Edge Detection Techniques in Dental Radiographs (Sobel, T1FLS & IT2FLS)

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Abstract. Dental image processing plays a vital role in case of human identification. Proceeding a pace ahead in the area where image processing of dental radiographs for effective detection and diagnosis of dental diseases required. Edge detection plays an important role on dental radiographs as it contains the information of object discontinuity in an image. In this research, three edge detection techniques are implemented they are Sobel, Type 1 Fuzzy Logic System (T1FLS) and Interval Type 2 Fuzzy logic System (IT2FLS) on dental radiographs of different patients. If the image information of healthy and effected teeth are available in the form of pixels, the diseases can easily be identified by edge detection technique for further better diagnosis. The main aim of this research is to provide fast and best edge detection technique applied on the dental radiographs. Comparison among mentioned techniques are on the bases of total edge detected pixels, time taken by algorithm and ability to detect the dental diseases clearly. By considering all those parameters, IT2FLS gives better results shown in this paper.

Keywords: Dental diseases · Sobel operator · T1FLS · IT2FLS
Edge detection

1 Introduction

In dental x-ray imaging, edge detection acts a very helpful function in detecting and diagnosis of the dental diseases. Since, brightness of x-ray image are not good enough because of sequins occurs due to the presence of water on teeth. The biggest difference between the digital dental x-ray of other important x-ray development mechanisms is that the digital dental x-rays are usually recorded by the dentist by the use of x-ray equipment in several orientations although with other significant x-ray mechanisms, the x-ray device is also static or goes in a solidly aligned path. Dental radiograms are poor and complicate in some of the diseases extraction such as tooth decay, cavities [2], tooth abscess [3], impact tooth, chipped tooth, diastema, crooked teeth etc.

Edge detection is the procedure of placing and positioning lack of continuity, differences and divergent orientations in an image. Edges plays a vital role in image processing applications. It can be specified by the group of immediate pixel location where a sudden changes in intensity information occurs. Edges be the outline of objects and background. An edge detector can be applied for feature extraction, image segmentation and object identifications [1].

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Conventional edge detectors Sobel, Perwitt and Roberts [4] are centered on derivatives of an image concentration purpose. They have high performance speed and are widely implemented. However, they fail to detect edges in complex medical images and those with acquisition artifacts. Therefore, it necessitates a comprehensive modification to enhance their performance. The algorithm of Multiple Morphological Gradient (mMG) is applied in [5] for clearly visibility of boundaries of object in panoramic radiograms. Furthermore, mMG algorithm should be applied for the detection of more number of dental diseases.

To overcome the problems of conventional edge detectors. Fuzzy Logic technique came into existence. Fuzzy logic is soft computation procedure designed for modeling partial information or ambiguous information. The usage of type-1 fuzzy logic in actual computer structures is wide, especially in user productions and operating applications. Fuzzy logic is field of soft computation which alters a computer organization to argue with uncertainness. A fuzzy inference system (FIS) comprises a set of rules determined above fuzzy sets. Fuzzy sets simplify the theory of a conventional set by granting the degree of membership to be several value with in 0 and 1 [6].

Nowadays, the effectiveness of type-2 fuzzy logic is what it accept one further pace towards the destination of 'Computing with Words' or the purpose of computers to act human sensing. This study focused on the impression of a fuzzy set whereas the membership degree of a fuzzy sets are evaluated with linguistic relations such as small, medium and large. [7, 8] at this phase, the explore was of extremely numerical, theoretic nature and actually was around constructing more or less of the foundations to more recent work.

The section of this research is prepared as follows; the description of sobel edge detector and the way of edge detection process used by gradient method is demonstrated in Sect. 2. The detection of edges using T1FLS with all the inputs applied at the time of process is described in Sect. 3 same as in Sect. 4, edge detection with IT2FLS along with input and output membership function are described and fuzzy inference rules which is applied in both T1FLS and T2FLS to evaluate the input and output variables. In Sect. 5, results and discursion takes place by taking different types of dental radiographs of different patients. Finally, in Sect. 6, conclusion and future scope according to the results takes place on the basis of parameters found in previous sections.

2 Sobel Edge Detection

Sobel edge detector applied on the digital image having gray scale values, that computes gradients of an intensity of the light of every pixels, affording the way of larger potential gain of dark to light [9]. Sobel operator comprises of the matrix of 3×3 masks for convolution over an input image. As shown in Eq. (1) where the Sobel_x and Sobel_y are sobel operators across horizontal and vertical direction respectively used for detection of edges in an image in respective directions. For the result, this mask moves throughout over an image [9].

$$\text{Sobel}_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad \text{Sobel}_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & 1 \end{bmatrix} \tag{1}$$

$$G_x = \text{Sobel}_x * I \tag{2}$$

$$G_y = \text{Sobel}_y * I \tag{3}$$

$$g = \sqrt{gx^2 + gy^2} \tag{4}$$

Equations (2) and (3) defines '*' defines the convolution operator, 'I' as input image (dental radiographs), 'Gx', 'Gy' shows that images of every level comprises of horizontal, vertical derivative estimation and in Eq. (4) magnitude is determined that is given by 'g'.

3 Edge Detection with Type-1 Fuzzy Logic System (T1FLS)

Especially, in biomedical images, where there the images are less contrasted, there edges are advantageous to detect. Because, the wrong choice of edges might contribute to improper treatment to the diseases. After concerning all those problems edge detection using T1FLS is introduced to detect edges, which considers image be a fuzzy. And extract some parameters of images for creating fuzzification using membership functions. In majority of images where edges aren't distinctly determined, that is to say edges are discontinued, unclear, or blurred and in that situation edge detection gets more hard. For this purpose, different steps to be followed by fuzzy logic system that are fuzzification, applying rule base, decision making unit and defuzzification process to get desired output [10].

3.1 Input to T1FLS

In the T1FLS method, primarily four inputs be required, out of them two are based on the gradients computed called as variable GH and GV respectively which are mentioned in Eqs. (2) and (3) of previous section and another two inputs are the filters that are high pass filter (HPF) and low pass filter (LPF) shown in Eqs. (5) and (6). First two inputs calculated the edges in different direction of images and next two that are HPF and LPF are used to calculate the high frequency (edges) and blurring of image. For these function, two mask of HPF and LPF are used that are shown in Eqs. (5) and (6)

$$\text{HPF} = \begin{bmatrix} -1/16 & -1/8 & -1/16 \\ -1/8 & 3/4 & -1/8 \\ -1/16 & -1/8 & -1/16 \end{bmatrix} \tag{5}$$

$$\text{LPF} = (1/25) \times \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} \tag{6}$$

Therefore, the inputs to T1FLS are GH, GV, HP = HPF * I and D = LPF * I where 'I' denotes the input image (dental radiograph) and '*' denotes the convolution operator.

3.2 Input and Output Membership Functions

Membership function comprises of linguistic variables say low, medium and high. Basically, MFs are used at the time of fuzzification process in fuzzy logic system. Different types of MFs are available, but in this research gaussian MFs are used because of always continuity provides by this type of curve. Here, three linguistic variables are applied they are low, medium and high represented by blue, red and yellow color curve in following figures. The four parameters of images extracted in previous section are shown in the form of membership functions used as the input and output of fuzzy variables that are GH, GV, HP, D and EDGES in T1FLS (Figs. 1, 2, 3, 4 and 5).

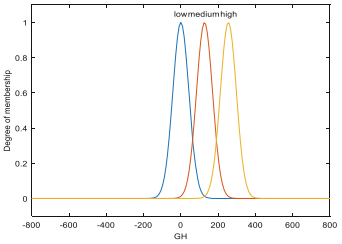

Fig. 1. Input variable GH (Color figure online)

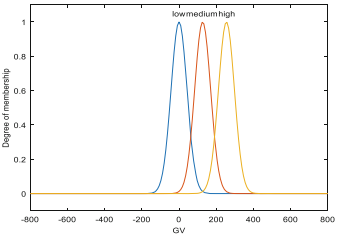

Fig. 2. Input variable GV (Color figure online)

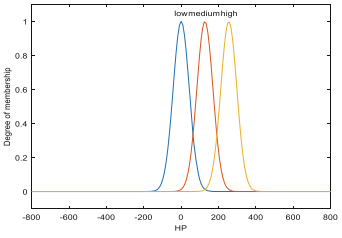

Fig. 3. Input variable HP (Color figure online)

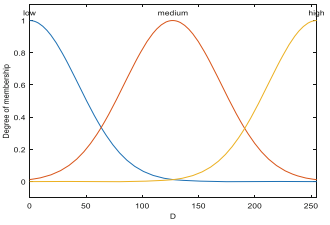

Fig. 4. Input variable D (Color figure online)

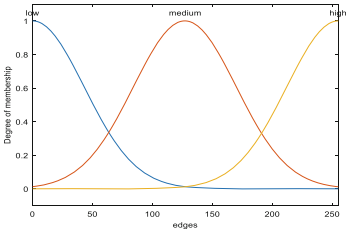

Fig. 5. Output variable edges (Color figure online)

4 Edge Detection with Interval Type-2 Fuzzy Logic System (IT2FLS)

Similarly, for IT2FLS all process of fetching the desired output is same as T1FLS but the difference is that in IT2FLS input and output membership functions has been fuzzy type-2 sets. And for conversion of type 2 sets to type 1 sets, one additional unit is required in the process called type reduction. Benefits of using IT2FLS are, it is much helpful in conditions where it's hard to defines appropriate membership functions towards the fuzzy sets [11].

Edge detection with IT2FLS follows the same process that in T1FLS but only difference is in applied membership function and results outcomes after the comparison. It consists of upper and lower MFs with the broad of the footprint of uncertainty (FOU) [12] which is the union of all primary MFs. FOU is the bounded region between upper and lower MFs.

4.1 Input and Output Membership Functions

The major difference between T1FLS and IT2FLS is difference in membership function used. Here, membership function itself in fuzzy set. The MFs used to define the input and output variables of IT2FLS are also Gaussian type curve. Following are the membership functions defined for the fuzzy variable as an input and output that are GH, GV, HP, D and EDGES for IT2FLS. As all these variables are shows in previous section of this research (Figs. 6, 7, 8, 9 and 10).

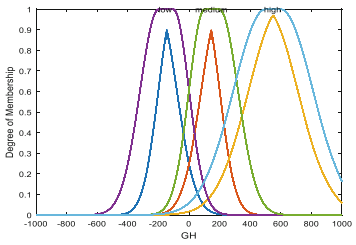

Fig. 6. Input variable GH

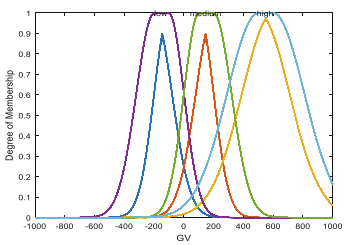

Fig. 7. Input variable GV

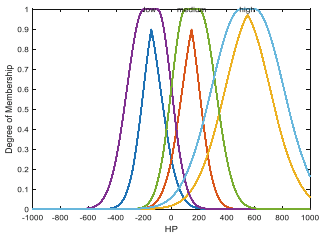

Fig. 8. Input variable HP

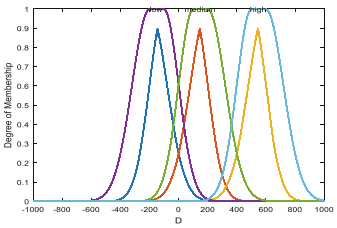

Fig. 9. Input variable D

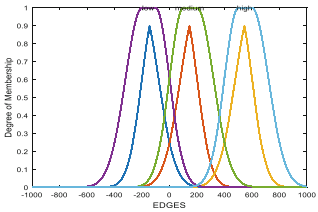

Fig. 10. Output variable edges

4.2 Fuzzy Inference Rules

The main principle of fuzzy inference is to map given input in an output by the use of fuzzy logic. The process of this mapping comprises one essential unit that is 'rule base'. Rule base consist of if-then statements depending upon application. For aggregation of these rules conjunctive operator is applied which calculates the minimum of both antecedents used in the rules. Following are the inference rules [13] which is used for evaluation of the input and output variables for both T1FLS and IT2FLS.

Rule 1 : If (GH is Low) and (GV is Low) then (EDGES is Low).
Rule 2 : If (GH is Medium) and (GV is Medium) then (EDGES is High).
Rule 3 : If (GH is High) and (GV is High) then (EDGES is High) .
Rule 4 : If (GH is Medium) and (HP is Low) then (EDGES is High).
Rule 5 : If (GV is Medium) and (HP is Low) then (EDGES is High).
Rule 6 : If (D is Low) and (GV is Medium) then (EDGES is Low).
Rule 7 : If (D is Low) and (GH is Medium) then (EDGES is Low).

5 Results and Discussion

Edge detection techniques employed over three different patients having different diseases they are chipped teeth, diastema and crooked tooth. Results of sobel edge detection are shown at different threshold values. Following are the results obtained by applying implemented algorithms (Sobel, T1FLS and IT2FLS) (Figs. 11, 12 and 13).

From figure results of applied techniques it is clearly visible that edge detection using IT2FLS gives better results because edge detected pixels of patient 1 are 125406 which are comparatively larger than the other techniques applied in this research. In sobel edge detection, four threshold values are taken, through which at threshold 210 more number of edge detected pixels are detected say for patient 1 total 5072 pixels present in the output image. In the above images, red boxes indicates the area of concern, used by doctor in the process of diagnosis.

Table 1 shows the total number of edges obtained from sobel, T1FLS and IT2FLS for all the three images. Thus, IT2FLS is improved than T1FLS. It can be seen from the table that IT2FLS provide more edge pixel than T1FLS of same image and edge pixels have good appearance in IT2FLS than T1FLS. Table 2 shows comparison is based on total time taken by the algorithm to detect edges from the image, which shows that less time is taken by IT2FLS.

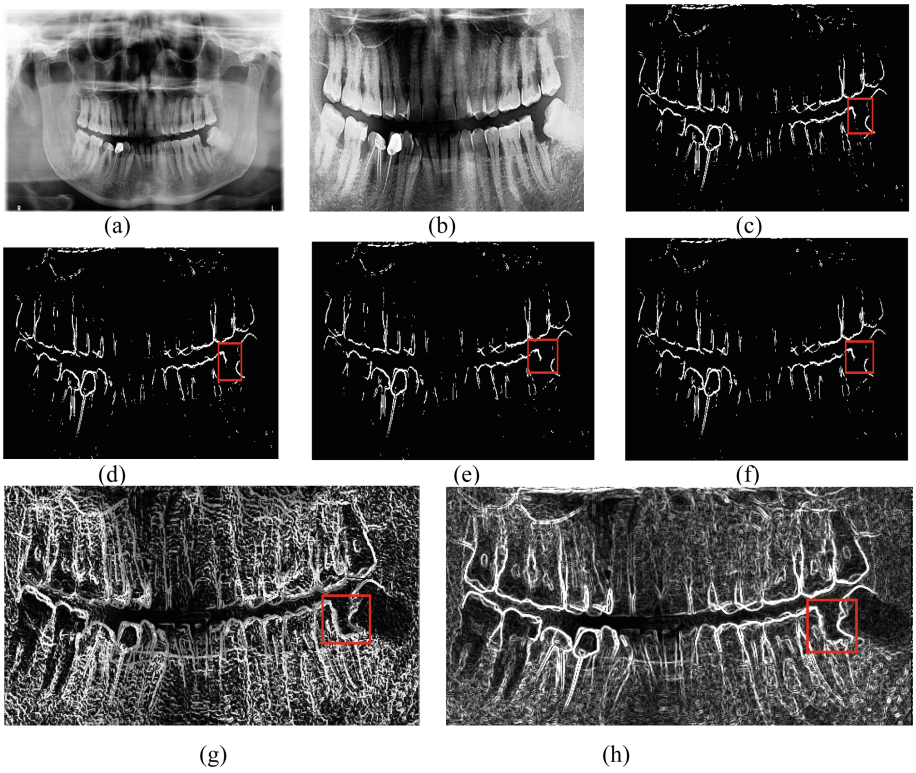

Fig. 11. (a) shows the input x-ray image of patient 1, (b) shows the cropped image, figure (c) to (f) shows the results of sobel operator at various thresholds that are 210, 220, 230 and 240 respectively, figure (g) shows the results of T1FLS and (h) shows the results of IT2FLS. (Color figure online)

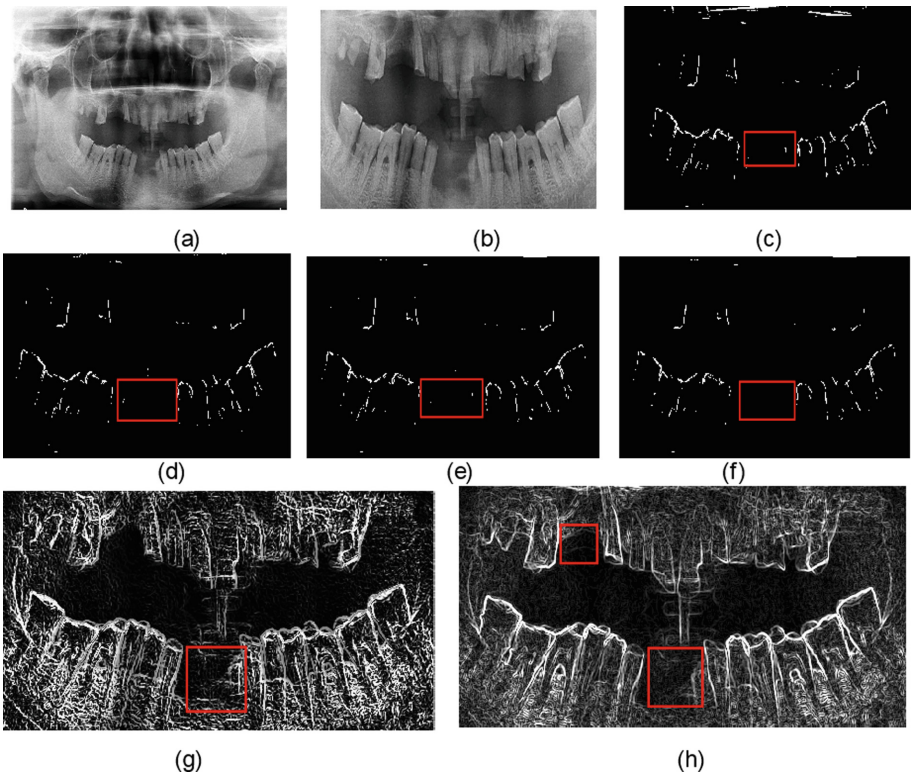

Fig. 12. (a) shows the input x-ray image of patient 2, (b) shows the cropped image, figure (c) to (f) shows the results of sobel operator at various thresholds that are 210, 220, 230 and 240 respectively, figure (g) shows the results of T1FLS and (h) shows the results of IT2FLS. (Color figure online)

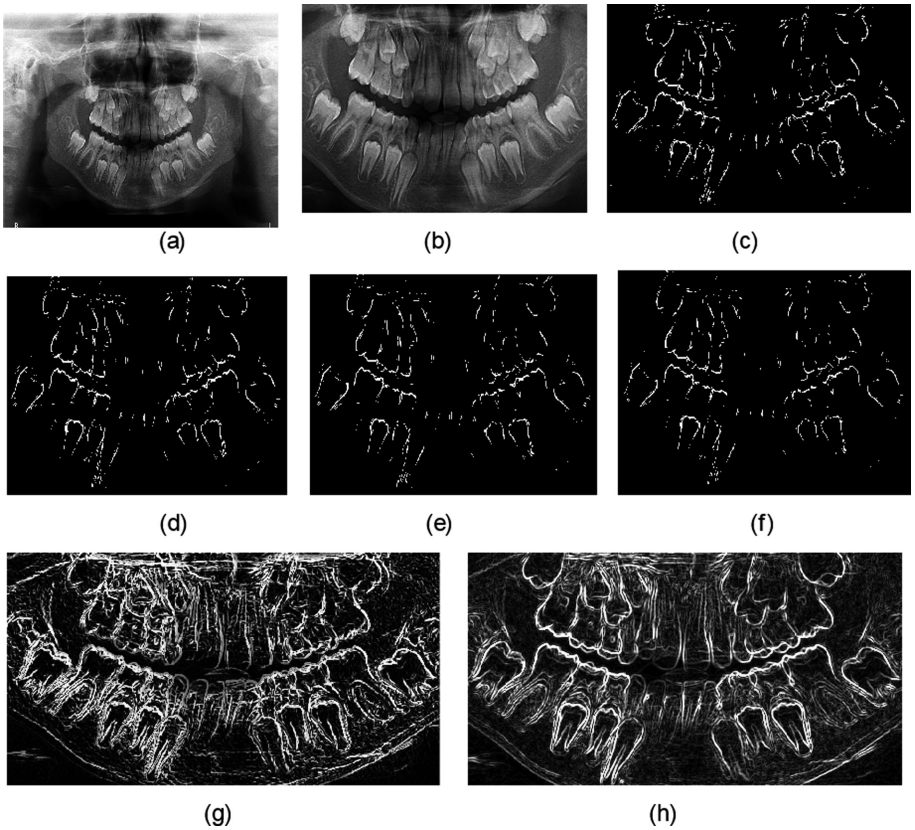

Fig. 13. (a) shows the input x-ray image of patient 3, (b) shows the cropped image, figure (c) to (f) shows the results of sobel operator at various thresholds that are 210, 220, 230 and 240 respectively, figure (g) shows the results of T1FLS and (h) shows the results of IT2FLS.

Table 1. Total edge detected pixel and dental diseases detected

Input images of patients	Algorithms						Diseases (trying to detect)
	Sobel edge detector				T1FLS	IT2FLS	
	T = 210	T = 220	T = 230	T = 240			
P1	5072	4565	4118	3769	25120	**125406**	Chipped teeth
P2	2030	1749	1530	4133	16017	**125385**	Diastema
P3	4125	3623	3192	1344	20552	**125113**	Crooked tooth

Table 2. Total time taken by algorithm

S. No.	Name of algorithm	Time taken in seconds
1	Sobel	100.838 s
2	T1FLS	109.303 s
3	IT2FLS	**97.841 s**

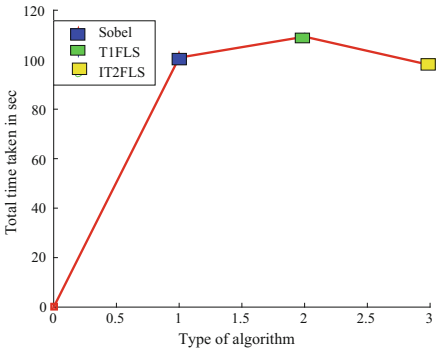

Fig. 14. Total time taken by algorithms

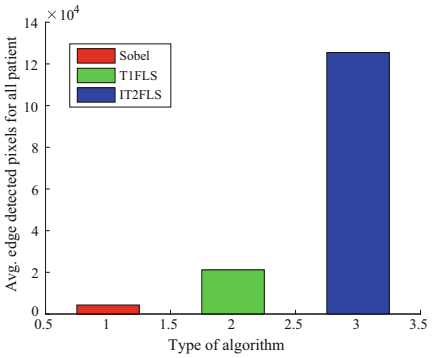

Fig. 15. Total edge detected pixels by algorithms

6 Conclusion

These three methods (Sobel, T1FLS and IT2FLS) are very simple and small but very efficient algorithms to shorten the concepts of artificial intelligence and digital image processing. The parameters, total edge detected pixels and total time taken by algorithm are helpful for the conclusion of this research, that a large number of edge pixels are detected by IT2FLS can be easily analyzes by the following graphs. And less time is taken by IT2FLS for the process of edge detection method. Since, IT2FLS is useful to handle and deals with real world uncertainties. Thus the results of three algorithms, shows to the doctor and that results are very helpful for them, for the identification and better diagnosis of dental diseases from edge detected x-ray image. Following are the graphs based on total time taken and total edge detected pixels from image by all three algorithm shows in Figs. 14 and 15 respectively.

Time shown in Fig. 14 is in second and for sobel edge detector average time taken for all threshold value executions. In Fig. 15 graph shows between type of algorithm and total edge pixels detected.

In Future Research, look forward to get more precise and improved results by applying general type-2 fuzzy logic system (GT2FLS) [14, 15] for detection of edges application because it deals with real time application by taking consideration all possible parameters. Additionally, helpful in detecting several types of dental diseases from the edge detected image.

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