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ORIGINAL ARTICLE

Implementation of Edge Detection as an Efficient Algorithm to the Evaluation of the Dental Caries

Mohammad Karimi Moridani[1], Shabnam Ghahari[2]
[1]Department of Biomedical Engineering, Tehran Medical Branch, Islamic Azad University, Tehran, Iran
[2] Department of Biomedical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran.

ABSTRACT
Regarding the collected data from the patients, the dentists can offer them with a defined treatment plan. In many cases data collection from the patients is not complete and in some cases it is even vague and complicated. This issue causes the determination process to become problematic and makes it unable to suggest a final complete opinion about the disease type and the treatment plan. This article offers an edge detection based algorithm aiming for cavity detection which has been applied in Simulink environment of MATLAB software. The results of using this algorithm have been evaluated by several evaluation processes for segmentation of images which shows the performance of the proposed system in the detection of dental caries areas. This system can help the dentists to determine the treatment plan at stressful situations to a great extent, and it also can be used as educational software at dental faculties to offer a better education to the students.
Keywords: Edge Detection, Image Processing, Dental Caries, Treatment Plan, Image Segmentation

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INTRODUCTION

Dental caries is also known as tooth decay or cavity [1]. Currently, the cavity is one of the most common diseases around the world. The first sign for a new caries is the appearance of a chalky white spot on the surface of the tooth which shows a demineralized area of the enamel. This white spot lesion is called the initial carious lesion or microcavity. The cavity will become more significant once the enamel and dentin are destroyed. The affected areas will change color and become soft [2].

Caries that has entered the dentin must be recovered because they are no longer returnable to the prior condition, and they will merely advance and develop. To preserve the tooth structure and performing the dentistry with minimum invading, the carious lesions must be detected as quickly as possible. At the time these lesions are detected in the earliest stages, it is possible to prevent the caries development; as a result, the furthermore invasive surgeries are being prevented.

Although there are new techniques that by using them it is possible to diagnose and treat caries in their primary stages, but still due to lack of enough dentists comparing to the number of patients, it is very crucial to either increase the number of the dentists or to allocate some complementary technologies to the dentists, therefore, using computers for detection and diagnosis is necessary.

So far, numerous methods have been used for dental caries identification. Within the last years, several imaging methods whose their frequency range is from a typical Pulse-Echo Imaging in the central frequencies [3-5], coding imaging CHIRP [6] up to coding imaging CHIRP Laser Detector [7] have been studied. In the last years, high-frequency ultrasound waves are used for detection of dental caries [8-9]. However, the obtained images from this method come with the weak contrast between the enamel of normal and abnormal teeth, in addition to the fact that using ultrasound technique requires a connection space between the sound source and tooth which cannot be executed in a dentistry clinic.

Photo-Acoustic imaging is also used as a proper and useful method in noninvasive medical imaging [10-13]. The result of Photo-Acoustic is the production of photonic waves after absorbing the photonic pulse in the matter, and this kind of imaging is used for dental tissues [14-17].

The studies above shows the usage of the ultraviolet light source which is extremely absorbable by dental enamel and can also help the dentists with dental cleaning [17].

In 2014, Moridani et al. [18] worked on a paper for dental caries detection using histogram and power spectrum analysis. That study was concerned with dental caries detection in primary stages by using histogram and power spectrum analysis. The decay rate was analyzed and evaluated by X-Ray images of normal and decayed teeth of every person through signal processing tool. For every single image, the histogram and power spectrum was calculated. The pixel intensity histogram of normal and decayed teeth was focused in different ranges. There are also clear differences in gained spectrum from normal and decayed teeth. The spectrum of the decayed tooth has high-frequency components comparing to a normal tooth. The conclusion of that study showed that pixel intensity of the histograms depends on the decay stages, are positioned in the center of different ranges. For example, for a normal tooth it is limited and for a severely decayed tooth, it has been distributed. In spectrums, the various values of magnitude for different decay stages of the tooth is shown. Classifying the different stages of caries, based on the pixels concentrated area by considering the histogram and based on the magnitude values is done by considering the spectrum. This method shows a good ability for separation and detection in primary stages of initializing decays [18].

The endeavor for using artificial intelligence in medicine started from early 1970's [19]. Currently, many expert systems in medicine among which we can name the expert system Puff for pulmonary diseases diagnosis, Blue Box expert system for diagnosis and treatment of depression and Mycin expert system for diagnosis and treatment of bacterial diseases [20-24].

In 2002, Kawahata et al. designed a system called TXDent for dentistry diagnosis and treatment. The offered system had good speed, but it was not precise [25].

In 2008, Mago et al. used the busy network for designing expert system. The designed system in this study was used for caries treatment in adults. The precision of the designed system by these researchers was enough, but it had relatively low speed [26].

The aim of this article is to offer a relatively understandable feedback on caries existence and rate which helps the dentistry experts to analysis and combining the data within the primary stages for detecting the carries.

In this article, the proposed algorithm can provide the required diagnostic assistance without the need for expensive equipment such as DiagnoDent and Difoti, which are currently being used. This algorithm can detect caries in radiographic images and pictures of the intraoral camera. Not only this algorithm helps to overcome low manpower issue, but also it will provide a precise and inexpensive method for detection and treatment of caries.

In continue this article has been organized as follows: in the second section, it will discuss the proposed algorithm and the used data. In the third section, the outcome of the presented method in this article will be shown, and the conclusion will be offered in the fourth section.

MATERIALS AND METHODS
Used Data
The used data in this paper includes intraoral digital radiography images of the tooth which have been captured by Bitewing Radiology method. This sort of radiology is performed in molar teeth area, and the crown of the lower teeth and upper part of one side can be seen. The images have been captured from adults' teeth, and male and female adults are used equally. Regarding the decay intensity in different people's teeth, the captured images have different ranges of caries.

In this article, the carries percent and its depth and rate have no effect on the process of this research because with the offered method it is possible to detect any caries at any rate, and the important point is the quality of the images.

Proposed Algorithm
The suggested algorithm of this article in a model in the form of figure 1 has been implemented in Simulink environment of MATLAB software. In this model, the image is received through the input and by the assistance of the different-located blocks in design, the image is being segmented by Sobel edge detection, and also, the intensity of pixels of the picture is compared to the given quantity and consequently detects the decayed areas. The proposed model based on segmentation of image is an

innovation in image processing. This model is concentrated on processing pixel by pixel in the picture and modification of pixel neighborhoods that can be applied to the whole picture.
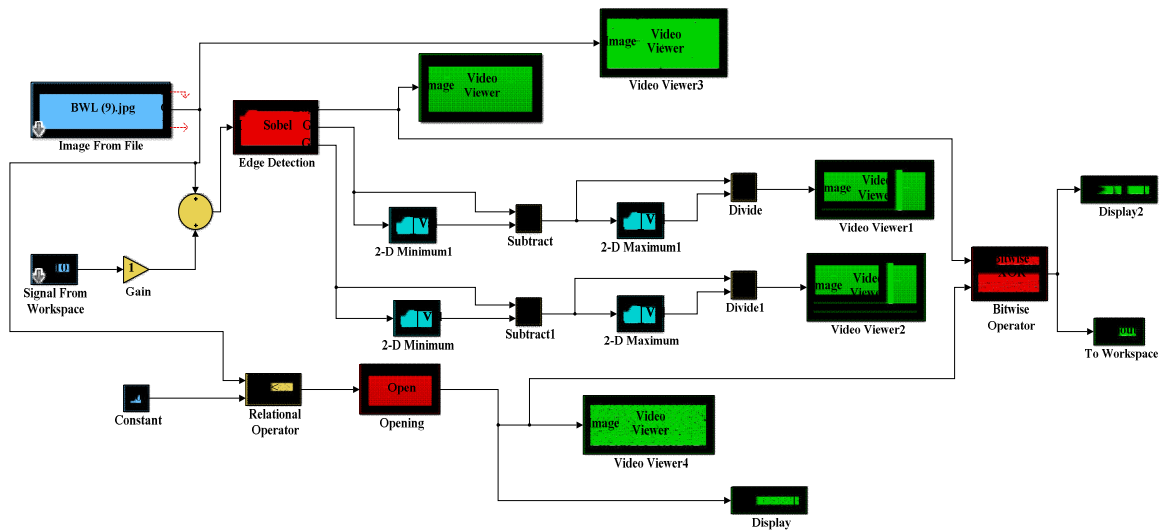

Figure 1: The proposed algorithm for detection of decayed tooth areas in the Simulink environment

Introduction of Used Blocks in Model Design
In this section for analyzing the performance of the proposed algorithm, the used blocks in the model will be described; Image From File block is for receiving the image so that the presented idea in the model can be performed on the received image. For placing the image, you must double-click on the Image From File so that the setting window opens. The image must be chosen by Browse through Main part, and then the image name appears in File Name field, and then hit the OK button. Ultimately it is possible to execute the offered algorithm by the model in the picture.
Video Viewer block is used to show the image. Video Viewer3 block shows the main image that received through Image From File.
Edge Detection block is a block which segments the image by Sobel Edge Detector although other edge detection methods such as Prewitt, Roberts, and Canny can also be used. Edge output of Edge Detection block directly connects to Video Viewer block and shows an image of the segmented teeth (the teeth are segmented separately from the boundary between teeth). Gv and Gh outputs of Edge Detection block are connected to 2-D Minimum, Subtract, 2-D Maximum and Divide blocks, and then they are respectively connected to Video Viewer1 and Video Viewer2 blocks which show a gray scale image of teeth in which every tooth is shown separately from the other.
Relational Operator block is used to compare two quantities, in a manner that its output is either zero or one. If the determined condition between the two input quantities is true, the output will be one and otherwise the output is zero. Tooth image is connected to the input of Relational Operator block. The other input of Relational Operator block is connected to a Constant block that determined 200 for its initial value. Relational Operator block compares the value of every pixel to 200, and if its value, considering the determined condition, is lower than 200, the output is one and otherwise the output is zero. The output values of Relational Operator block enter to Opening block and then come to Video Viewer4 block to show the created image. The blackened areas are the decayed areas. The steps of executing the proposed algorithm which has been implemented in Simulink environment is illustrated in figure 2.

Introducing Some of the Performance Evaluation Methods of Proposed Algorithm
Area detection algorithms can be evaluated in an experimental or analytical manner so the evaluation methods can be divided into analytical and experimental groups. The analytical methods naturally evaluate the segmentation algorithms by analyzing the scientific principles and their features.
The experimental methods indirectly analyze the segmentation algorithms by applying them to test images and quality evaluation of the segmentation results. The experimental methods can be subdivided into two categories called accuracy based and disparity based methods.
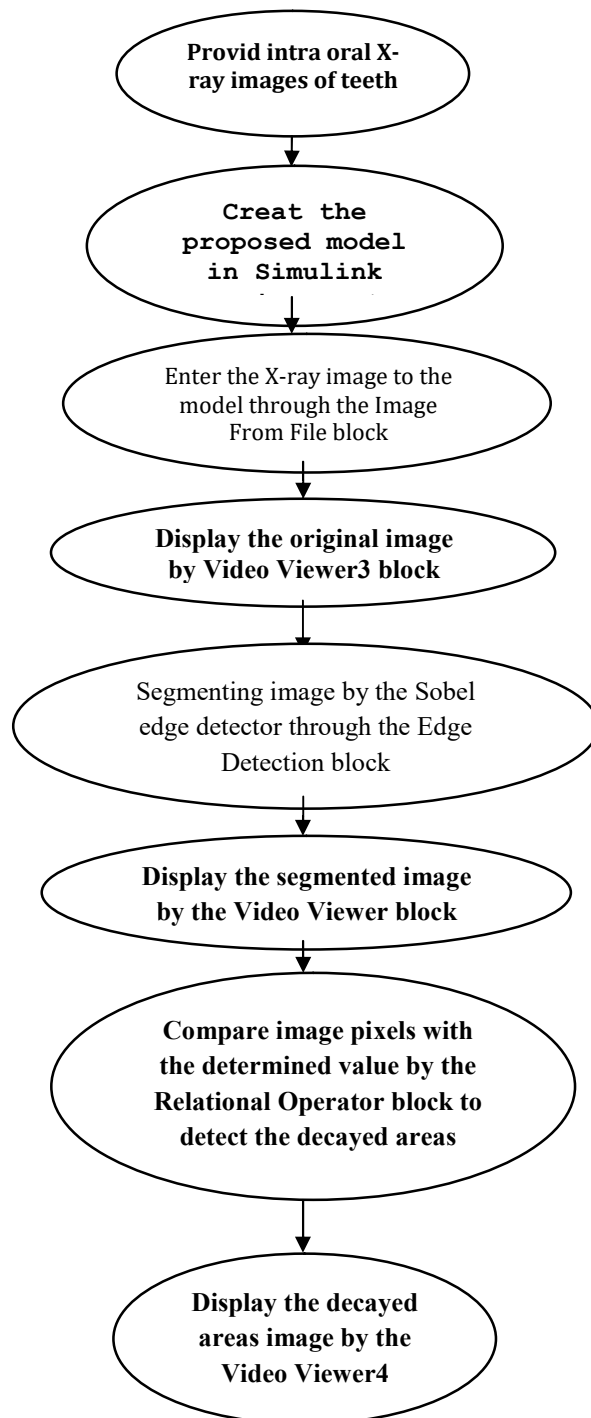
Figure 2: The steps of executing the proposed algorithm in Simulink environment

The accuracy based experimental methods can be cited evaluation based on intraregional similarity, intraregional contrast-based method, region shape based method and second-order of entropy criterion. Also, the experimental evaluation methods based on the disparity including the number of false segmented pixels, the location of the wrong segmented pixels and disparity based on the values of the feature of the segmented objects.

Creating a Graphic Environment for Ease of Algorithm Evaluation
The developed environment of the graphical interface of MATLAB software provides a collection of tools for creating user's graphical interfaces. In this environment, the user can load his/her image and after executing the proposed algorithm in this article, observes the output. Among its abilities, we can mention,

choose the different threshold levels for segmentation and comparison between the evaluation methods based on accuracy and disparity.

RESULTS
In this section, the precision of the offered method for approximation of dental caries treatment is evaluated. For the same reason, only the evaluation methods are used which use some of the educational data for learning the network and use the rest of the data for testing the network.

Figure 3 shows three samples of the original image which have been used for execution of the proposed algorithm. Images A and B have caries and image C has no decay, and the teeth are healthy. It must be mentioned that the decay rate in images is different. Figure 4 shows the model output by using Sobel edge detector.

(A)- The first sample
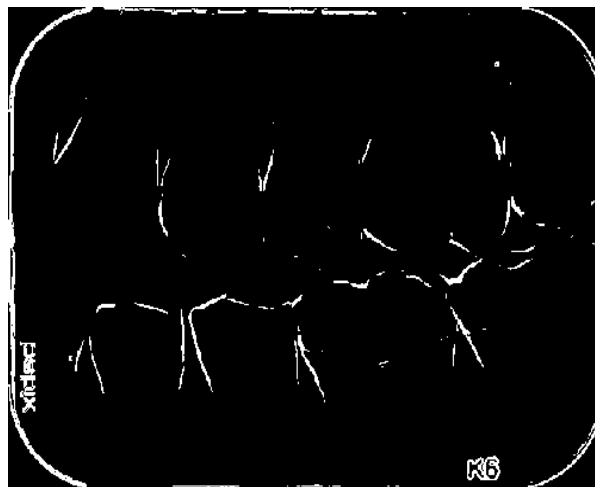
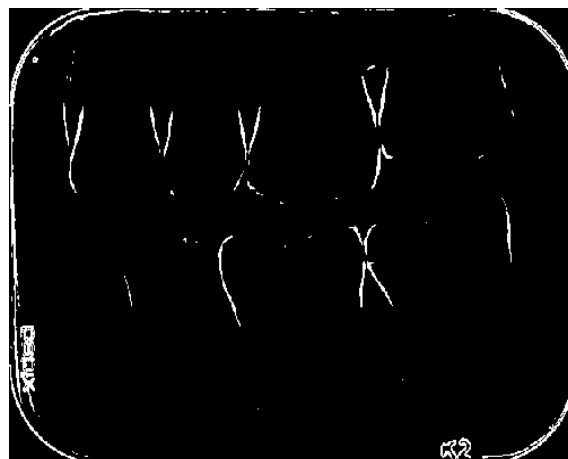(B)- The second sample

(C)- The third sample
Figure 3: The original images

(A)- The output image of Sobel edge detector for first sample

(B)- The output image of Sobel edge detector for the second sample

(C)- The output image of Sobel edge detector for the third sample
Figure 4: The model output by using Sobel edge detector

The performed studies showed that every pixel with more than 200 brightness intensity in radiography images shows the carries. It was also previously explained that Relational Operator block compares every pixel with 200, and if its value is less than 200, the output is one. Otherwise, the output is zero. For the same reason, if the output of Relational Operator block reaches one, that point is blackened in the image. So if the pixels in the picture are black, in fact, they are the decayed areas. Those pixels are shown in the

Video Viewer 4 block. Figure 5 indicates the output of the proposed model which is, in fact, the decayed areas.

(A)- The image of the decayed areas for first sample

(B)- The picture of the decayed areas for the second sample

(C)- The picture of the decayed areas for the third sample
Figure 5: The proposed model output that are shown the decayed areas

In the first and second sample of figure 5 due to the existence of decayed areas in teeth, the decayed areas are clearly shown in the figure. However, as it is evident there is no decay of the teeth in the third sample of figure 5, so in the mentioned figure the whole tooth is white, and there is no decayed area.

The results of this research showed that the proposed algorithm can exactly indicate the decay rate and depth. This method is entirely cost efficient and practical and also precise and in future with the probable developments, it can estimate the distance between caries and the root, and offer treatment suggestion for it.

DISCUSSION AND CONCLUSION

Studying the dentistry images can be considered as one of the primary methods for disease diagnosis, treatment plan and treatment process evaluation for the dentists.

Considering that the medical images show the body condition in 2D and even in 3D, it is safe to say that they are among the most important diagnostic devices for the physicians which have always allocated a huge part of research to their own and the dentistry science is no exception.

The different imaging methods such as radiography, visible light, laser, electric current, etc. are used for imaging the tooth or teeth. Among the methods mentioned above, radiography techniques are more popular because of their non-destructive nature and providing the possibility to analyze the 3D structure of the tooth, the ability of quantitative evaluation of carious lesion of different anatomical structures of the tooth and its accessibility comparing to some other similar methods.

If a dental caries is detected at its primary stages, it is possible to prevent decay, infection and losing the tooth more quickly. The proposed algorithm of this article which has been implemented in the form of a model in Simulink environment of MATLAB software is a method that can significantly detect the decayed areas and can be a great benefit for the dentists to diagnose the decays at their early stages. The dentists determine the treatment plan based on the collected data from the patients. Despite this matter, in many cases, many of the current observations are vague and incomplete. Therefore, the decision-making process can be with uncertainty.

The proposed model focuses on processing pixel by pixel of the image and amendment of the neighboring pixels which can be generalized into the whole image. The obtained results from the offered Simulink model suggest that this is a very easy model regarding execution and comprehension. This method can be complementary software for the dentists to help them with a better diagnosis of the carries. The dentists can easily load the captured image of the tooth into the model and behold the decayed areas in no time. Another advantage of this method is that it offers a visual feedback for the user.

Among the most important applications of dentistry image processing we can recall teeth modeling, studying the impacted teeth which are not easily visible, studying dental tumors, separating the teeth from each other in normal radiographic images, segmentation and detection of lesions in 2D images of the tooth, segmentation and estimation of the lesions in 3D images of the tooth, determining the bones dimensions for determination of dental implant lengths [28].

Through perform quick and precise evaluations on the captured X-ray image of the teeth, the offered system in this article can help the dentists with a correct diagnose of the decayed location and regarding the fact that planning treatment for a less experienced dentist can take too much time; this system can play the role of an expert assistant for the less experienced dentists. This method can also be used as an educational assistance software in dentistry faculties for educating the students.

Some other benefits of the proposed algorithm are a good performance, quick respond, excellent reliability, simplicity, and flexibility.

Due to the case of usage and accurate and precise diagnosis of the proposed model in this article, this method can be used as a supplement for other approaches and tools employed by the dentists. The results of this study can be used for studying the effectiveness of some treatment
methods regarding the comparison of decay condition before and after the treatment.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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