

SURVEY OF METHODS OF AUTOMATIC UPPER AND LOWER JAWS SEGMENTATION ON INTRAORAL OR EXTRAORAL X-RAY IMAGES

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Abstract

Nowadays every modern dental clinic has X-Ray equipment that used in treatment process. Images from this equipment could be intraoral or extraoral. They can capture dentition, both jaws, temporomandibular joints, nasal cavity and the portion of the maxillary sinus. These visual modalities are being used to detect hidden defects, to find pathological creations at the tip of the tooth root, to help during curing of teeth root channels etc. In this paper is given survey of methods of automatic lower and upper jaws segmentation based on morphological operations with purpose of further classification of all possible problems and increase of caries detection accuracy rate.

Keywords

Dental X-Ray panoramic image, mathematical morphology, top-hat transform, bottom-hat transform, integration

1. Introduction

X-Ray diagnostics and more advanced CT variant of it are being used in most modern dental clinics and medical establishments in the world. Such type of diagnostics is able to detect various problems such as caries of crown and root parts of the tooth, cysts and tumors, defects of jaws surgery, bone damages and irregularities. Another application is human identification in automated dental identification systems (ADIS). At the same time invasion of this method is reasonably low and painless for patient. There are many modalities those doctors are using for detection of possible teeth problems: bitewing, periapical, panoramic. Bitewing image gives detailed information about teeth in the area of the mouth. Periapical image shows in detail one individual tooth. Panoramic image gives a view of entire mouth area and all teeth. Actually, panoramic X-Ray images are very popular because they are allow to view the whole picture, method is more smooth, reliable and precise taking in account capabilities



Figure 1 – Typical panoramic dental X-Ray image

of modern X-Ray equipment with digital output. An example of panoramic image is given below (Fig. 1).

However, the diagnostics performed by doctors using any images is very subjective and sometimes there is problematic to distinguish between possible diagnoses in case when medic have no any formal description of the image. This problem could be resolved applying computer aided diagnostics as a part of medical treatment process. Currently modern computer equipment is present in any hospital, so installation of specialized computer decision support system that is able to segment, emphasize and visualize important features of the image and give advice to the doctor will increase objectivity and reliability of diagnostics. Before generating decision of any type such system will require to segment dental image, extract important information that will be processed later through knowledge base and classify main objects.

2. Approaches to the panoramic dental X-Ray images segmentation

During last several years, several groups of scientists all around the world performed a lot of work on researching topic of dental image segmentation. In [1] was proposed method for performing segmentation of dental panoramic images used for human identification based on calculation of sums of the pixels intensities for jaws separation and using probabilistic features followed by greedy scan for teeth identification on the image. This method is working on good images but cannot reliably separate teeth when it is impossible to put straight line between them. Methods proposed in [2], [3], [4] and [5] using on mathematical morphology on several stages of dental images processing: from preprocessing to individual teeth isolation. Approach in [2] uses statistical learning for ROI selection and a feature based classification for caries detection. It works with visually good performance but according to authors research could produce wrong results for images where present jaws with missing teeth. In addition, it is sensitive to noise and teeth overlapping. In [3] authors are using morphological preprocessing together with morphometric data extraction. They propose to find match between model and tooth shapes by simple brute forcing contour shift of etalon contour and extracted contour of tooth. More promising is method described in [6] that is combining mathematical morphology with watershed algorithm based on distance transform. Some research teams are also using methods based on energy minimizing segmentation algorithms. For example, in [7] and [8] authors used active contours modifications: geodesic active contours and active contours without edges. In addition, we can find application of variational level set methods [9] for solving this task or in simple cases classic threshold limitation methods [10]. Despite found variety of approaches to preprocess, segment and recognize source data it is possible to extract main pipeline that reflects processing of any type of digital X-Ray dental images. Such process consists of the following main steps: preprocessing, upper and lower jaws separation, teeth isolation and finally teeth recognition, as shown below (Fig. 2).

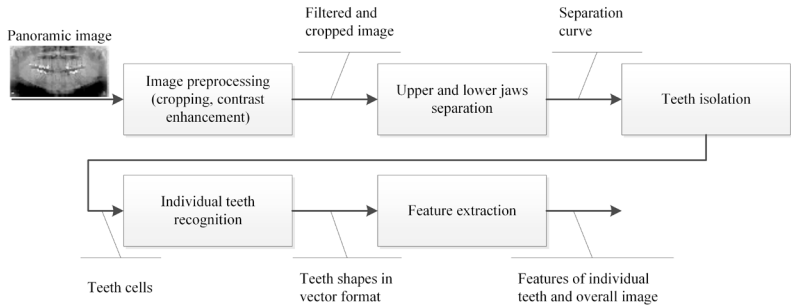


Figure 2 – Block diagram of the dental image segmentation process

This processing pipeline is also applicable to panoramic dental images. As we can see, the first steps are preprocessing and jaws separation. Preprocessing aims preparing image for further segmentation while jaws separation is the first step of necessary information extraction. In the next section, we describe a survey and proposed methods for these steps.

3. Methods of panoramic image preprocessing and jaws separation

Panoramic dental X-Ray images could be entered into the computer by the several ways. In most modern medical systems, equipment provides images directly in DICOM format that contains information in digital form and typically having 12 or 16 bits per pixel. However, sometimes it is present proxy stage where doctor acquire X-Ray film and then scan it. In this case, input information is grayscale image with 8 bits per pixel or the same image in 24-bit true color representation. According to that and taking in account different equipment and patients' particular properties to perform segmentation reliably images need preprocessing. Purpose of this preprocessing is to increase contrast between bright and dark regions and remove artifacts of film scanning if any. Many authors propose to use different combination for preprocessing and searching valley between teeth based on mathematical morphology. In [5], [6], [9], [10] and [11] proposed to use morphological opening and closing operators or top-hat and bottom-hat transforms for increasing difference between peaks and valleys. Typical definitions of these transforms could be defined as follows.

Denote input image I , and structuring element b , then top-hat transform definition will look in following way:

$$I_{\text{top}} = I - (I \circ b) . \quad (1)$$

Here operator $I \circ b$ denotes morphological opening of image I by structure element b , defined through basic erosion \ominus and dilation \oplus operators as follows:

$$I \circ b = (I \ominus b) \oplus b . \quad (2)$$

Bottom-hat transform definition is following:

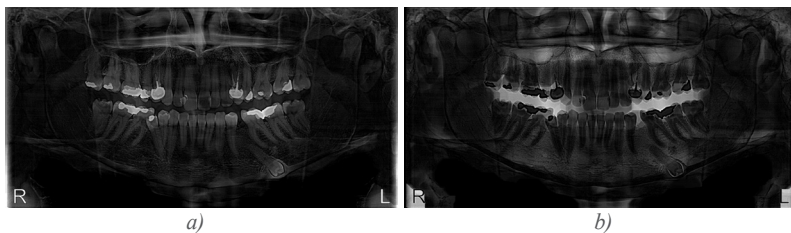


Figure 3 – Results of top-hat transform (a) and bottom-hat transform (b) of dental X-Ray image shown on Fig. 1

$$I_{\text{bot}} = (I \cdot b) - I . \quad (3)$$

Here $I \cdot b$ denotes morphological closing of image I by structure element b , defined as follows:

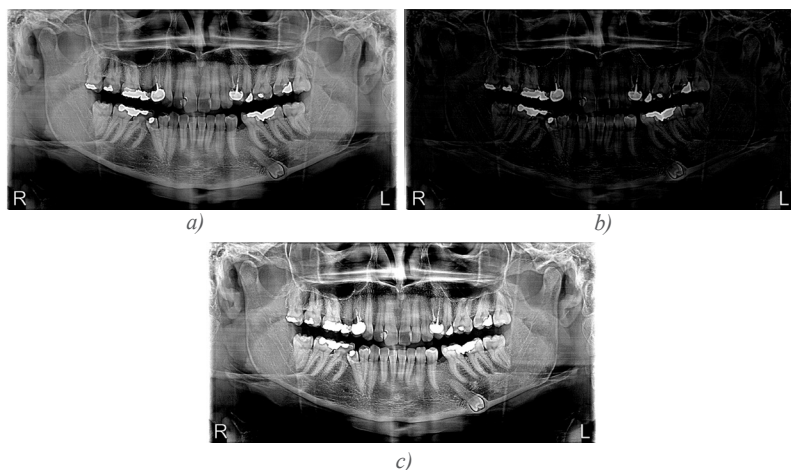
$$I \cdot b = (I \oplus b) \ominus b . \quad (4)$$

Examples of top-hat and bottom-hat transforms are presented on next figure (Fig. 3). It is obvious that combining these images allows achieving different results from the contrast enhancement point of view. In work [12] authors proposed to use difference between source image and bottom-hat transform of this image:

$$I_E = I - I_{\text{bot}} . \quad (5)$$

Authors of [3] propose to enhance image by subtracting bottom-hat transform result from top-hat transform result:

$$I_E = I_{\text{top}} - I_{\text{bot}} . \quad (6)$$



Obrázek 4 – Enhancement results (a) difference between image and its bottom-hat transform; (b) difference between top-hat and bottom-hat transforms; (c) combined method, defined in expression (7)

In [5] for filtering source image authors apply closing top-hat transform that allows to detect pixels on image that are significantly darker than other. This transform is defined as difference between image and its morphological closing. Another approach is proposed in [6]. For enhancing contrast of grayscale image could add original image with preprocessing result defined in (6):

$$I_E = I + I_{\text{top}} - I_{\text{bot}} . \quad (7)$$

Described enhancement results do their work but in slightly different way, that we can see from images (Fig. 4).

According to preprocessing result, we suggest that for jaws separation it is reasonable to apply enhancement technique defined in (7) because it gives more contrast between valley and teeth.

Jaws separation itself also could be performed in several ways. One of the approaches is to set gap valley according to minimum point on vertical diagram and taking in account user input like described in [1] and [12]. This technique is user-assisted, so not completely automated. Algorithm builds gap valley in such way and then connects strokes into the smooth curve using spline function.

Another approach is matching jaws separating curve by high order polynomial [2]. To build such polynomial authors take central point with local minima of vertical intensity function. After that algorithm adds other points evenly distributing them along X axis. To avoid falling down or raising up towards gaps between teeth authors added constraints that prevent such curve behavior:

$$p_i(x_i, y_i) = \begin{cases} p_i(x_{i+1} + T, y_i), & |p_i(x_i, y_i) - p_{i+1}(x_{i+1}, y_{i+1})| > T \\ p_i(x_i, y_i), & \text{otherwise} \end{cases} . \quad (8)$$

Here T denotes threshold introduced with purpose to limit high changes, especially in case of missing teeth. After spreading points of the line the final curve that separates jaws is given by 10th order polynomial built by least squares method:

$$p_0 = a_0 + a_1 x + \dots + a_{10} x^{10} . \quad (9)$$

In works [7] and [8] it is proposed to use energy minimizing algorithms based on well-known active contours method. The difference is that for separating jaws active contour should not be stick to the edge and should be somewhere between the teeth instead. Another difference is that active contour that splits jaws should be open. Considering that separation method in [7] uses pixel energy in the neighborhood and puts next point minimizing cumulative energy for seam being built along all the pixels from starting point until the possible next. Energy function in this approach is defined as gradient magnitu-

de. In [8] for building separation curve authors used geodesic active contours without edges. There are also some attempts to separate jaws using straight line, but review of source panoramic images has shown that jaws have different curvature and straight line will give large error.

4. Conclusion

Performing analysis of existent works allowed proposing steps for jaws separation on panoramic dental images. Main goal is to achieve smooth separation curve that situated approximately on the equal distance from upper and lower teeth. Smoothness and binding to teeth line are required for further usage of this curve as integration template on steps of teeth isolation and segmentation. Therefore, most perspective image preprocessing is morphological filtering using both top-hat and bottom-hat transform, as shown in (7). This enhancement algorithm gives more contrast between valley and teeth. Next step will be search of key points of separating curve. Here could smoothly work approach that analyses local change of intensity in the neighborhood of previous point and that uses curvature penalty function to help in cases with missing teeth or sharp valleys between them. On the last stage curve could be smoothed by spline function with purpose of achieving smooth line.

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