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Individual Teeth Segmentation in CBCT and MSCT Dental Images Using Watershed

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***Abstract*—Teeth segmentation is an important step in human identification and Content Based Image Retrieval (CBIR) systems. This paper proposes a new approach for teeth segmentation using morphological operations and watershed algorithm. In Cone Beam Computer Tomography (CBCT) and Multi Slice Computer Tomography (MSCT) each tooth is an elliptic shape region that cannot be separated only by considering their pixels' intensity values. For segmenting a tooth from the image, some enhancement is necessary. We use morphological operators such as image filling and image opening to enhance the image. In the proposed algorithm, a Maximum Intensity Projection (MIP) mask is used to separate teeth regions from black and bony areas. Then each tooth is separated using the watershed algorithm. Anatomical constraints are used to overcome the over segmentation problem in watershed method. The results show a high accuracy for the proposed algorithm in segmenting teeth. Proposed method decreases time consuming by considering only one image of CBCT and MSCT for segmenting teeth instead of using all slices.**

Key words: Dental x-ray segmentation, CBIR, Human Identification, watershed, morphological operation

I. Introduction

In this paper we focus on segmentation of individual teeth with complete crown and root parts from CBCT and MSCT dental images. To this end, we propose adaptive active contour tracking algorithms: single level set method tracking for root segmentation to handle the complex image conditions as well as the root branching problem, and coupled level set method tracking for crown segmentation in order to separate the touching teeth and create the virtual common boundaries between them.

Dental X-ray image segmentation can be useful in many applications. One such application is Ante mortem (AM) and post-mortem (PM) segmentation of dental X-ray images that is important in human identification for forensic dentistry. Since PM identification cannot be performed by only considering the behavioral characteristics (e.g. speech) and also some of the biometric identification parameters may be lost in such accidents as car or airplane crash, dental characteristics are the most robust candidates. A post-mortem biometric identifier persist such harsh conditions and resists to decay would happen to body tissues. Therefore, dental features make PM identification possible even in severe conditions [1]. For example, 20% of victims in 11/9 and 75% of Tsunami victims in Thailand were identified by dental X-ray images while 0.5% was identified by DNA [2].

An Automated Dental Identification System (ADIS) contain different parts, which includes segmentation of Teeth X-ray. The main parts of ADIS are the automatic searching and matching of digitized X-ray images [1]. The system consists of the preprocessing step, a coarse-grained matching step that makes a list for fine-grained image comparison [2]. Finding the best candidate matching for identification is the main aim of this system. Also, decreasing the time of retrieval is important with the purpose of finding the results of digital image repository (DIR). Better matching and decreasing the time of retrieval causes when better segmentation is done. Preprocessing step of ADIS is a very challenging step in segmentation problems. The digitized dental X-ray record of a person often consists of multiple films. A digitized dental X-ray record has to be cut into its basic slices [2]. Each cut slice must be segmented into multiple teeth area. Each tooth region has to be separated in order to simplify other features extraction processes. It is the part of tooth ROI and teeth contours isolation. At the end, each tooth must be isolated individually [2].

For segmenting the tooth in CBCT and MSCT, Hosntalab and et al [3] made panoramic projection by calculating the integral projection, they segmented tooth. There is some similar work in panoramic projection that has proposed by Zhou and et al [4]. They used adaptive thresholding on enhanced image for segmenting teeth. Patanachai et al [5] proposed an algorithm based on wavelet transform for segmenting teeth on panoramic projection. For segmenting all teeth region from other regions such as soft tissue and bony area, AkhoondAli et al [6] proposed a region growing algorithm that uses four thresholds for segmenting teeth regions. They also proposed the MIP mask [7] for separating the bony and teeth regions of the jaws from other parts. Gao and Chae [8] proposed adaptive active contour tracking algorithms which is single level set method tracking for root segmentation and coupled level set method tracking for crown segmentation. In another research [9], segmentation methods were developed based on Bayesian and Level Set frameworks to segment human facial tissue which contains very thin anatomic structures. Wang et al [10] showed a watershed-based algorithm to be useful for automatic lesion segmentation in dermoscopy images and they also utilized a neural network classifier [11] to improve the first-pass watershed segmentation in order to reduce the border detection errors.

Considering the resolution and noise of images and touching adjacent teeth, touching teeth and jaw bones, tooth segmentation may be a challenging issue. The proposed method in this paper uses watershed for segmenting teeth regions which apply on the enhanced image. The enhancing step consists of morphological operations. The over segmentation problem is solved by considering an anatomical

The rest of the paper is organized as follow: in Section 2 we explain our method for segmenting teeth using morphological operation and watershed. Section 3 discusses the experimental results. Finally, section 4 concludes the paper.

II. THE PROPOSED METHOD:

The proposed method can be summarized in three steps as shown in the block diagram of Fig. 1. The details of each step will be explained in the following sections.

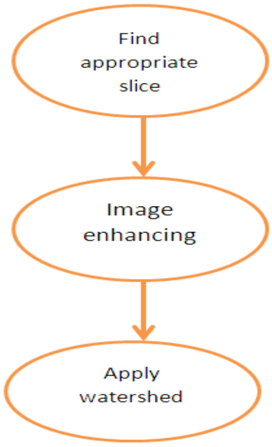


Figure1. block diagram of the proposed method

A. *Finding an appropriate slice*

First of all, we must find a slice that contains all teeth. We can obtain this slice by finding a slice in volumetric data that has the most teeth pixels in it. This slice can be obtained by applying a threshold to separate bony and teeth pixels and calculating the sum of all bony and teeth pixels. In the slices that contain teeth regions, the numbers of tissue pixels are usually similar, so the threshold can be found easily by using Otsu's method. Fig. 2(a) shows an appropriate slice.

B. *Applying morphological operation*

Without any enhancement, watershed algorithm cannot separate teeth regions correctly. For enhancing image, a MIP mask is used for considering only teeth and bony regions. The MIP mask is a maximum intensity projection of CBCT or MSCT in axial orientation followed by a threshold (See Fig. 2(c)).

To enhance this slice, we used morphological operators in two steps. First step is image filling. Because there may be holes in teeth, image filling in gray intensity image is used for filling these regions (Fig. 2(e)). The second step is separating the teeth regions from the background. It is done by closing operation followed by an opening. This step enhances the image by emphasizing teeth regions (Fig. 2(f)).

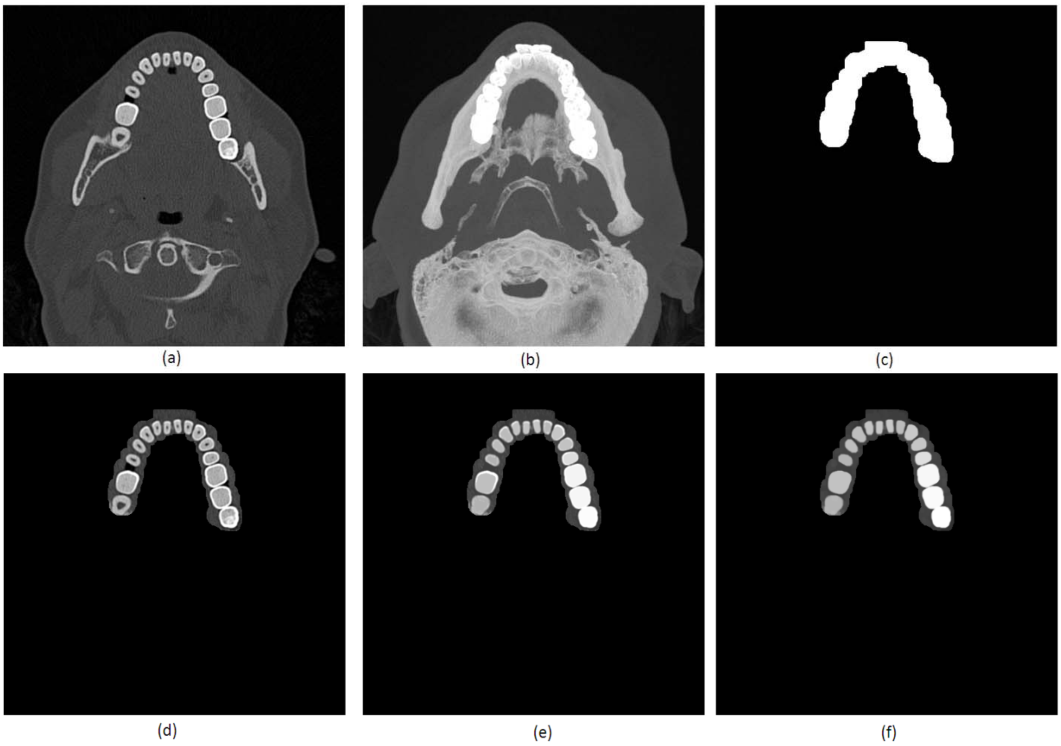


Figure 2. (a) an appropriate slice for teeth segmentation. (b) Maximum Intensity projection of volumetric data. (c) MIP mask by applying threshold on MIP. (d) cropped slice with MIP mask. (e) filled image for removing holes in teeth. f:morphological operated image for reaching uniform intensity on teeth.

C. Watershed

After morphological step, we face some separated elliptic based region as it is shown in Fig. 2(a) .Watershed can separate these regions with a reliable precision.

The watershed algorithm uses an intensity-based topographical representation in which the brighter pixels represent higher altitudes or the 'hills' and the darker pixels correspond to the 'valleys,' which allows for the determination of the path that a falling raindrop would follow. Watershed lines are the divided lines of 'domains of attraction' of water drops (or the boundaries of catchment basins).

The flooding modification of the watershed algorithm is analogous to immersion of the relief in a lake flooded from holes at minima. This variant is more efficient than the original falling raindrop approach for many applications [10].

After using watershed, we may encounter the over segmentation problem. Anatomical constraint is used to solve this problem. Teeth cannot be smaller than a specific size. This constraint is used to handle the over segmentation problem. For applying this constraint, a region must have two conditions: these regions real size must not be smaller than a specific value and their neighboring percentage must not be greater than a threshold. If a region meets these conditions, it is a candidate for merging with another region. The real size is obtained by considering both the number of pixels that make an area and size of each pixel that can be found from the DICOM format. Neighboring percentage is the percentage of pixels that are in the boundary of two regions. By taking these points into consideration, we solve the over segmentation problem (See Fig. 3(b)).

III. EXPERIMENTAL RESULT

To asses proposed method, we utilized the CBCT images which taken in radiology imaging center by Dr. Dalili in Tehran, Iran. This database contains 18 patient pictures in dicom format. The size of each picture is 512*512 with 16 bits resolution and taken in axial position. Approximately 45 to 75 slices are taken from each jaw. For segmenting each tooth from other teeth there are two thresholds that must be chosen correctly. First one is the minimum area of a normal tooth. We selected 30mm^2 for this value by considering the minimum area of a real tooth. The second threshold is the minimum neighboring percentage of two regions. We considered 30% for this value by trial and error.

For evaluation of the performance of the proposed method we compare the results to those hand-segmented ones. The result is shown in Table 1. Three types of pixels have been compared for each jaw.

- Pixels that belong to a tooth and our method successfully marked this pixel as a tooth pixel (True-Positive).
- Pixels that belong to a tooth, but our method assigned those pixels as a non-tooth region (False-Negative).
- Pixels that are not really tooth pixels, which our method interpreted this pixel as a teeth region (False-Positive).

The computation time is also added to the table. Because the proposed method uses only one slice for segmenting instead of all slices, it reduces the time consuming.

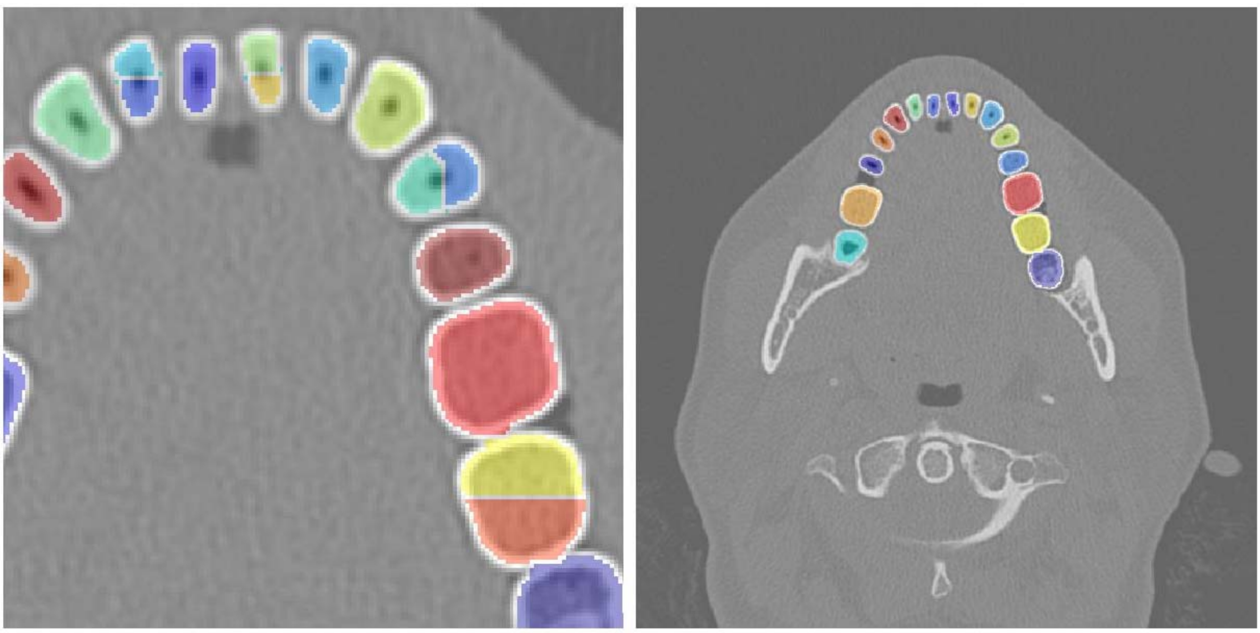
TABLE I. RESULT OF TEETH SEGMENTATION

Jaws	True-Positive	False-Negative	False-Positive	Computation time
Mandible	99.42%	6.02%	0.04%	2.03 second
Maxilla	95.38%	9.05%	0.08%	2.04 second

Our method can be used for separating each tooth from other teeth. So, an evaluation on tooth numbering can be done. Table 2 shows the result of numbering the tooth. We calculated the percentage by dividing the number of found tooth to the actual number of teeth. The result is calculated both for maxilla and mandible.

TABLE II. PERCENTAGE OF CORRECT FOUND TOOTH

Jaws	Correct number of finding tooth
Mandible	89%
Maxilla	90%



(a) (b)

Figure 3. (a) watershed image without considering the constraint. (b) same watershed slice that anatomical constraint is used to deal with over segmentation.

IV. CONCLUSION AND FUTURE WORK

A new algorithm for segmenting each tooth from the other teeth in CBCT and MSCT dataset by applying a morphological enhancement and watershed were proposed in this paper. We use an anatomical constraints to deal with the over segmentation problem. Our method starts with a slide that has maximum teeth pixels in it and finishes with segmented teeth. The results showed a high accuracy for the proposed method in separating the teeth regions from other regions such as bony and tissue areas. This ability can also be used for making 3D view of teeth. Furthermore, our method can separate each tooth from the other tooth with acceptable result. Also our method can be used for numbering the tooth and finding features for CBIR and human identification systems. When the metal artifact of input dataset increases, the accuracy of our method decreases. In addition, it is important to find appropriate slice because segmenting would be applied to this slice. It could be a good idea for ongoing work to remove this metal artifact before using the proposed method.

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