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Multipoint Search Algorithm for Automatic Segmentation of Tooth from Digital Intra Oral Periapical Radiographs

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Abstract

Objectives: In the present study digitally recorded Intra Oral Periapical radiographs (IOPA) are investigated. **Methods/Analysis:** This paper presents an innovative algorithm for automatic segmentation of the digital IOPA radiograph in one or more qualified regions of interest. Segmentation of IOPA is done repetitively till all teeth in the image are extracted. These segmented images resulting from this algorithm will now have one tooth in one image. **Findings:** A radiograph with exactly one tooth in image is extremely useful for further study and analysis of individual tooth in many and diverse applications of computer assistance in processing of dental radiographs. The segmentation algorithm proposed in this paper, necessarily being a spatial segmentation method, separates regions of interest without any loss or alterations in the data. The algorithm works successfully on 76 digital IOPA radiographs out of 80 images in test data. **Novelty/Improvements:** The algorithm proposed in the paper is fully automatic and does not require any human intervention. The segmentation algorithm proposed separates one tooth with its perimeter region intact in one image. The number of output images generated are equal to number of teeth in input IOPA.

Keywords: Image Processing, Image Segmentation, Intraoral Periapical Radiograph, Vertical Integral Projection

1. Introduction

There is an extensive use of computers in diagnosis of dental diseases. Computer aided diagnosis of dental diseases mainly involves processing of dental radiographs, thereby providing assistance to dentists for accurate diagnosis and treatment planning. Region of Interest (RoI) in radiographs needs to be extracted correctly in every medical image processing application to ensure accuracy and reliability in the analysis carried out on RoI.

After studying various segmentation methods available in literature, used for processing dental radiographs, a need is felt to develop an automatic segmentation algorithm to extract a tooth without any loss or alteration in the perimeter data obtained from IOPA radiographs.

The challenges in automatic processing of IOPA radiographs are due to their inherent characteristics. The IOPA radiographs are low contrast images. Slight changes caused by any abnormalities, such as tooth decay, abscess, etc. are more evident as they appear darker gray than surrounding area. In IOPA radiographs white area indicate high density objects while black area indicates low density objects. White areas represent metallic restorations in the tooth while black areas represent

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air spaces. The areas with densities in between these two extremes represent soft tissues, pulp tissues, tooth structure, bone, amalgam, enamel, cementum base etc. The objects that are radiographed are radio-lucent or radio-opaque.

The segmentation method used by[1–2] performed iterative thresholding followed by adaptive thresholding before using integral projection for segmenting teeth. As a result, teeth were separated from background and boney area. The input images used were dental bitewing radiographs on which the segmentation method was applied. Therefore, a need was felt to develop an algorithm for segmentation of IOPA radiographs.

Oprea et al.[3] proposed a segmentation method for IOPA radiographs. Human intervention was necessary to work with this segmentation method. The input images were IOPA radiographs but researchers claimed that with slight modification, this method might work for any type of dental radiograph. Sela et al.[4], selected RoIs for IOPA radiograph of each patient around the trabecular area. These RoIs were decided manually by a dentist by marking points on the trabecular area. Human intervention was a limitation to these methods, as such, a need was felt to minimize or eliminate human intervention in the process of segmentation.

Said et al.[5] solved the problem of teeth segmentation using a mathematical morphology approach. The objectives for teeth segmentation were to automatically extract as many qualified ROIs as possible, to operate on bitewing and periapical views and in the worst case scenario, extract at least one qualified ROI from each film. The qualified ROI shows one tooth as a whole. In [6–8], the method used failed for images of feelings in tooth, impacted tooth and overexposed images. A need was felt to develop an algorithm which will work on IOPA radiographs to improve upon limitations discussed above.

Region based, texture based and edge based segmentation techniques were discussed by BalaSubramanyam et al. in their research article[9]. These techniques were implemented on dental radiographs and good results were obtained as compared to conventional thresholding based technique. The need was felt to explore combination of region based and edge based segmentation technique to develop a new algorithm.

Kumar and Arthanariee[10] have compared different edge detection techniques in their research work. Sobel, Prewitt and Roberts edge detection operators were compared. It was decided to use Sobel operator as it was simple and it detected thin edge. Prewitt and Roberts edge detector were of no use for the algorithm proposed as Prewitt gave multiple edges while Roberts gave thick edges.

In some of the papers referred above, radiographs were films, scanned to digitize the images. While others used digital dental radiographs. In most of the research work manual or semi automatic methods were used for segmentation. In all the papers discussed above intraoral bitewing radiographs were used as input, where alignment of x-axis to the gap valley between upper and lower jaws was ensured. This is not so for IOPA radiograph inputs, because sensor may be placed in patient's mouth as per the judgement of the dentist. The algorithm proposed in this paper for segmentation is fully automatic having input images as IOPA radiographs.

2. Methodology

The algorithm proposed in this paper is implemented in four stages using MATLAB R2013a. The input to this proposed algorithm for segmentation is digital IOPA radiograph. The four stages are shown in the block diagram of Figure 1.

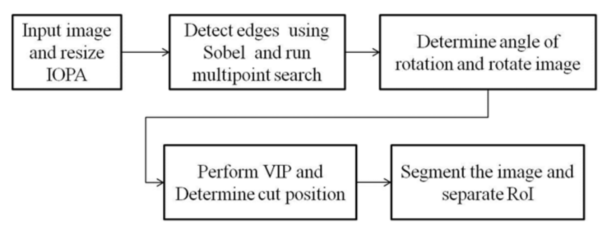

Figure 1. Block diagram of proposed algorithm

2.1 Block Diagram

The block diagram indicates stages involved in segmenting the input IOPA radiograph. The input image is jpeg colour image. This colour image is then converted into gray scale image. For medical image processing applications, gray scale colour map is used. The image is then resized to fit pixel resolution of 240 x 300 approximately as exact size of the image will depend on size of input image.

2.2 Edge Detection

First stage shown in the block diagram is edge detection. The edge detection operation is performed on the resized IOPA radiograph. Sobel operator is used for edge detection. As compared to other operators, performance of Sobel edge detection is found suitable for this algorithm. Sobel operator returns only predominant edges in the image.

Thinning and verticalization are performed during Sobel edge detection returning almost a single pixel edge.

Multipoint search is then run on this edge detected image. The multipoint search is an important module of segmentation algorithm proposed in this paper. This search method is used to determine the left most edge on first tooth radiographed in the image. Multipoint search returns minimum three points on the edge of first tooth from left. The edge detected image is virtually subdivided in number of vertical strips. This search is performed on virtual vertical strips of edge detected radiograph, starting from left most strip. For this algorithm, the width of a strip is of an approximate size of 48 pixels. 48 pixels represent $4/5^{th}$ part a complete tooth. Horizontal scan from top left corner of left most strip is initiated. Point on edge is detected by comparing intensities of neighboring pixels on horizontal line. This point is then marked as first point on edge. Scanning is initiated again by vertically shifting the search point 15 pixels bellow. On detection of every point on edge, scan point shifts vertically down by 15 pixels.

Experiments are performed with 3-point scan, 5-point scan, 7-point scan and 9-point scan. In each experimental set up 3,5,7,9 points on the edge are recorded respectively. If the points are not detected in current vertical strip the search is carried out on the next strip. The spatial distribution of these points is analyzed to determine outliers. Outliers are those data points which do not belong to the same edge of the tooth. Outliers are determined by simple statistical analysis of standard deviation and mean value. The outliers are removed from the set of detected points. Within 48 pixels (width of virtual strip), if a tooth is present, at least three points on the edge of that tooth are returned.

2.3 Angle of Rotation

Second stage shown in the block diagram determines angle of rotation. Angle of rotation is that angle through which IOPA radiograph is to be rotated. The spatial distribution of the points obtained from the first stage is taken into consideration to determine the angle and direction of rotation. The angle of rotation is calculated to rotate the IOPA radiograph. This calculated angle rotates the radiograph in clockwise or anticlockwise manner according to the requirement of the input image. The image is then rotated through this angle for further processing. After rotation of the image, the first tooth from the left becomes almost perpendicular to x-axis. Figure 2 shows four sample images and rotation performed on them. These are the same images for which edge detection is shown in Figure 3.

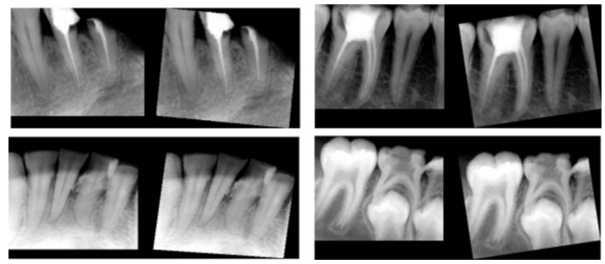

Figure 2. Original image and rotated image.

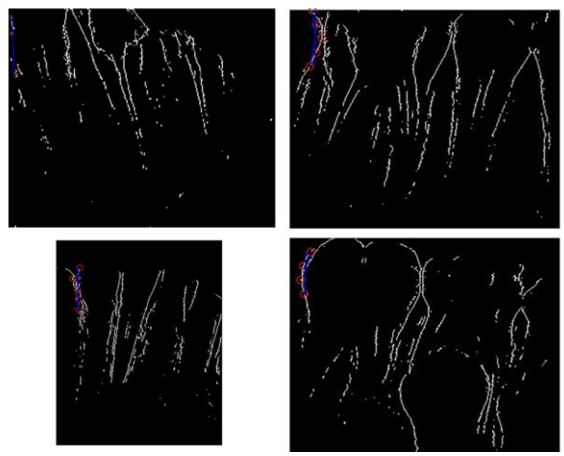

Figure 3. Edge detected image with Sobel.

2.4 Cut Position of a Tooth

Third stage shown in the block diagram determines the position of the vertical line where image is to be segmented. Vertical Integral Projection (VIP) of rotated image is then recorded (Figure 4). The rotation of image carried out in second stage ensures almost correct matching of valley positions in VIP to cut positions for segmentation. The output graph of VIP is smoothened by averaging over seven pixels to avoid false detection of cut positions at local minima. Appropriate cut position for segmenting is determined after calculating average depth of all valleys in VIP. Valley positions with average depth less than sixty percent of the maximum valley depth for that image are discarded. Valley positions thus obtained lead to segmenting location to determine RoI. Vertical cut at this position separates tooth from rest of the image. Cut position is shown by vertical blue line in Figure 5 for the same sample images shown earlier in Figure 2, Figure 3 and Figure 4.

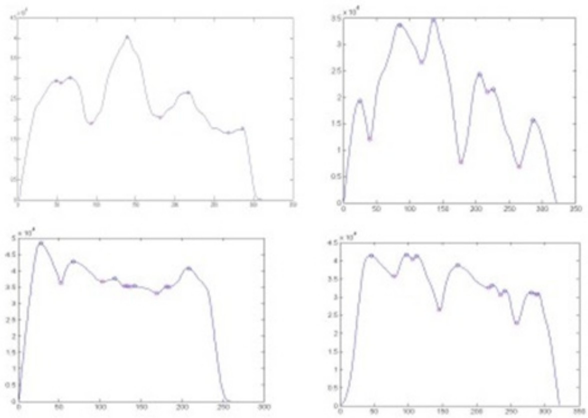

Figure 4. VIP after removing local minima.

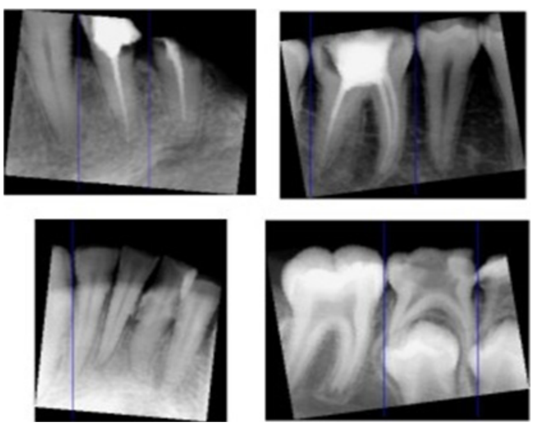

Figure 5. Cut position for segmentation.

2.5 Segmentation

Fourth stage shown in the block diagram is the segmentation module. The rotated image is segmented at cut position. The image is split into two sub images. First sub image contains data for leftmost tooth and second sub image for the remaining teeth. The stages to detect edge, to rotate image, to determine cut position and to segment left most tooth are repeated till each tooth in the IOPA is extracted. Figure 6 shows one sample image with three teeth in the image segmented sequentially.

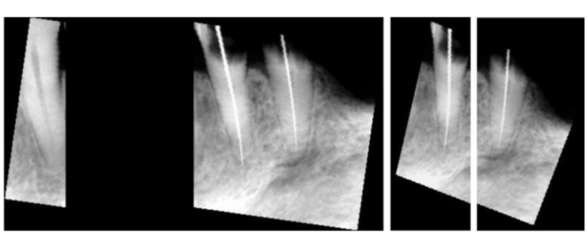

Figure 6. Three teeth in one image extracted one after other.

3. Results

To test the developed algorithm, around 100 radiographs are obtained from practicing dental professionals. These radiographs are coloured jpeg images. Image size in pixels is 468 x 578 and pixel resolution is 458 dpi with bit depth as 8. Image data contain images of upper as well as lower jaws. Radiographs of molar, pre-molar, canine and incisors are included in input data set.

The results obtained by testing the algorithm on digital IOPA along with test conditions and parameters used are discussed in following subsections.

3.1 Edge Detection Module

The input to edge detection module is a resized grayscale IOPA radiograph used in vertical edge detection and thinning modes. Results of edge detection are shown in Figure 2. Different edge detection operators are tried and it is found that Sobel operator gives best results for the algorithm proposed. Canny edge detection is not very effective for the present algorithm as it detects edges of tooth canals and also a slight demineralization of tooth. All these edges detected by Canny are confusing inputs for the multipoint search algorithm proposed in the paper.

Comparative study on test data of 40 images is carried out with 3 points, 5 points, 7 points and 9 points searches. Search with 3 points could not handle outliers in search results, as after discarding even one such outlier, dimension of data reduced to two, making it insufficient for analysis during further stages. 7 and 9 point searches unnecessarily made the result space multidimensional for second order function representing edge of the tooth. Complexity, time as well as space increased unnecessarily with 7 and 9 point searches. Therefore, 5 point search has been used to search edge of the leftmost tooth.

3.2 Angle of Rotation Module

In this module, angle of rotation is calculated based on 3 to 5 points obtained from the 5 point search. Spatial distribution of these points is analyzed based on mean and standard deviation of these points. The sense of rotation, whether clockwise or anticlockwise, is decided based on spatial distribution of first and last points on the edge. The angle of rotation is calculated based on spatial relations between mean value and first point, and between mean value and last point. Once the direction of rotation and angle of rotation are obtained, the original

IOPA radiograph is rotated through this angle. Figure 3 shows result of rotation on various images.

3.3 Vertical Cut Position Module

Vertical integral projection is found for the rotated image. After the image is rotated the first tooth from left is almost perpendicular to x-axis. Rotation of IOPA radiograph in the earlier module is very effective step for obtaining correct location of valley from vertical integral projection. The valley positions represent inter-teeth spaces. The cut position is selected correctly from the valley positions given by vertical integral projection. This third module returns cut position for first tooth from left (Figure 5).

3.4 Segmentation of Image

The vertical cut position returned from third module is the value where vertical cut is taken. Left side of the cut position is the image where first tooth from left is positioned. Right side of cut position is remaining part of the IOPA radiograph. The rotated image is segmented at this cut position to generate two sub images. First sub image contains first tooth from left and second sub image contains the remaining teeth from the original IOPA radiograph. RoI is the image which contains exactly one tooth. Second sub image is segmented further using the same algorithm repetitively.

4. Conclusion

Various researchers have published literature on different segmentation techniques. It was found necessary to have a segmentation technique for IOPA radiographs in which human intervention is eliminated. Also the technique should take care of fillings in the tooth or work on the tooth, impacted tooth as well as overexposed tooth. In threshold based segmentation techniques proposed by various researchers, there is a possibility of losing data required for analysis after segmentation. It was therefore necessary to overcome this limitation of conventional thresholding based segmentation techniques.

A completely automatic segmentation algorithm is presented in this paper. This algorithm works on digital periapical radiographs. This separates each tooth keeping intact its perimeter. Such single tooth segmentation is very useful in medical field for disease diagnosis, treatment planning and prediction of systemic diseases. The algorithm works well, for images with dental work, images with extracted tooth and images with impacted teeth. It does not work so well in case of images which are blurred, images with overlapping teeth and images with very low contrast between tooth and bone intensity.

5. Acknowledgement

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