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RESEARCH TITLE

INVESTIGATION OF IMAGE PROCESSING FOR DETECTING TEETH CONDITIONS OF DENTAL X-RAY IMAGES

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Abstract

The recent progress of real-time x-ray of dental image and image processing may provide several new possibilities, including identification, treatment, and follow-up of the patients. Therefore, this study investigates the capability of x-ray image and image processing techniques to improve visualisation of x-ray image and to detect the teeth conditions. Moreover; a new evaluation methods are suggested to classify the health of the teeth using image processing. Three kinds of image processing systems, namely Canny detector, gradient and threshold are applied in this paper in order to examine their abilities while used to process x-ray image to classify teeth health. In addition, the study aims to develop an imaging system based on image processing for dental applications, such as teeth classification, caries, teeth infection and filled of the teeth. All images are conducted in dental cooperation clinic in Souk Alkhamis, Alkhoms-Libya. The results show that the x-ray image, when integrated with suitable image processing techniques can offer a powerful tool for the estimation of teeth conditions.

Key Words: Dental Application; X-Ray Images; MATLAB software and Image Processing.

1. Introduction

In recent times various image processing algorithms have been proposed for efficient and effective computer aided detection. Moreover, there are different image processing techniques has been developed for medical image such as noise reduction, different filtering image algorithms, histogram equalization. For example, ultrasound or x-ray among others, have been applied in recent years for the diagnosis of different illnesses is described in [1]. Reference [1] has used analysis of image processing for digital X-Ray Image (XRI). The results of the paper have shown the perfect information about bone illness. Moreover, a technique for segmentation and feature extraction of Dental X-Ray Images (DXRI) is presented in [2]. The k-mean clustering has been implemented for segmentation of DXRI. A comparison between original images and four image enhancement techniques has been presented in [3]. The paper has outlined the use of adaptive filters into dental x-ray images. Enhancement of DXRI using image processing techniques is described in reference [4]. The paper presented recognition approach for the dental structures tissue with high accuracy rate and helped in enhancing the dental images. Dental images recognition technology and applications is reported in [5]. The paper has visualized the use of neural network in dental applications, such as the discovery of teeth, caries, filled teeth, crown, prosthesis, dental implants and endodontic treatment. Reference [6] has offered a deep learning based framework that numbers for classifying multiple sicknesses at the same time on a dental radiograph. Study outcomes look favorable with some limitations. A review of different segmentation and classification methods broadly used for DXRI is presented in [7]. The paper has reviewed more than 130 methods recommended by different academics over the last few years. The used approaches are considered as image processing, deep learning and conventional machine learning. Image enhancement techniques have been described in [8]. The paper has used different methods including, Adaptive Histogram Equalization (AHE), Contrast Adaptive Histogram Equalization (CLAHE), Median Adaptive Histogram Equalization (MAHE) and Sharp Contrast Adaptive Histogram Equalization (SCLAHE) for DXRI. The results show that the used approaches have enhanced the pathology slightly well than the original image. The use of edge detection method for DXRI segmentation based on a genetic algorithm approach has been presented in reference [9]. The paper has investigated the use of the edge detection method for DXRI segmentation based on a genetic algorithm approach. However; some time x-ray does not offer or analysis the illness because there is some noise in the image or blurring images. From above discussions it can been seen that there are multiple challenges in the field of DXRI detection and classification, such as poor image quality due to noise, intensity variation in the x-ray images and limitations of capturing devices. This paper has addressed this concern and presents a novel algorithm, which can help doctors to select the appropriate region and to enhance acquired images. Moreover, this study aims to design a digital X-Ray Imaging System (XRIS) using image processing techniques which can be used for a rapid and precise classification of teeth condition using the information acquired from the DXRI.

2. Materials and Methods

This work is done with the extensive support of in dental cooperation clinic in Souk Al-Khamis, Al-Khoums-Libya. All the images are provided from the clinic and the

experiments are carried out in accordance with the applicable general regulations and laws. The DXRI are selected from the clinic database away from patient's personal information such as name, gender, etc. Selected images are then saved in a computer in jpg format for further analysis. MATLAB software and image processing tool box are applied for image enhancement and image processing.

3. Research Aim

The overall purpose of this work is to investigate the capability of DXRI and image processing techniques to improve visualization of x-ray image and to detect the teeth conditions. In addition, the study aims to design a reliable imaging system for dental applications. This could help the dentist to deal with different dental therapies such as; fillings, lesion therapy, root canal treatment, surgical extraction, etc. In the suggested methodology, three image processing techniques are used in order to investigate their capability to detect teeth conditions.

4. Research Methodology

A schematic diagram of the proposed methodology is shown in Figure 1. Since this paper examines the capability of x-ray data and image processing techniques, to detect teeth conditions, therefor; research methodology contains four main steps as following:

1. The x-ray image is captured using high resolution x-ray device and saved in a computer in jpg format for further analysis.
2. MATLAB software and image processing tool box are used for pre-processing and image processing stages. Pre-processing is used in order to convert acquired image into grey-scale level. Also, Region Of Interest (ROI) is selected in this stage (see Figure 4).
3. Three types of image processing algorithms, namely Canny detector, gradient and threshold are used in this study. These methods are combined in a vision monitoring system in order to examine their capabilities when used to process x-ray data to detect teeth conditions.
4. As a final point is to classify and evaluate the used image processing techniques.

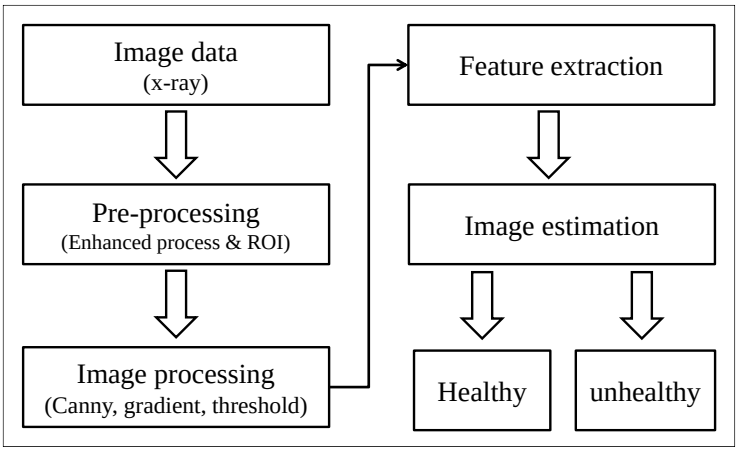

Figure 1: Research methodology.

5. Digital Imaging System and Image Processing

5.1. Dental Vision System

The dental imaging system is used to capture x-ray dental image and is also, used to enable dentist to detect teeth health. It contains three main components including imaging device, computer and computer software as shown in Figure 2.

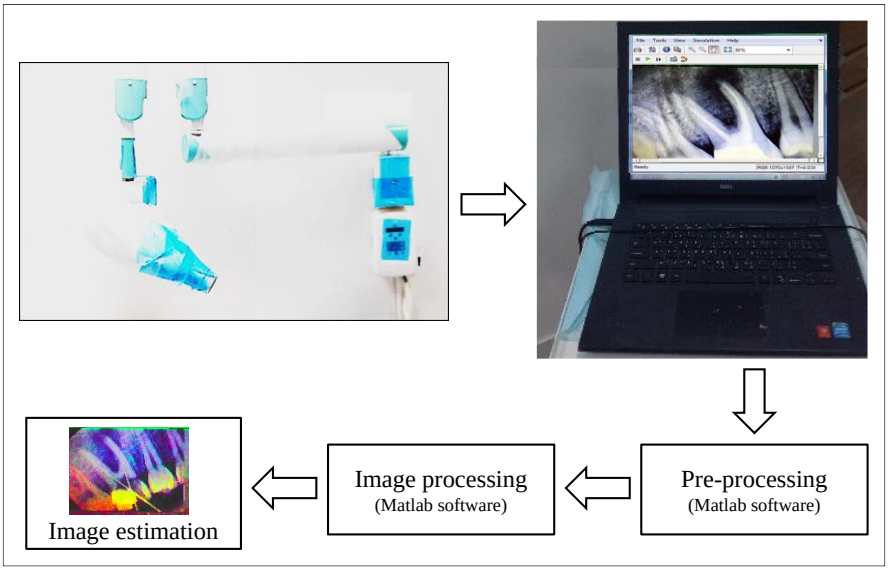

Figure 2: The structure of X-Ray imaging system (XRIS).

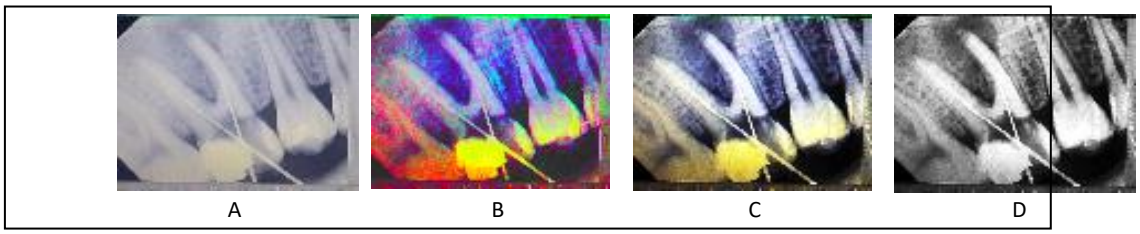

Figure 3: Shows (A) original, (B and C) equalized of RGB and (D) equalized of gray image.

5.2. Image Processing

A significant number of images of healthy and unhealthy teeth are used in this study. Therefore; image processing is acquired for improving image visualisation and to extract main features. The main stages of image processing can be defined as following:

5.3. Canny Detector

Canny detector is a method that is broadly used in image processing and vision system. It is stronger to noise and more likely to detect true weak edges. The calculation derives the gradient using a Gaussian filter. It is used to observe strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges as shown in Figure 7. The advantage of Canny algorithm is therefore less likely than the others to be fooled by noise, and more effective to observe true weak edges. Canny edge method uses multi-steps edge detection procedure. Use of Gaussian filter in order to reduce noise and unwanted details and textures.

$$g(m,n)=G_\sigma\ (m,n)*f(m,n) \quad (1)$$

Where:

$$G_\sigma = 1/\sqrt{(2\pi\sigma^2)}\ exp\ [(m^2 + n^2)/(2\sigma^2)] \quad (2)$$

1- Computing gradient of *g(m, n)* by using gradient operations such as (Roberts, Sobel or Prewitt) reference.

$$M(n,n) = \sqrt{(g^2_m\ (m,n)+g_n{}^2\ (m,n))} \quad (3)$$

And

$$\theta(m,n)= tan^{-1}\ [g_n\ (m,n)/g_m\ (m,n)] \quad (4)$$

2- Thresholding *M*

$$M_T = \{(M\ (m,n)\ \ if\ \ M(m,n) > T\ \ \ 0\ \ \ otherwise)\} \quad (5)$$

T is a threshold so that only edges stronger than a certain value would be preserved.

5.4. Gradient Image Technique

Theorem: Based on [6], If *f(x, y)* is differentiable, then *f* has a directional derivative in the direction of every unit

$u = \langle a, b\rangle$, and $D_u = f_x\,(x, y)\ a + f_y\,(x, y)\ b.$

The pattern of above equation for calculating the directional derivative can be viewed as the dot product of the unit direction vector $u = \langle a, b\rangle$ with the vector $\langle f_x\,(x, y), f_y(x, y)\rangle$. This vector is called the gradient of *f* [6]. In this paper gradient function is applied to analysis the DXRI in order to evaluate the state of the teeth as shown in Figure 7 (column c).

5.5. Thresholding

Thresholding is a method that is used to separate out the Regions Of Interest (ROI) in which the user is interested in [7]. A parameter □□called the brightness threshold is chosen and applied to the image *f[m,n]* as follows:

if *f[m,n]* □□□ *f*[*m,n*] = *object* = 1

else *f*[*m,n*] = *background* = 0

Thresholding work by looking for each pixel in the image and compare it with the threshold □. Then, the pixel is set to the value 1 (white) in the output if it's intensity value is higher than the □, otherwise it is set to 0 (black) [7] (see Figure 4).

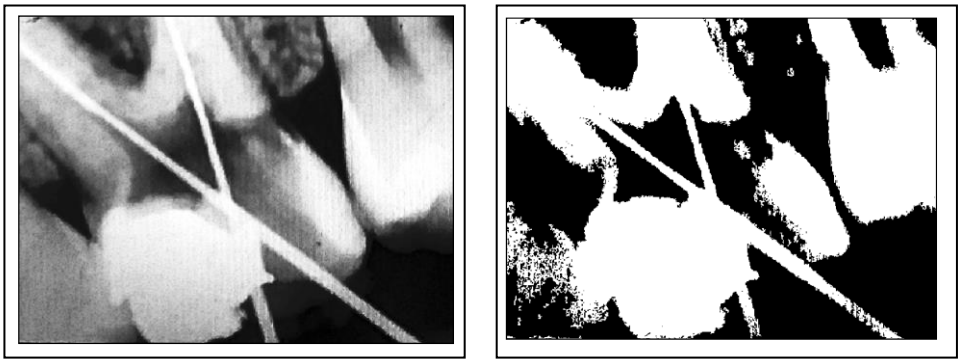

Figure 4: ROI of original DXRI and its threshold.

6. Results and Discussion

The proposed imaging algorithm in this paper enables the dentist to select the desired ROI by holding the image and dragging it to the desired ROI as shown in Figure 5; C and D. Moreover, the system provides the dentist capability to improve the image visualisation by enhancing the histogram of the image. Moreover; the system enables the doctor to change colour map of the acquired image in order to improve image visualisation as shown in Figure 3. In addition to that the system enables the doctor to measure distance between two points as shown in Figure 6 A and B. Results of the used image processing methods can be discussed in next sub-sections.

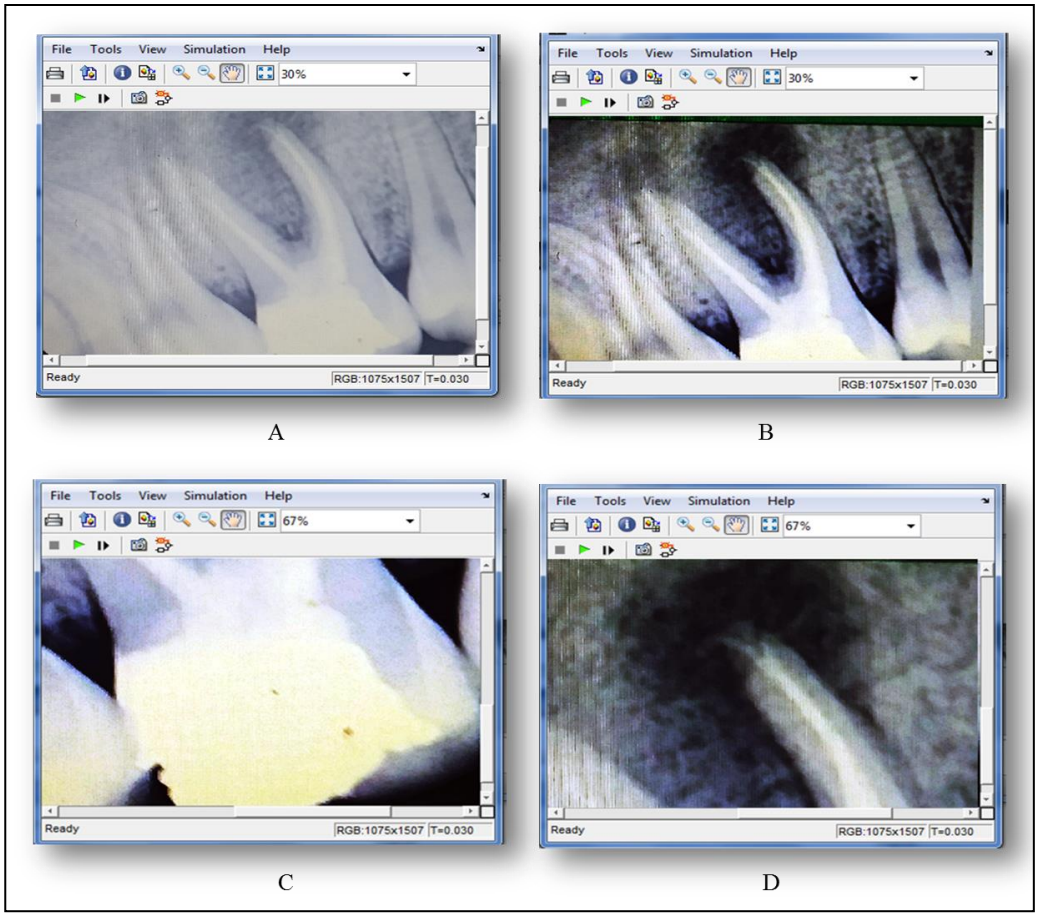

Figure 5: User interface of XRIS, A) original, B) equalised, C) and D) are ROI.

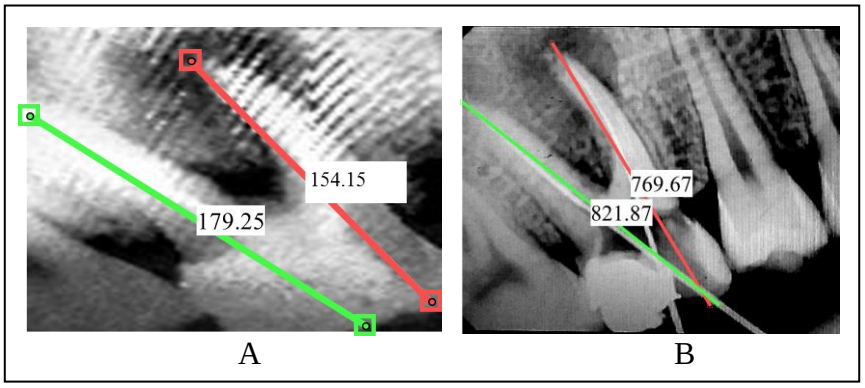

Figure 6: Illustrates measuring distance between two points.

6.1. Canny Detector

Canny detector is a method that broadly used in image processing and vision systems. It is applied for the purpose of finding image edges by observing for local maxima of the gradient of the image. Figure 7 (column b) shows the use of Canny detector in this study. From the Figure 7 (column b) it can be seen that canny detector has been unsuccessfully estimated the teeth conditions.

6.2. Gradient Image Technique

Theorem: Based on [6], If $f(x, y)$ is differentiable, then f has a directional derivative in the direction of every unit

$$u = \langle a, b \rangle, \text{ and } D_u = f_x(x, y)\, a + f_y(x, y)\, b.$$

The pattern of above equation for calculating the directional derivative can be viewed as the dot product of the unit direction vector $u = \langle a, b \rangle$ with the vector $\langle f_x(x, y), f_y(x, y) \rangle$. This vector is called the gradient of f [6]. In this study gradient method is used for analysing the image for evaluating the state of the teeth as shown in Figure 7 (column c). It illustrates images of two conditions of totally damaged (first row) and infected (second row) teeth. From Figure 7 (column c), it can be clearly seen that the gradient technique has clearly improved the visualisation of the image and successfully has described teeth detection.

6.3. Thresholding

Figure 7 illustrates two different ROI of unhealthy teeth. Column a, b, c and d in Figure 7, present the region of interest of original, edge detector, gradient image and binary image respectively. From Figure 7 (column d) it can clearly be seen that the threshold can describe tooth conditions. Moreover, Figure 7 (column d) first row it clearly indicates the damage to the tooth and it clearly has defined tooth infection (second row).

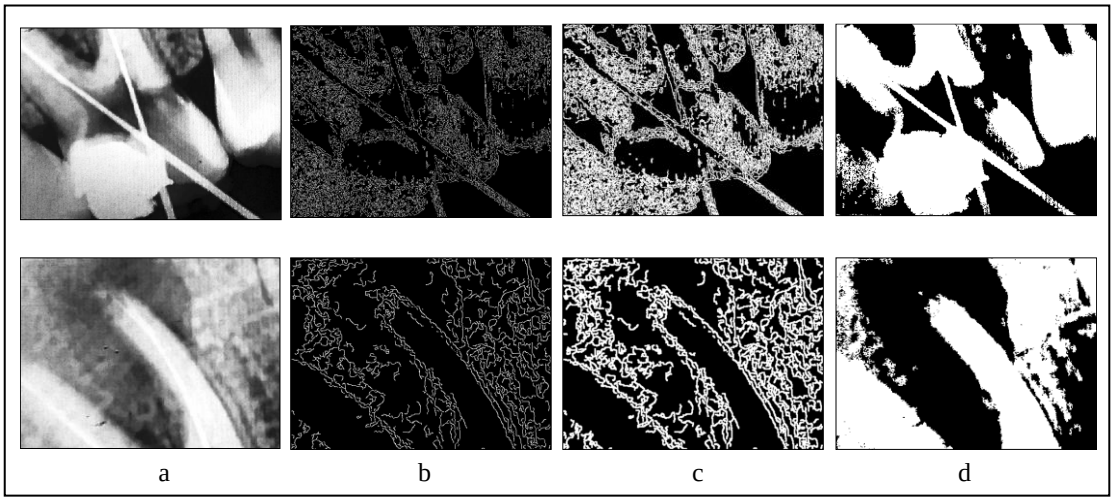

Figure 7: Images of two regions of the x-ray of the damaged and infected teeth (first and second rows). Moreover; it presents the use of canny detector, gradient and threshold (b, c and d respectively).

7. Conclusion

The paper has presented imaging algorithms for dental applications. Three image processing techniques have been applied to x-ray images representing different scenarios in order to investigate their capability to differentiate between teeth conditions. The results can be summarised as following:

1. Canny detector and gradient technique has been used in this research work in order to estimate the tool conditions. The results show that the used techniques have successfully applied and they correctly estimated the different teeth conditions. In addition to that the visualisation of the images has been improved by using image gradient technique.
2. Threshold has successfully applied and detected teeth health.

8. Future Work

More x-ray images should be acquired and analysed in order to design a reliable and effective imaging system for dental applications. The captured x-ray image data will integrate with image processing and combined with suitable computational intelligence techniques to improve the prediction of the health of the teeth.

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