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Challenges in Edge Extraction of Dental X-Ray Images Using Image Processing Algorithms – A Review

Gayathri V[1], Hema P Menon[2]
Amrita Viswa Vidyapeetham University
Coimbatore, 641112

Abstract: The paper focuses on the major challenges faced during the processing of misaligned dental x-ray image. The objective of the paper is to discuss about the challenges faced during the root canal edge extraction from dental x-ray images, which forms a pre-requisite step prior to many other advanced automatic processing of x-ray images. For the edge extraction process of dental x-ray images, the effect of image processing algorithms is discussed and analyzed in this paper. Since edge extraction is the foremost step of all the major processing, the performance of the edge extraction stage is carried over to the later stages of processing. Some of the major areas that require processing dental x-ray images are root canal treatment, infection and other malignancy diagnosis.

Keywords: Dental x-ray image, edge extraction techniques

1.INTRODUCTION

A dental x-ray image is acquired by the dentist during several diagnosis and treatment procedures such as root canal treatment, identification of various parameters like the root length, root and gum decays and detection of other infections and anomalies. The x-ray image contains details of the teeth including its root canal, cavity, tooth filling and also the gum region. The major difference between the digital dental x-ray from other major x-ray acquiring mechanisms is that the digital dental x-rays are generally captured by the dentist using the x-ray equipment in different orientations while in other major x-ray mechanisms, the x-ray device is either static or moves in a fixed aligned path. Due to this different capturing methodology, the resulting dental x-ray images have several issues such as illumination inequalities and varied orientations.

There are many categories of teeth such as the incisors and canines which are single rooted, the pre-molars which have bifurcated roots and the molars which have either 3 or 4 roots. Figure 1(a) shows a dental x-ray image of single-rooted teeth where tooth filling and root filling are seen. Figure 1(b) shows a typical example of an x-ray image of a pre-molar tooth. In the figure 1(b), the position of the root, structure of the teeth and the gum area can be noticed. Also, the details about the root like filling can be observed in the figure. The figure 1(b) shows a pre-molar tooth which is characterized by its double roots. An example of triple-rooted canine tooth is shown in Figure 1 (c). There are cases where all these roots get superimposed and could be detected as a single root as can be seen in Figure 1(c). All the capturing teeth need not be healthy and well-structured. The teeth can have decays. One example of a decayed double-rooted tooth is visible in the Figure 1(d).

The present work focuses on the issues related to the segmentation of the root structure from the dental x-ray image. There are some existing works in this direction. For the pre-processing step, the basic morphological operations are used over perfectly aligned x-ray images used in the paper [1]. Later, the inbuilt command is used for finding the root canal length [1]. The concepts like mathematical morphology and gray scale stretching is used in the paper [2], where the authors use automatic approach for tooth segmentation. Another approach is by using a matching function which can be obtained by utilizing several special features of the different categories of teeth [3]. Then, there are several human identification projects using the dental x-ray images by matching ante-mortem (AM) radiography over post-mortem (PM) radiography dental images [4]. Several conventional edge extraction techniques used in basic image processing are being used and analyzed in this paper to extract the root canal edge information from dental x-ray images which are discussed in Section 2.

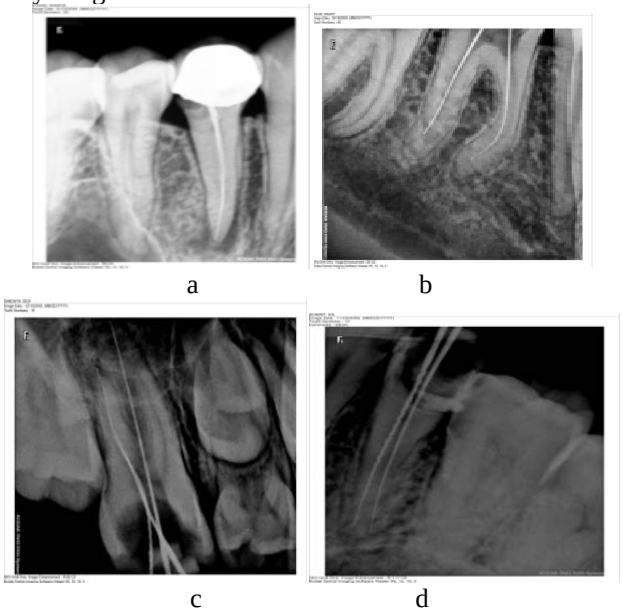

Figure 1: Examples of dental x-ray images with varied illumination. (a) single-rooted tooth (b) double-rooted tooth (c) triple-rooted tooth (d) decayed double-rooted tooth

This paper is organized as follows. Section 2 discusses the issues on the root canal edge extraction using various edge extraction techniques. Section 3 shows the result obtained. Section 4 discusses about the observations and findings. Finally, Section 5 concludes the paper with the scope for future work.

2. EFFECT OF VARIOUS CONVENTIONAL EDGE EXTRACTION TECHNIQUES ON DENTAL X-RAY IMAGES

The root edge extraction is needed for analyzing the structure of the tooth as well as for finding the root canal length. There are several accepted and widely-used edge extraction techniques like the Robert, Sobel, Prewitt, Canny and Laplacian of Gaussian (LoG). These operators/algorithms are being used in this paper to obtain the root canal edges. The paper also discusses about the results obtained using these conventional methods over the dental x-ray images.

2.1 Issues of Conventional Edge Extraction Operators in Dental x-ray Images

2.1.1 Roberts Operator: Roberts operator as described in paper [8] focuses on obtaining edges which are clearly distinct and have minimum noise intervention as possible. The first order derivative of the image is being used in this method.

The result of using Roberts filter over single rooted tooth Fig.2(a) is shown in Fig.2(d). Also the results obtained on double rooted tooth Fig.2(b) and Fig.2(c) are shown in Fig.2(e) and Fig.2(f) respectively. It can be clearly noted that the border of the original image has been obtained in the output, but, the necessary edges of the teeth or the root canal regions are not obtained using the Robert filter. By this, it is evident that the Roberts filter is not an ideal option for edge extraction in dental x-ray images since the edges of the dental x-ray images are of different illumination and orientations.

2.1.2 **Sobel Operator**: The Sobel operator[9] makes use of a pair of 3×3 convolution kernels as shown below. Each kernel is obtained by rotating the other kernel by 90°.

Fig.2(g), Fig.2(h) and Fig.2(i) gives the output obtained by using Sobel operator on digital x-ray image of single rooted tooth, double rooted tooth and triple rooted tooth respectively. It can be noticed that apart from the frame of the image, a slight detection of the edge of the filled root can be seen. Again this indicates that the Sobel filter is producing better results than the Roberts filter, but, not sufficient as most of the edges of the teeth present in the original image is lost.

2.1.3 **Prewitt Operator**: Generally**,** for the detection of horizontal and vertical edges in an image, mainly the Prewitt operator [10] gives good results.

The Fig.2(j), Fig.2(k) and Fig.2(l) show similar results by using the Prewitt filter as that of the Sobel filter in the dental x-ray images of single, double and triple root tooth images as shown in Fig.2(a), Fig.2(b) and Fig.2(c) while obtaining the edge features of the root. Thus, the Prewitt filter also does not produce desirable output since the prominent edge features are not available in the filtered image.

2.2 Challenges of Laplacian of Gaussian (LOG) Edge Extraction Algorithm in Dental X-Ray Images: The LOG filter [11] can be characterized as a 2-D isotropic measure of the second spatial derivative of an image. The following shows the Laplacian L(x,y) of an image with pixel intensity values I(x,y):

$$L(x,y)= \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}$$

The result figures shown in Fig.2(m), Fig.2(n) and Fig.2(o) use the LoG algorithm which provide sufficient edge features as compared to the previously discussed operators. Since the masks of the LoG filter accommodates also the diagonal edges, the root edge features can be obtained better than the above mentioned conventional operators. But, unfortunately, the issue in using this filter is that unwanted edge features other than the root edges are also produced in the output image. Also, the obtained edge features of the root region are not continuous and have breaks in between. Another issue in algorithm is that it is extracting the edges of the filled root while the unfilled root edges still remain unclear or undetected accurately. So, identifying the edges of the unfilled root which has poor illumination as compared to the filled root is another challenge posed by the processing of dental x-ray images.

2.3 Impact of Canny Edge Extraction Algorithm for Dental X-Ray Images: The Canny edge extraction algorithm [12] is a multi stage algorithm. It is popularly known as the optimal edge detector. The regions are represented by the local maxima which are marked as the edges in the gradient image. A non-maximal suppression is used to find the local maximum points in the gradient edge map. Lastly, the weak edge areas are suppressed by double thresholding.

The edge maps obtained on dental xray images with the most popular Canny edge extraction algorithm are shown in Fig 2(p), Fig.2(q) and Fig.2(r). The algorithm is producing over segmented images from which none of the root features can be identified. Generally, the Canny edge extraction algorithm is assumed to provide optimum results, but is proving over segmented edge maps in the case of these dental x-ray images which have illumination variations, noise and different gradient angles.

2.4 Issues of Zero Frequency Resonator (ZFR) Based Method in Dental X-Ray Images:

The ZFR filter provides the impulse-like features of a signal. The obtained impulse-like discontinuities correspond to the edges of an image. Thus ZFR filter based method provides edge map of an image. The ZFR filter is designed with the assumption that the energy of the signal is distributed uniformly around all the frequency values of the signal including the zero frequency. Thus, using an double integration of the entire signal, the energy distributed around the zero frequency of the signal can be filtered out. Later, trend removal can be performed over the filtered signal to produce the edge map.

The edge maps obtained (Fig.2(s), Fig.2(t), Fig.2(u)) using the ZFR filter removes the presence of spurious edges as in the case of Canny since the algorithm provides the impulse-like discontinuities of the image signal. Even though the edge localization is better in the ZFR based method, the obtained edges are not continuous. There is presence of line breaks in the obtained edge map.

3. RESULTS

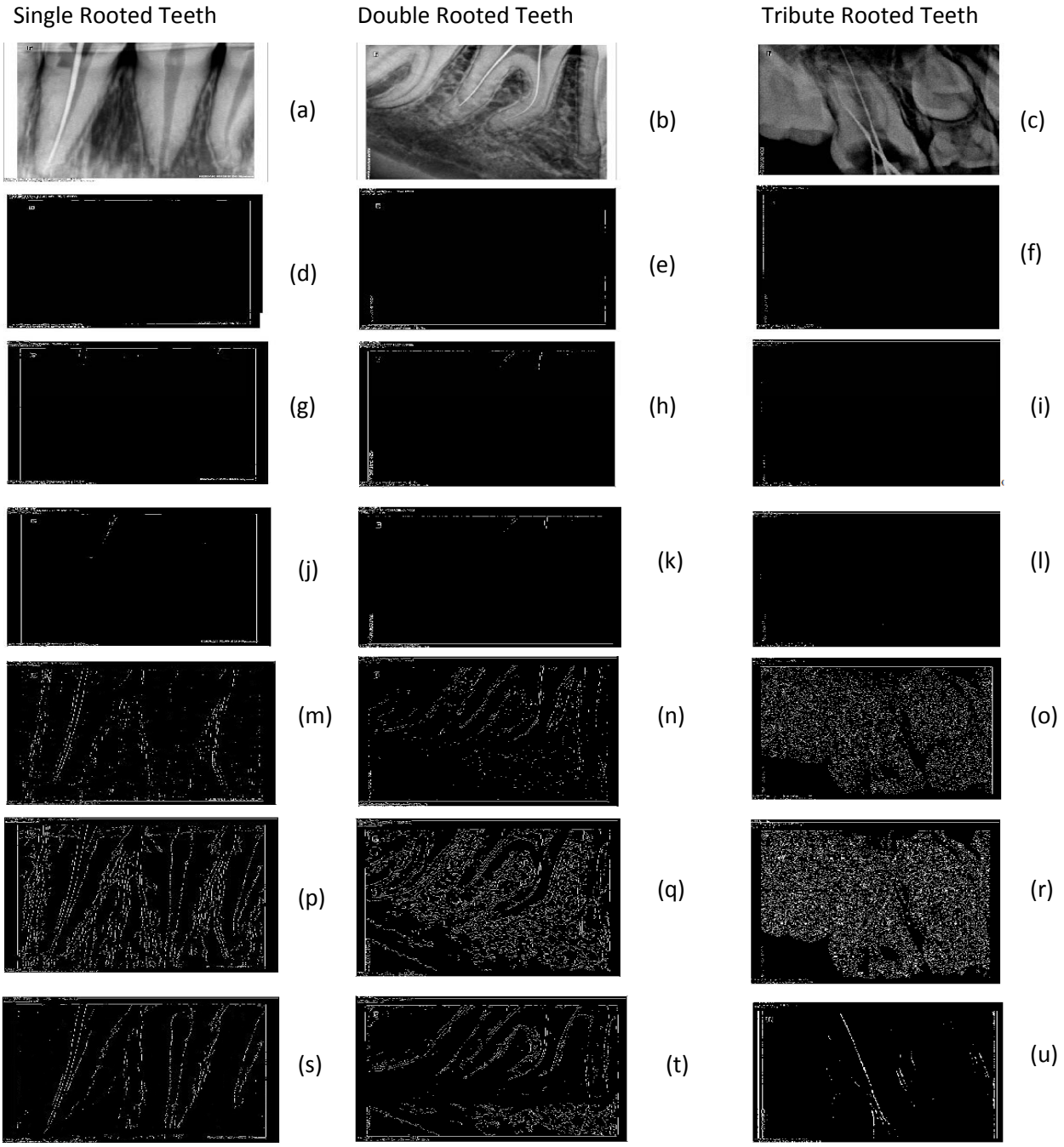

Figure 2. Dental x-ray images of (a) single rooted tooth (b) double rooted tooth (c) triple rooted tooth , edge maps obtained using (d) Roberts operator on single rooted image (e) Roberts operator on double rooted image (f) Roberts operator on triple rooted image (g) Sobel operator on single rooted tooth (h)Sobel operator on double rooted tooth (i) Sobel operator on triple rooted tooth (j)) Prewitt operator on single rooted tooth (k) Prewitt operator on double rooted tooth (l) Prewitt operator on triple rooted tooth (m) LoG on single rooted tooth (n) LoG on double rooted tooth (o) LoG on triple rooted tooth (p) Canny algorithm on single rooted tooth (q) Canny algorithm on double rooted tooth (r) Canny algorithm on triple rooted tooth (s)ZFR algorithm on single rooted tooth (t) ZFR algorithm on double rooted tooth (u) ZFR algorithm on triple rooted tooth

4. OBSERVATIONS AND FINDINGS

From the above results, the challenges posed by various image processing edge extraction techniques on non-uniform dental images can be evaluated. The Roberts operator being a 4 X 4

operator, the edge maps obtained for dental x-ray images is not providing sufficient edge details in the edge map. The Sobel and the Prewitt operators too provide edges which are not complete and sufficient. Better noise removed edges are obtained by using the LoG algorithm. The Canny algorithm, known as the optimal edge extraction algorithm is producing over segmented edge map containing edges of unwanted noise areas also. The advanced ZFR algorithm provides a better localized edge map in dental x-ray

images. But, the edges obtained contain breaks. And also, the details of the curved edges are also not sufficient in using the ZFR based algorithm on digital dental x-ray images. Thus, a better algorithm which can make use of the linear character of the edges must be developed.

5. CONCLUSIONS AND FUTURE WORK

In this paper, the issues obtained in using different image processing edge extraction methodologies on misaligned dental x-ray images have been discussed. The conventional edge extraction techniques mentioned in this paper seems to be inadequate for successfully obtaining the edge features from dental x-ray images. Thus, the study shows a necessity for an improved edge extraction algorithm over dental x-ray images.

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