ISEF Based Identification of RCT/Filling in Dental Caries of Decayed Tooth

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Abstract

Dental image processing is one of the emerging fields in case of human identification in forensic sciences. Dental x-rays have been quiet effective for the diagnosis and detection of problems in tooth. This paper presents an add on approach in the same area of medical biometrics to detect and diagnose the dental caries in case of decayed tooth. The enhancement and segmentation of digital dental x-ray image is done by using Infinite Symmetric Exponential filter (Shen Castan Algorithm). The aim of this paper will be to enhance the extracted part of the tooth from digital dental x-ray, finding edges corresponding to caries affected tooth and decide the dental treatment like filling or Root Canal Treatment.

Keywords: Lesion, Enamel, RCT, caries, Dentine, Pulp, ISEF, Dental Radiograph, Dentistry.

1. INTRODUCTION

The process of extracting features, collecting & analysing the useful image information for clinical diagnostics of teeth is the prime need of today's medical science [1]. In this domain of dental image processing, most of the research done is beneficial for forensic science experts for the purpose of human identification. Moving a step ahead in this domain of dentistry the diagnosis of dental diseases from digital dental x-rays is being beneficial and helpful for both doctor as well as patient. Bardia Yousefi et al. in 2012 improved the visibility of digital dental x-ray for teeth, bone and canals using Laplacian transform along with morphological operation. Wavelet transforms and Bayesian classifier is used to classify teeth and canals from resultant image [2]. Ştefan Oprea et al. in 2008 performed dental caries classification based on the edge detection. The dental x-ray image is segmented into individual tooth and then it is converted into binary image of the tooth. The edge detection gives the outline of the dental cavity. The number of carries affected pixels is determined. The carries is classified as *pulpal* if black caries region is adjacent to the white border enclosing the tooth. If there exists two or more number of black regions and the width of the black region is less than 2 *mm* then it is *Enamel* carry [3].

Prof. G.A. Kulkarni et al. in 2011 proposed two degree differential gray scale method for dental image recognition. The two degree differential method isolated the un-matched part of the two images and gave a satisfied similar rate when the matching location was found. If the matching location was not found, this method enhanced the difference and reduced the similar rate [1]. EyadHaj Said et al. in 2008 performed gray scale stretching transformation for enhancement.

Morphological filtering like top-hat and bottom-hat filters were used for segmentation. 2-D modified wavelet kernels were used to detect boundaries of individual tooth [4].

In this paper we have applied ISEF edge detection to inspect the depth of dental caries in cases of decayed tooth. The paper has been divided in to six parts. Section 2 discusses the problem of dental radiography and possible solution through dental x-ray imaging. Section 3 comprises of the basic concepts of dental caries, the caries affected tooth extraction, its edge detection and further details. In section 4 we propose a novel approach for detection of depth of dental caries. Section 5 concludes the paper. In section 6 acknowledgments are being provided to specialized dental doctors, without their massive support nothing would have been possible.

2. PROBLEM DEFINITION

The raw data obtained directly from x-ray acquisition device may yield a comparatively poor image quality representation. In case of medical images human involvement and perception is of prime importance. It is a difficult task to interpret fine features in various contrast situations.

Nowadays digital dental radiographs, in which enhancement is done automatically, are available but the system are very costly. Our algorithm will give alternate solution to this problem. It includes X-ray imaging & its processing for identifying the exact location & depth of damage in affected tooth.As radiographic imaging study in medical practice provides better clue for diagnosis, but it is not merely the final tool; as investigations must be co-related with clinical findings [Courtesy by Dr. Ronak Panchal].

Dental caries, the common dental diseases, have affected human widely in modern times. Dental caries is an infectious microbiological disease that results in localized dissolution and damage of the calcified tissues of the teeth. Infection of the dental pulp will take place if dental caries are not treated at proper time.

3. BASIC CONCEPTS OF DENTAL CARIES

Classification of dental diseases is decided on the basis of certain criteria, such as based on either the caries lesion is within the enamel, dentine or caries lesion touches the pulp. Dental caries is visible in the x-rays. Image processing techniques will help check the x-rays and detect the depth to which the caries lesion is present and then classify the type of caries present in the dental x-rays. Dental treatment is also dependent on this classification. If caries is developed up to the enamel, it is classified as enamel caries and if caries extended up to the dentine then it is classified as dentinal caries. In above two cases, filling is the best solution. And if caries extended up to the pulp then it is known as pulpal caries, RCT (Root Canal Treatment) is the required treatment.

4. SUGGESTED TECHNIQUE

Sr.No.	Steps
1	Acquire digital dental images.
2	Apply morphological and filtering operations for image enhancement.
3	Extraction of caries affected tooth from image.
4	Edge detection using ISEF (Infinite Symmetric Exponential Filter).
5	Detection and decision based on caries extension inside the tooth as shown in table 4.

TABLE I: Suggested Technique.

4.1 Image Enhancement

In peraipical view, as shown in figure 1, we classify three main classes of “objects”; teeth, gum, and air. An area with “bright” gray scales (except for the pulp tissue) consists tooth area while areas with “mid-range” gray scales consists gum area, and “dark” gray scales indicates air. For better segmentation, it is desirable to convert poor quality dental x-rays in to considerable degree of contrast between the dominant gray scales used in capturing the different classes of objects.

FIGURE 1: Paraipical View of Dental Radiograph {Courtesy: Dr. Ronak Panchal}.

FIGURE 2: Enhanced Dental X-ray.

Top-hat and bottom-hat filters are applied on the original image to achieve an enhanced and desired image for further processing. Enhanced image is shown in figure 2.

4.2 Caries Affected Tooth Extraction

Caries affected tooth is extracted from enhanced dental X-ray, so that caries affected area can be visible more properly as shown in figure 3.

FIGURE 3: Caries Affected Tooth.

4.3 Edge Detection Using ISEF [16]

Edge detection of caries affected tooth is done by ISEF (Infinite Symmetric Exponential Filter).

Sr.No	Steps
1	Apply ISEF Filter in X direction
2	Apply ISEF Filter in Y direction
3	Apply Binary Laplacian Technique
4	Apply Non Maxima Suppression
5	Find the Gradient
6	Apply Hysteresis Thresholding

TABLE 2: ISEF Algorithm.

Shen Castan Infinite Symmetric Exponential Filter is an optimal edge detector. First the whole image will be filtered by the recursive ISEF filter in X and Y direction respectively which can be implemented by using following equations:

Recursion in x direction:

$$y_1[i,j] = \frac{(1-b)}{(1+b)} I[i,j] + b\, y_1[i,j-1],\ j = 1 \ldots N,\ i = 1 \ldots M \ \ldots \ldots \ (1)$$

$$y_2[i,j] = b\frac{(1-b)}{(1+b)} I[i,j] + b\, y_1[i,j+1],\ j = N \ldots 1,\ i = 1 \ldots M \ \cdots \ (2)$$

$$r[i,j] = y_1[i,j] + y_2[i,j+1] \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ (3)$$

Recursion in y direction:

$$y_1[i,j] = \frac{(1-b)}{(1+b)} I[i,j] + b\, y_1[i-1,j],\ i = 1 \ldots M,\ j = 1 \ldots N \ \ldots \ldots \ (4)$$

$$y_2[i,j] = b\frac{(1-b)}{(1+b)} I[i,j] + b\, y_1[i+1,j],\ i = M \ldots 1,\ j = 1 \ldots N \ \ldots \ (5)$$

$$y[i,j] = y_1[i,j] + y_2[i+1,j] \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ (6)$$

b=thinning factor (0<b<1)

Subtract the filtered image from the original image to obtain the Laplacian image. In the filtered image, there will be zero crossing in the second derivative at the location of an edge pixel because the first derivative of the image function should have an extreme at the position corresponding to the edge in image. Non maxima suppression is used for thinning purpose for false zero crossing. The gradient is either a maximum or a minimum at the edge pixel. If the second derivative changes sign from positive to negative, it is known as positive zero crossing and if it changes sign from negative to positive, it is known as negative zero crossing. We will permit positive zero crossing to have positive gradient and negative zero crossing to have negative gradient. We considered all other zero crossing as false zero crossing. Thresholding is applied on gradient image. One cutoff is used in simple thresholding but Shen-Castan suggests for Hysteresis thresholding in which two cut offs are used. Thresholding is applied on the output of an edge detector to decide significant edges. Noise will create spurious response to the single edge that will create a streaking problem. Streaking is defined by breaking up of the edge contour caused by the operator fluctuating above and below the threshold.

Hysteresis thresholding is used to eliminate streaking problem. Individual weak responses usually correspond to noise, but if these points are connected to any of the pixels with strong responses, they are more likely to be actual edge in the image. Such connected pixels are treated as edge pixels if their response is above a low threshold.

We use different thresholds and calculate Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) values for each experiment. High threshold is selected as 0.8 and low threshold is selected as 0.6. These threshold values gives minimum mean square error as expressed in table 3.

$$MSE = \frac{1}{M * N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (f(i,j) - g(i,j))^2 \tag{7}$$

Where f(i,j) is the input image and g(i,j) is the edge detected image.

$$PSNR = 10 * [[\log(255 * 255)] / MSE] \tag{8}$$

	Low Threshold				High Threshold			
THRESHOLD	0.2	0.4	0.5	**0.6**	0.6	0.7	**0.8**	0.9
MSE	0.3544	0.3618	0.3467	**0.3440**	0.3622	0.3606	**0.3491**	0.3558
PSNR	52.6359	52.5463	52.7309	**52.7650**	52.5409	52.5610	**52.7008**	52.6185

TABLE 3 Threshold Selection.

The ISEF algorithm is given in table 2. Output is shown in figure 4.

FIGURE 4: ISEF Operated Tooth (LT=60% of max. intensity HT=80% of max. intensity).

5. RESULTS AND DISCUSSION

After converting the dental x ray image to gray scale image, morphological operation using top hat and bottom hat transformation is applied. The resultant image so achieved is shown in figure 5.

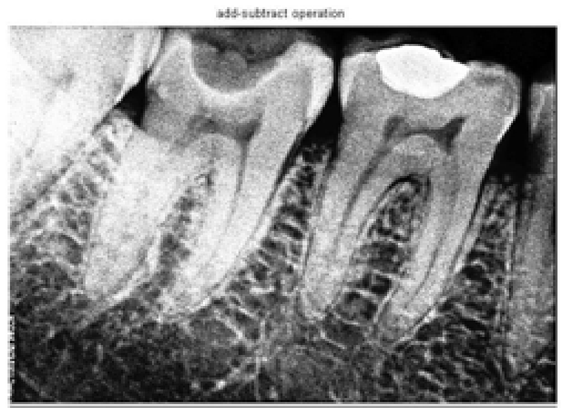


FIGURE 5: After Applying Morphological Operation.

Morphological operated image is converted in to binary image. The caries affected tooth is extracted using image cropping operation. Due to presence of noise factor in the binary image median filter is applied on it. The result is shown in figure 6.

FIGURE 6: Removal of Noise Using Median Filtering.

Edge detection of tooth is done using ISEF as shown in figure 4. Now to decide the treatment planning, the following technique is used as presented in Table 4.

Sr.No.	Steps
1.	Decide a horizontal region of interest as shown in Figure - 8.
2.	Bottom line of the region of interest is taken as a reference.
3.	If caries areas are in the enamel region or extended up to the dentine region then filling is to be done.
4.	If caries areas are falling below the dentine region then RCT is required.

TABLE 4: Steps for Deciding Filling / RCT for Horizontal ROI.

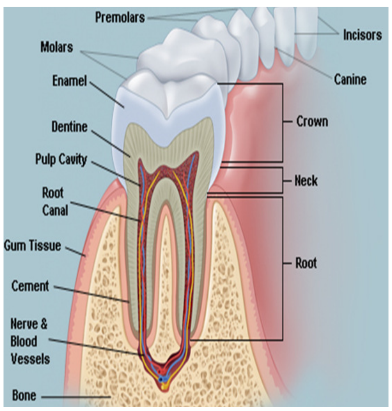


FIGURE 7: Tooth Structure {Courtesy: Dr. Ronak Panchal}.

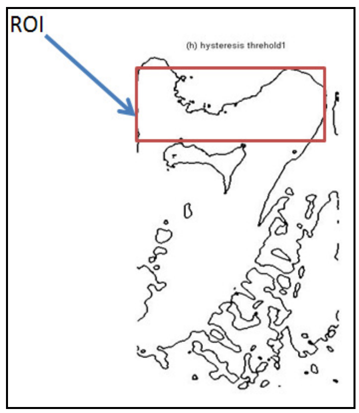


FIGURE 8: Image With Horizontal Region of Interest.

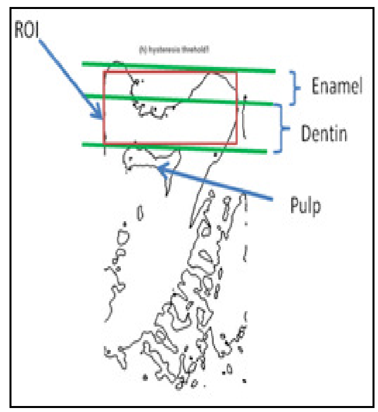


FIGURE 9: Image Showing Different Areas in Horizontal ROI.

Sr.No.	Steps
5.	Decide a vertical region of interest as shown in Figure - 10.
6.	Inner Slanted line of the region of interest is taken as a reference.
7.	If caries areas are in the ROI region then filling is to be done.
8.	If caries areas are falling beyond the ROI region (inner part of the tooth) then RCT is required.

TABLE 5: Steps for Deciding Filling / RCT for Vertical ROI.

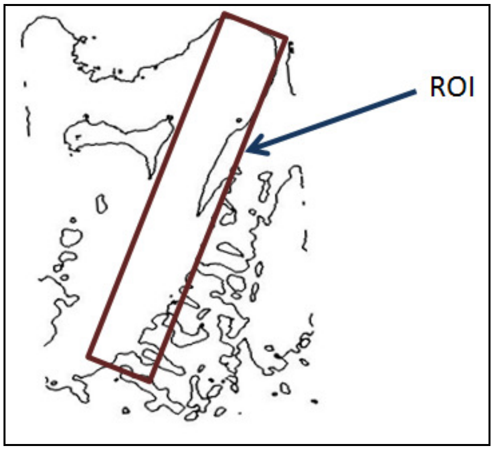


FIGURE 10: Image With Vertical Region of Interest.

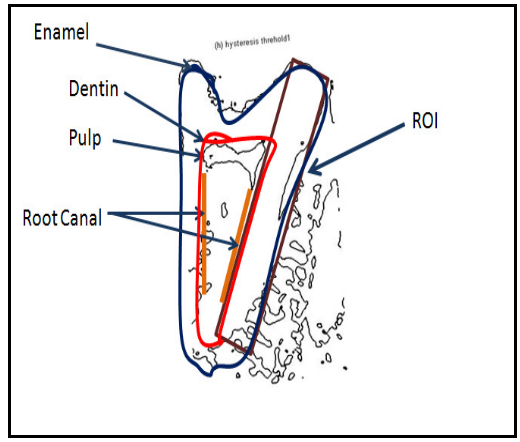
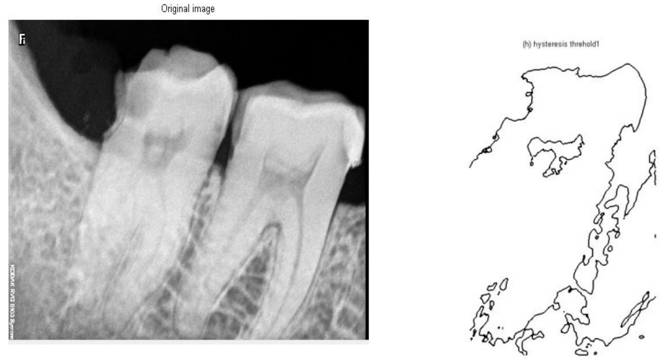
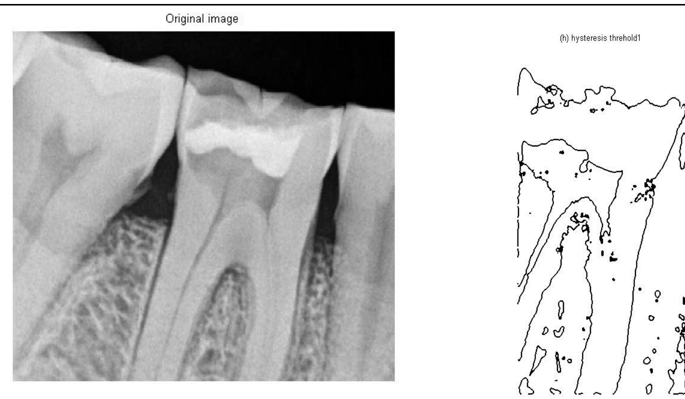
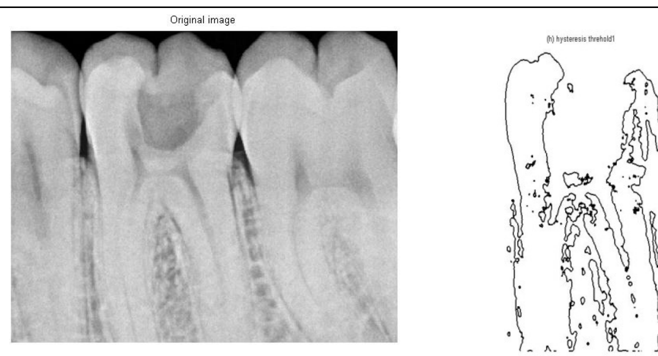


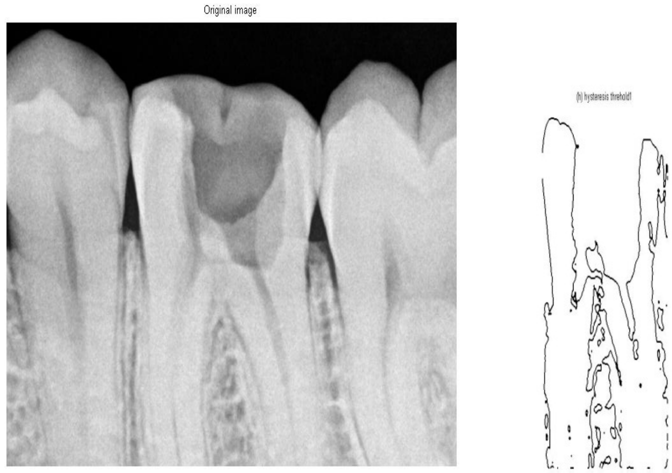
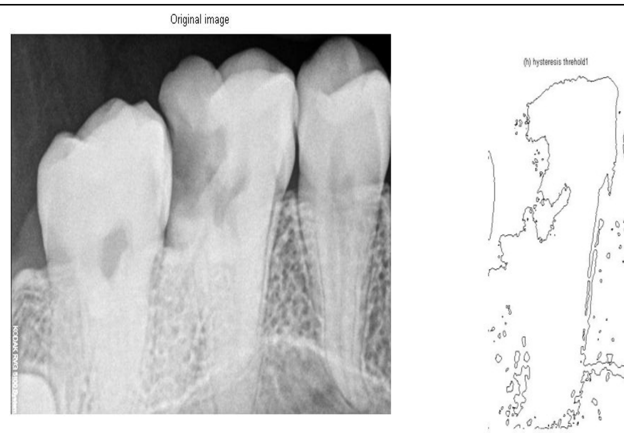
FIGURE 11: Image Showing Different Areas in Vertical ROI.

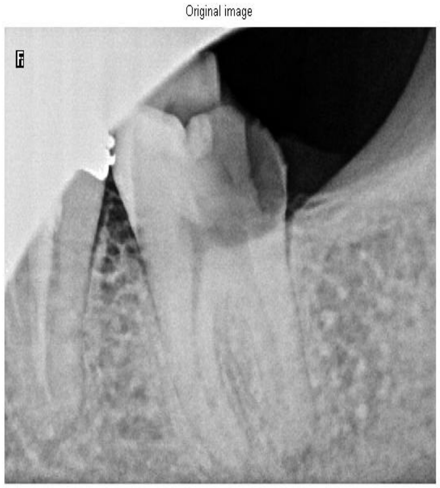
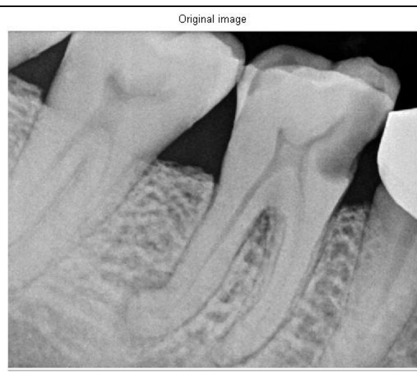
As discussed in table 4 if caries affected area is on the top side of the tooth in the selected region of interest as shown in figure 8 then filling is to be done. If caries affected area is not only in enamel and dentine region as shown in figure 9 then RCT is to be done.

As discussed in table 5 if decaying is from the sides of the tooth then the selected ROI as shown in figure 10 can be effectively used. Taking figure 7 as reference figure which would give us the idea about how much is the caries affected portion. If the decaying is reached up to the roots as shown in figure 11 then RCT is the only option. The same approach is applied on various dental x-ray images and the result is shown in figure 12.

Sr.No.	Image	Result using reference
1	 	RCT–Fig.8

2		Filling- Fig. 8
3		RCT- Fig.8 and Fig. 10
4		RCT- Fig. 10
5		RCT- Fig. 8

6		RCT- Fig. 8
7		Filling- Fig.8
8		RCT- Fig. 10

9	 	RCT- Fig. 8 and Fig. 10
10	 	Filling- Fig. 8
11	 	RCT – Fig. 10

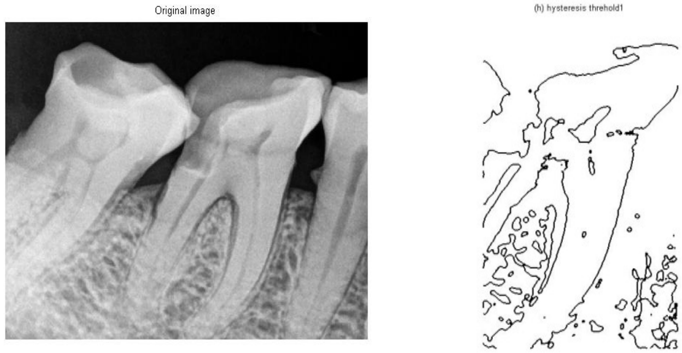
12		Filling- Fig.10

FIGURE 12: Results of Various Dental x-rays of Various Patients for Decision Making to be Operated for Filling or RCT.

6. CONCLUSION

Figure 8, 9, 10, 11 and 12 are the resultant images which were also shown to various dentists and the results were not only accurate but well appreciated and recommended for further research. Figure 12 is the edge detected dental x ray images of patients which gives a clear idea of the caries areas affected either from top or sides. The decision so taken were easy and clear as the dental x-ray edge detected images were noise free as well as clear lines depicted the caries affected areas of enamel , dentine or pulp. In figure 12 second figure (12 (b)) from first row results in filling rest all five results show that RCT has to be done as the carries affected areas have crossed the horizontal or vertical ROI.

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