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Analyzing edge detection techniques for feature extraction in dental radiographs☆

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Summary Several dental problems can be detected using radiographs but the main issue with radiographs is that they are not very prominent. In this paper, two well known edge detection techniques have been implemented for a set of 20 radiographs and number of pixels in each image has been calculated. Further, Gaussian filter has been applied over the images to smoothen the images so as to highlight the defect in the tooth. If the images data are available in the form of pixels for both healthy and decayed tooth, the images can easily be compared using edge detection techniques and the diagnosis is much easier. Further, Laplacian edge detection technique is applied to sharpen the edges of the given image. The aim is to detect discontinuities in dental radiographs when compared to original healthy tooth. Future work includes the feature extraction on the images for the classification of dental problems.

Introduction

A dental X-ray image is attained by the dentist during several diagnosis and treatment procedures such as root canal treatment, identification of 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 (Bjorndal et al., 1974). 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 (Lain and Chen, 2004). Edge detection is the process of identifying and locating lack of continuity, inequalities and varied orientations in an image (Prewitt, 1970). This discontinuity describes the sudden changes in the pixel intensity or first derivative of the image intensity. Discontinuities in image intensity can be step edge, line edge (Nomir and Motataleb, 2006). These

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discontinuities are rare in real images because instant changes rarely occur.

Image enhancement

Medical image enhancement technologies have been a focused area of research since advanced medical instruments and equipments have been introduced in medicine. Enhanced radiographs are required by a physician for the diagnosis and interpretation since the quality of medical images are mostly lowered by either noise or some data possession devices, illumination conditions, etc. Medical images are very special kind of images as they are used for the disease diagnosis in the patients (Said et al., 2006; Kiattisin et al., 2008). Various techniques are available for obtaining these images of which the most common ones are Computed Tomographic Imaging (CT), Cone Beam Computed Tomography (CBCT), etc. Our focus here will be on the image obtained through Cone Beam Computed Tomography (CBCT), which is mainly designed for dental purposes.

Cone beam computed tomography (or CBCT) is a medical imaging technique consisting of X-ray computed tomography where the X-rays are deviating, forming a cone-like structure. This technique has become increasingly important in treatment planning and diagnosis in implant dentistry, interventional radiology (IR), among other things. Because of the increased access to such technology, CBCT scanners are now finding many uses in dentistry, such as in the fields of endodontic and orthodontics. Integrated CBCT is also an important tool for patient positioning and verification in image guided radiotherapy. The only disadvantages of CBCT known as of now is high cost and limited imaging centres available that provide CBCT facility, often creating a problem in utilizing the technique to its fullest efficiency.

This paper is organized as follows: Section ''Application of edge detection techniques on dental radiographs'' discusses the edge detection using various edge detection techniques. Section ''Implementation of Gaussian and Laplacian filter on dental images'' shows the application of Gaussian filter and Laplacian method. Section ''Observation and findings'' discusses about the observations and findings. Finally, Section ''Conclusion and future work'' concludes the paper with the scope for future work.

Conventional edge extraction operators in dental X-ray images

Sobel operator: Most of the edge detection method are based on the assumption that edges are found in the image where there is discontinuity. Based on this assumption the derivative is taken for image intensity value and the points are located where intensity derivatives have maximum value so as to locate the edges (Harandi and Pourghassem, 2011). Sobel operator is used to calculate the gradient of image intensity and to find the direction of possible increase from light phase to dark phase and the rate of change in the direction. Results show the abrupt or smooth change in the intensity of point (Harandi and Pourghassem, 2011).

Prewitt operator (Gonzalez and Woods, 2002): It is computationally less expensive and faster method for edge detection. It is only appropriate for noiseless and well contrasted images (Kiattisin et al., 2008). Prewitt approximation is applied on the derivatives of intensity function. Its results in edges where gradient of intensity function has maximum value.

Gaussian filter — noise filtering in dental X-ray images

Image filtering is a crucial step in Image processing as it eliminates noise from noisy images. There are many filtering techniques to filter an image where each filtering technique has its own benefits. Noise is any undesired information that distorts an image. There are several ways through which noise can be introduced into an image, depending on how the image has been captured. Noise when get added to image destroy its details. Thus to preserve the real image, Noise should get removed from it. And for the purpose of enhancement the contrast of the image should be improved.

Gaussian noise: Additive noise is one of the most common problems in image processing. Even a high resolution photo is bound to have some noise in it. Gaussian filter is used to smoothen the image by removing additive noise from it. The purpose of smoothing is to reduce noise and improve the visual quality of the image. A variety of algorithms are used for filtering the images. Image filtering makes possible several useful tasks in image processing. A filter can be applied to reduce the amount of unwanted noise in a particular image.

Image sharpening: Laplacian based edge detection

Sharpening techniques improve the visibility of digital images by enhancing the marks of the objects which are present in the image. This improves their borders and their details, giving to the images greater neatness and depth. The Laplacian method searches for zero crossings in the second derivative of the image to find edges. An edge has the one-dimensional shape of a ramp and calculating the derivative of the image can highlight its location. This method of locating an edge is characteristic of the ''gradient filter'' family of edge detection filters and also includes the Sobel method. A pixel location is declared an edge location, if the value of the gradient exceeds some threshold. This method is known as the Laplacian edge detection.

Application of edge detection techniques on dental radiographs

Sobel and Prewitt edge detection techniques were implemented on a sample space of 20 teeth. The radiographs were taken for a set of 20 extracted teeth. Further, the radiographs were converted to jpeg format and the number of black and white pixels was calculated using Sobel operator, and Prewitt operator. Table 1 represents the difference between the numbers of black and white pixels of each tooth in the sample space.

Fig. 1 shows the comparison of digital X-ray image of tooth sample No. 6 converted using Sobel and Prewitt

Table 1 Pixel count.

No. of black and white pixels in Sobel and Prewitt techniques				
Tooth No.	Sobel		Prewitt	
(.jpg)	No. of black pixels	No. of white pixels	No. of black pixels	No. of white pixels
1	1,654,642	4358	1,654,643	4357
2	1,652,873	6127	1,652,931	6069
3	1,655,807	3193	1,655,805	3195
4	1,654,293	4707	1,654,329	4671
5	1,653,300	5700	1,653,350	5650
6	1,652,825	6175	1,652,847	6153
7	1,654,162	4838	1,654,147	4853
8	1,655,245	3755	1,655,272	3728
9	1,655,550	3450	1,655,557	3443
10	1,654,731	4269	1,654,734	4266
11	1,654,290	4710	1,654,271	4729
12	1,653,874	5126	1,653,907	5093
13	1,653,652	5348	1,653,668	5332
14	1,654,329	4671	1,654,359	4641
15	1,653,948	5052	1,653,989	5011
16	1,654,502	4498	1,654,515	4485
17	1,653,824	5176	1,653,793	5207
18	1,654,397	4603	1,654,433	4567
19	1,652,901	6099	1,652,917	6083
20	1,653,490	5510	1,653,605	5395

Figure 1 Sobel and Prewitt operator on X-ray image of tooth No. 6.

techniques. When 3D plotted, as in Fig. 2, the curves on the graph were look-alike with not much difference. Thus, there occurs a need to furthur smoothen the images to get much clearer view of the image.

Implementation of Gaussian and Laplacian filter on dental images

After converting the dental radiograph to Sobel and Prewitt images, somewhat similar results were obtained thereby generating the need for further application of filters for obtaining much clear view of the visual image.

When the number of white and black pixels were compared in both Sobel and Prewitt techniques, it was found that Sobel technique gives much better results than Prewitt images, though the difference was not much. Based on the assumption that a Sobel image may provide better results, Gaussian filter was applied on the Sobel image. Fig. 3 shows the effect of Gaussian filter on tooth sample No. 6 converted to Sobel image. It seems that it would be much easier to implement feature extraction on the Gaussian image so formed.

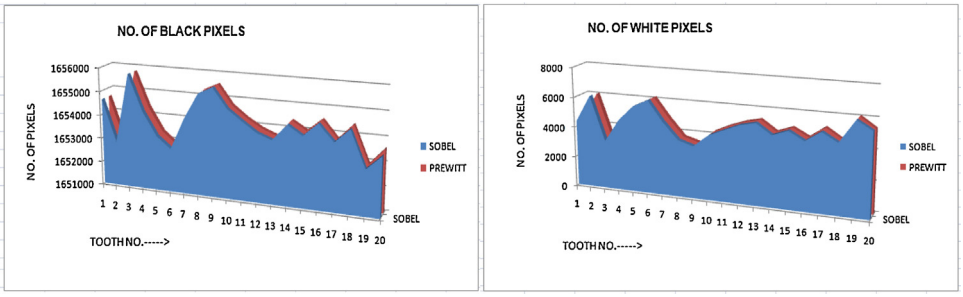

Figure 2 Comparison of black and white pixels in Sobel and Prewitt images.

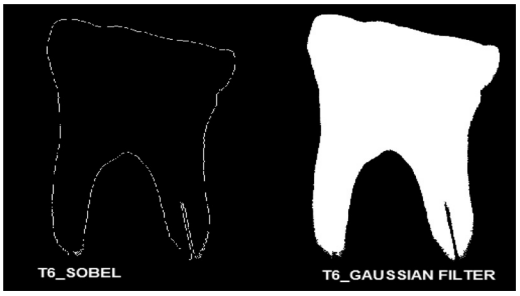

Figure 3 Gaussian filter applied to T6_Sobel image.

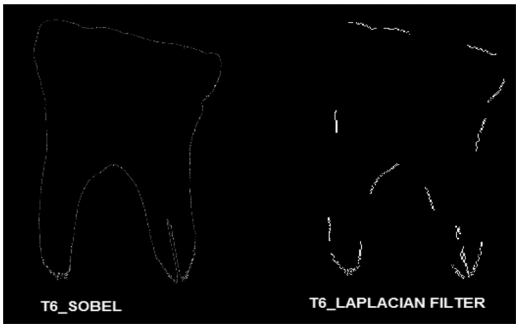

Figure 4 Laplacian filter applied to T6_Sobel image.

Since much better results were obtained when a smoothening filter, i.e. Gaussian filter was implemented on the Sobel converted radiograph, there may occur a need for finding the defects on the edges of the tooth than the surface. For this, the image needs to be sharpen. Laplacian filter was used on the Sobel image for further sharpening the image for the identification of defective edge in dental sample. Fig. 4 depicts the effect of Laplacian filter on Sobel image.

Observation and findings

From the above results, the challenges posed by various image processing edge extraction techniques on non-uniform dental images can be evaluated. Sobel and the Prewitt operators provide edges which are very nearer. 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, i.e. Sobel and Prewitt, mentioned in this paper seems to be inadequate for successfully obtaining the edge features from dental X-ray images. When Gaussian filter was applied on the Sobel image, much clearer image was formed and thus feature extraction can now easily be applied over the Gaussian image so formed which can easily be compared with the normal tooth image for the identification of actual problem in the tooth. Also, It was found that Smoothening and Sharpening of images have a greater effect in disease diagnosis in medical images.

Conclusion and future work

As discussed in the findings above that the smoother and sharper edges can now be made available for feature extraction for problem identification. Future work includes the implementation of above process on a larger sample space and extending the work to feature extraction for the identification of problems. Similar features shall be grouped together to form clusters and based on these clusters, pattern matching algorithm shall be implemented for the diagnosis purpose.

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