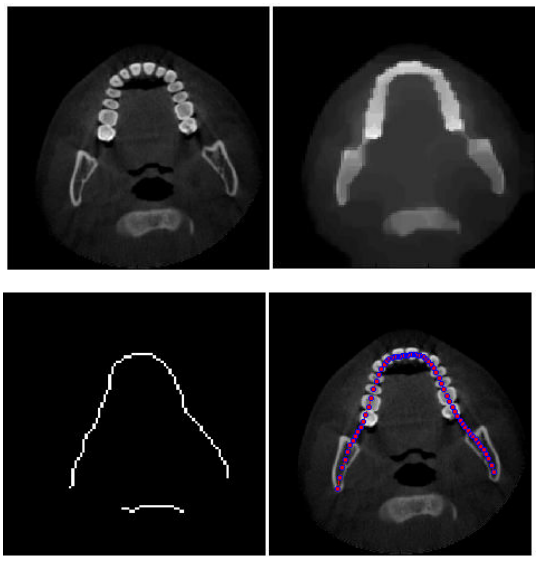


Figure 10. The dental arch detection of Sample #3

D. Sample#4

In this sample, we tested our proposed algorithm to detect the dental arch when the image contains metal artifacts from dental fillings. Since the metal artifacts may somehow change the structure of the component, the detected curve after thinning may contain small branches. This problem is overcome by using curve fitting. The overall process and the results are shown in Fig. 11. In addition, the ray-sum panoramic image with the thickness of 12.2 mm in the case of metal artifacts is shown in Fig. 12. From these results, our proposed algorithm can automatically detect the dental arch and automatically extract the panoramic images in this case.

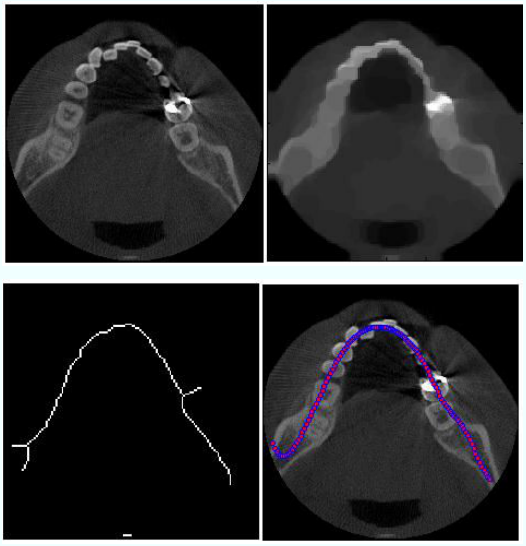


Figure 11. The dental arch detection of Sample #4

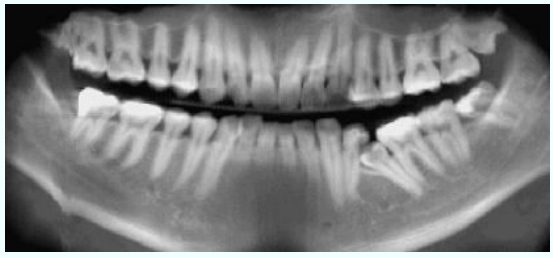


Figure 12. The ray-sum panoramic image of Sample #4

IV. Conclusion

In this paper, we propose the new algorithm for automatic detection of the dental arch based on thresholding and image morphological techniques. This algorithm can be computed quickly by downsampling the original image before any further processing. After detecting the dental arch, a series of simulated panoramic images and a ray-sum panoramic image can be generated automatically. We tested our proposed algorithm on 120 different axial images and they all can achieve decent estimates of the dental arch. Therefore, our proposed algorithm is suitable for automatic detection of the dental arch and can also automatically extract the panoramic imaging from CT images.

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