Edge Detection and Features Extraction for Dental X-Ray

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Received on: ١7/5/2016 & Accepted on:29/9/2016

ABSTRACT

Recently, the dental X-Ray images have been used in different applications, particularly in the forensic field. The researchers focuses on the separation of the underlying teeth individually to obtain their features. These features can be utilized as a key solution for the identifications. In this paper, an edge detection of the involved teeth is proposed using a three stages MATLAB algorithm based on different methods such as, CLAHE, Canny, Otsu's, and 8-Connectivity. In addition, the proposed algorithm extracts the features of the investigated teeth as an exported file. These features are Standard Deviation (STD), Euler number and Area which are extracted from the bite-wing images. The stages of the proposed algorithm are image segmentation, classification and features extraction. It is important to note that the missing teeth has been considered in case of appearance. The missing teeth are assumed to be a separated objects. This is to overtake the problem of missing teeth after registering the original ones in the stored database used for identifications. The obtained results show the clear outperformance of the proposed algorithm in terms of edge detection and features' extraction. The missing teeth in an image are tested and the achieved results presents the detection and features of such teeth dramatically. The proposed system is implemented and tested in the MATLAB software environment using a personal computer of a Core(TM) i7 processor and 6 GB RAM over a 64-Windows 10 operating system.

Keywords: Dental X-Ray, Teeth Edge Detection, Image Feature Extraction, MATLAB.

INTRODUCTION

Nowadays, the bioinformatics is adopted by different applications, such as human identifications and diseases analysis. The biometrics is a part of bioinformatics and can be used in human identification, for example finger print, eye, DNA and dental X-Ray. Dental X-Ray patterns are used efficiently in forensic field for the serious damaged bodies. In addition, the human identification based on dental X-Ray suffers from the accuracy due to different issues, such as segmentation and teeth edge detection. Additionally, dental X-Ray images can be changed according to the shoot and weather conditions [1].

It is important to find out a method to overcome the mentioned problems or at least reduce them. Moreover, the presented methods suffer from the low accuracy of edge detection for individual teeth. This comes from numerous reasons, such as image resolution, capturing position, etc. In

https://doi.org/10.30684/etj.34.13A.5
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terms of extracted features can be selected depending on the application. For example, in human identification, the area of separated teeth is the most important feature to be considered [2]-[4].

The subject of teeth edge detection has been considered in the research work so far. In [5], the authors proposed an intensity-diversification approach to raise the detection ranges of the underlying tooth using different intensity spaces. The diversification method explores the intensity of image information as transform. In this paper, gamma transform has been used to ensure the availability of intensity and diversified images. The statistical based Active Appearance Models (AAM) gas been employed to allocate a possible show of mandibular molar in tooth region on the images. In [6], a pre-processing method was presented to make the panoramic dental X-ray for segmentation. Then, the segmentation traditional algorithms were used to perform the wisdom teeth segmentation. In [7], the authors introduced a segmentation morphology method based on dilation, gradient and erosion algorithms. In addition, this method was developed to tackle the morphology dilation difference from erosion dilation. In [8], the contours of the teeth has been proposed to be a feature for finding the identity. The fuzzy problem in the tooth contours which is the results of the poor image quality is solved using a semi-automatic contour extraction method. The presented algorithm includes three stages: contour matching, pixel classification and radiograph segmentation. The authors of [9] presented a review on the types of human identifications. They also provided a new approach to facilitate the Human identification process. In [10], a study on the theory of edge detection for dental X-Ray image was proposed in addition to the segmentation using fuzzy logic approach. An automated scoring and ranking method was introduced in [11] that is used to augment other types of text-based methods such as Win-ID. It searched the database of ante-mortem (AM) radiographs to retrieve a closest match in comparison with a post-mortem (PM) radiograph with a marked region of interest (ROI). In [12], a novel method for teeth segmentation is proposed. This method uses the locations of areas located between necks to evaluate the separating lines. It also has not based on the articulation of spaces between the teeth. Therefore, developing the com out results in the situation of severe occlusions.

In this work, teeth edge detection method is proposed. The presented method comprises three main stages: enhancement, segmentation and edge detection in addition to feature extraction for each underlying tooth individually. Different traditional algorithms has been utilized in order to obtain the planned objectives of the proposed method. These algorithms and methods, explained in the next section, can be briefly listed as: Contrast-limited adaptive histogram equalization (CLAHE), Canny, Otsu's, 8-Connectivity, Vertical Mean, Horizontal Mean, Image Labeling, Area, Euler Value, and Standard Deviation.

The Proposed Method

At this process, a MATLAB three stages algorithm is considered as mentioned earlier: Image Enhancement, Image Segmentation and Feature Extraction. Figure (1) shows the block diagram of the proposed algorithm.

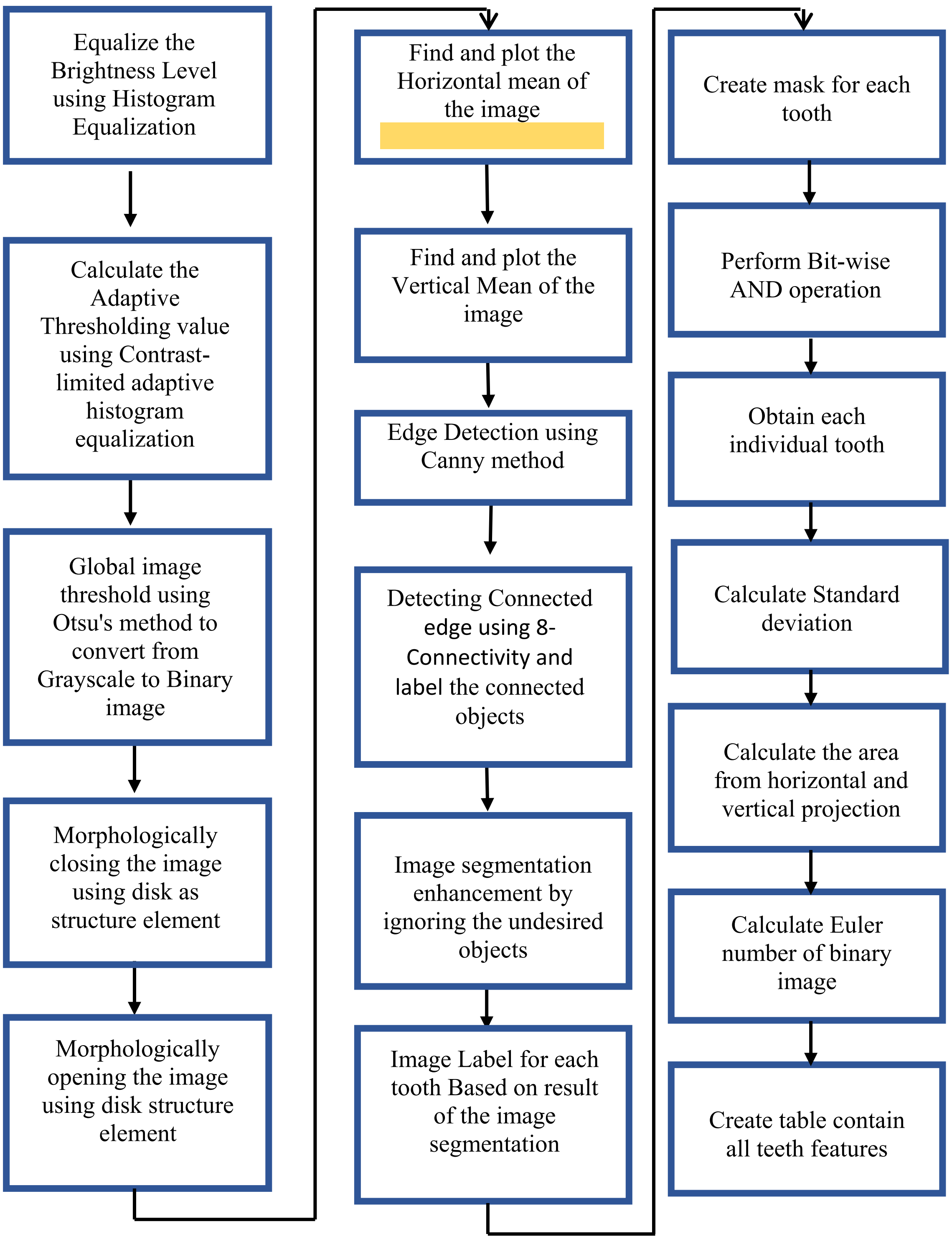

Figure (1). The block diagram of the image processing method.

Image enhancement is an important part of the proposed algorithm to produce more suitable image for the applications than the original image. In this stage, the histogram equalization is used to equalize the brightness level of the image. We utilize the MATLAB function of ***"histeq(image)"***to enhance the contrast of images by transforming the values in an intensity image. The histogram equalization for an image is computed as [2]:

$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j) = (L-1)\sum_{j=0}^{k}\frac{n_j}{M\times N}$$
$$= \frac{(L-1)}{M\times N}\sum_{j=0}^{k} n_j \qquad k = 0,1,2,\ldots,L-1 \qquad \ldots\ldots\ldots (1)$$

Where

r = input image, s_k = processed image (equalized image), T = an operator on r, L = gray level, p_r = histogram value, n_j is gray intensity of the corresponding gray level and N, M are dimension of image matrices

In addition, the two step thresholding is employed to convert the gray scale image to binary image. The Contrast-limited adaptive histogram equalization (CLAHE) is utilized using the MATLAB function of ***"adapthisteq(image)"*** to improve the contrast of images by transforming the values in the intensity image. Later on, Global image threshold (Otsu's method) is adopted, by utilizing the MATLAB's function of ***"graythresh(image)",*** which is operating on the gray level histogram to convert the input image to a binary image as shown in Figure (2). The main process of the Otsu's method is to compute a threshold level (T) over which all gray scale pixel are considered white (i.e. foreground) and the rest considered black (i.e. background). The main goal of this method is to minimize the error of classifying the foreground as a background and vice versa. Therefore, the threshold which *minimizes the weighted within-class variance* must be calculated as:

$$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t) \qquad \ldots\ldots\ldots (2)$$

Where, $q_1(t)$, q_2= the class probabilities which are estimated by the equation (3.3) , (3.4) respectively.

$$q_1(t) = \sum_{i=1}^{t} P(i) \qquad \ldots\ldots\ldots (3)$$

$$q_2(t) = \sum_{i=t+1}^{I} P(i) \qquad \ldots\ldots\ldots (4)$$

The class means are computed by this formula:

$$\mu_1(t) = \sum_{i=1}^{t}\frac{iP(i)}{q_1(t)} \qquad \ldots\ldots\ldots (5)$$

$$\mu_2(t) = \sum_{i=t+1}^{I}\frac{iP(i)}{q_2(t)} \qquad \ldots\ldots\ldots (6)$$

Then the individual class variances are calculated by the following equations:

$$\sigma_1^2(t) = \sum_{i=1}^{t}[i-\mu_1(t)]^2\frac{P(i)}{q_1(t)} \qquad \ldots\ldots\ldots (7)$$

$$\sigma_2^2(t) = \sum_{i=t+1}^{I}[i-\mu_2(t)]^2\frac{P(i)}{q_2(t)} \qquad \ldots\ldots\ldots (8)$$

To select the optimal t value, the full range of t are used to determined which t can minimize the $\sigma_w^2\,(t)$. Moreover, the morphological operation was utilized in this stage.

(a) **(b)** **(c)**

Figure (2). Dental X-Ray type: (a) Original Image; (b) Equalized Image; (c) Binary Image.

The second stage of the proposed method is image segmentation. The goal of this stage is to separate the teeth from the background and other tissue. At this stage horizontal and vertical projection are computed to detect the valley between jaws and teeth that ease the segmentation process. These projections are computed as [3]:

$$\boldsymbol{H[i]=\sum_{j=0}^{m-1} B[i,j]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{9})$$

$$\boldsymbol{V[j]=\sum_{j=0}^{n-1} B[i,j]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{10})$$

Where the $B[i,j]$ is a binary image, $H[i]$ is the projection of a binary image along the rows (horizontal projection). The $V[j]$ is the projection of the columns (vertical projection).

Edge detection is achieved using Canny method using the MATLAB function of ***"edge"*** that takes an intensity or a binary image as its input, and returns a binary image of the same size as the input image. The Canny method works in five separate steps, which are *Smoothing, Finding gradients, Non-maximum suppression, Double thresholding* and *Edge tracking by hysteresis*. To detect each teeth in the resulted image, the connected edges are detected using the 8-connectivity in which each teeth is considered as an object ready for extract features utilizing the MATLAB function of ***"bwlabel(BW,N)",*** which returns a matrix, of the same size as BW (binary image), containing labels for the connected components in BW. Figure (3) shows the segmented teeth. It is important to note that the proposed algorithm uses the detected edges of the teeth to allocate the area of each tooth individually. This can lead to use the AND operation to mask the tooth body with white color to be shown as a tooth.

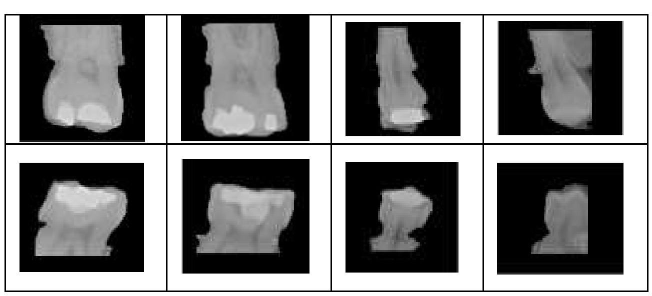

Figure (3). Segmented Teeth.

In the last stage, three features (Standard deviation, Euler value and Area of each tooth) are extracted from four teeth for each side (eight teeth for each individual as a result): fifth Upper Left, sixth Upper Left, fifth Lower Left, sixth Lower Left, fifth Upper Right, sixth Upper Right, fifth Lower Right and sixth Lower Right. The tooth is numbering by *Palmer Notation Method* as shown in Figure (4) [4]. Now a table of features is ready to be stored in the database.

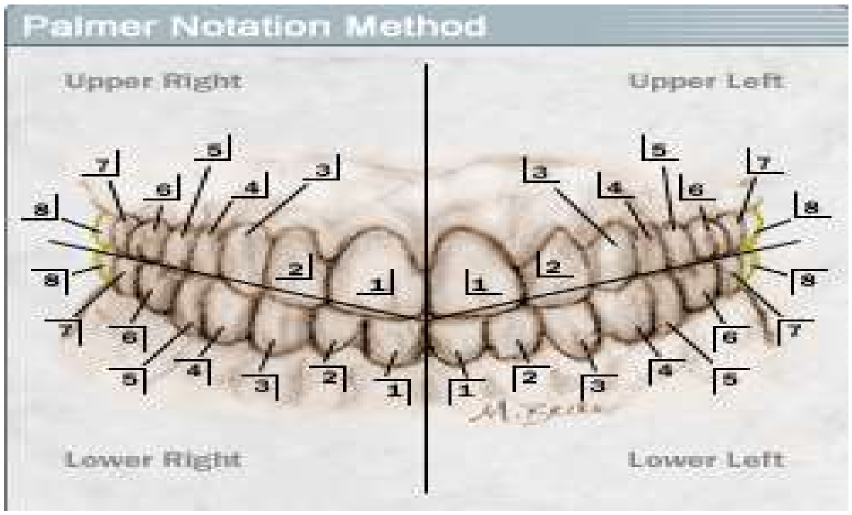

Figure (4). Palmer Notation numbering system [10]

At this stage, each tooth in the radiograph is considered as an object (pattern), where the features are extracted from each pattern. The STD is computed using MATLAB function of ***"std2(image)"*** and calculated as [14]:

$$\boldsymbol{STD} = \sqrt{\frac{\sum_{r=0}^{N-1}\sum_{c=0}^{M-1}(\boldsymbol{I_{rc}} - \boldsymbol{m})^2}{\boldsymbol{M} \times \boldsymbol{N}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\mathbf{11})$$

Where the
STD = Standard Deviation.
I_{rc} = Pixels of object matrics.
r, c = Denoted to the raw and column.
N, M= Dimension of object matrices.
m = The arithmetic mean of the data.
While the Euler number is fetched by the MATLAB function of ***"bweuler(image)"***, which produce a scalar whose value is the number of objects in the binary image minus the total number of holes in those objects [15], [16].
For example; as shown in the Figure (5) below, all the circles in the image touch so they create one object. The object contains four "holes", which are the black areas created by the touching circles. Thus the Euler number is (1 minus 4, or -3) [14], [17].

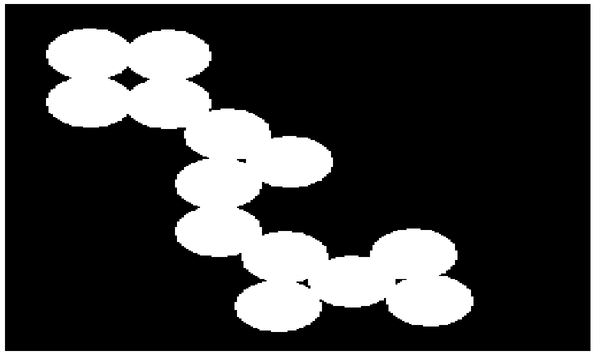

Figure (5) Example for creating the Euler number of a binary image

Finally, The Area of an object is performed on the gray scale image and calculated by the following equation [14]:

$$\boldsymbol{I} = \sum_{r=0}^{N-1} \sum_{c=0}^{M-1} \boldsymbol{X}(\boldsymbol{r},\boldsymbol{c}) \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..\dots(\mathbf{12})$$

Where

I = The intensity of the object

X = The object

r, c = Denoted to the raw and column.

N, M= Dimension of object matrices.

On the other hand, the proposed method can treat the problem of missing teeth in the investigated dental X-Ray images. This is done by evaluating the distance between the neighbor teeth and then evaluating the related area. At this point, if the area big enough, these spaces can be considered as a missing teeth.

GUI Design

In order to ease the dealing with the proposed system, Graphical User Interfacing (GUI) form has been designed using Visual Studio C# as shown in Figure (6). The C# is selected as it offers a link to MATLAB and the design is quite simple.

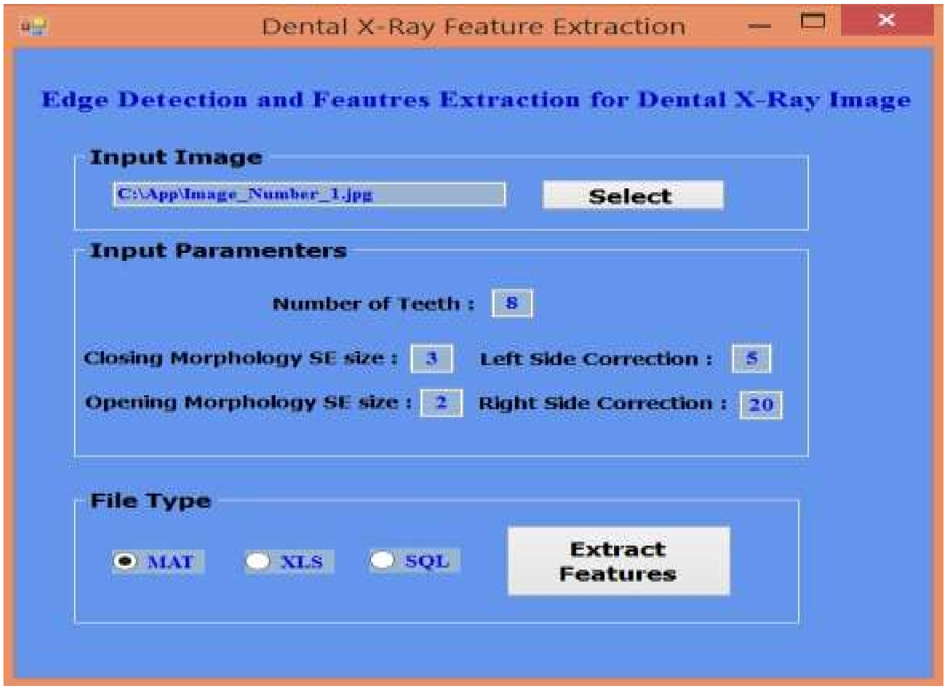

Figure (6). GUI of the proposed system

It is shown that the required X-Ray image can be uploaded using the upload link and by selecting the desired one. The input parameters is used to change the opening and closing of the teeth segmentation to enhance the outcome results. After choosing the file type, the mentioned three features for each tooth are extracted and exported in the selected file type by pressing Extract Features button. The exported file can be saved in the allocated location easily.

RESULTS

The proposed system has been tested over different bit-wing dental X-Ray images in order to ensure the quality and accuracy of the extracted features as well as the edge detection of teeth. All images are passed through the three stages of the proposed algorithm. Figure (7) illustrates the enhancement stage. It is noted the enhancement level over the images clearly.

Figure (7). Image enhancement

Figure (8) shows the steps of teeth segmentation as explained in the previous sections following the traditional methods and algorithms.

Figure (9) explains the teeth advanced segmentation and edge detection. It is well shown that the edge of each tooth is drawn nicely with high accuracy by considering each tooth as an object and the dental work as individual objects to be removed later. The removing of the dental work is removed by selecting the objects with small area where it is dynamic depending on the all areas of objects as shown in Figure (10). This figure illustrates the removing of objects with small areas known as dental work in addition to coloring the detected edges of teeth.

The next steps are the masking of each tooth individually as shown in Figure (3) above by evaluating the area of each tooth using the detected edges of it. By obtaining an image for each tooth, now it is easy to compute the three features for each. The final step is extracting the features of four images with eight teeth each in a table as shown in Table (1).

In terms of the case of including a dental image with missing tooth or teeth, the system is tested over different shapes. It is important to note that the proposed algorithm tackles the missing teeth by evaluating the area of each objects including the background and allocating the missing teeth depending on it. In other meaning, the tissue object with large area is considered as a missing tooth.

Figure (11) shows the image enhancement of the missing tooth of one Jew. In addition, Figure (12) illustrates the teeth segmentation them is detected. It is well shown that the missing tooth is considered as a separated object. On the other hand, the missing tooth and other teeth are rounded at the edge in the process of edge detection as shown in Figure (13). The objects with small area values are removed in Figure (14) following the process shown above in addition to coloring the detected edges. It is noted that the missing tooth has not allocated with edges.

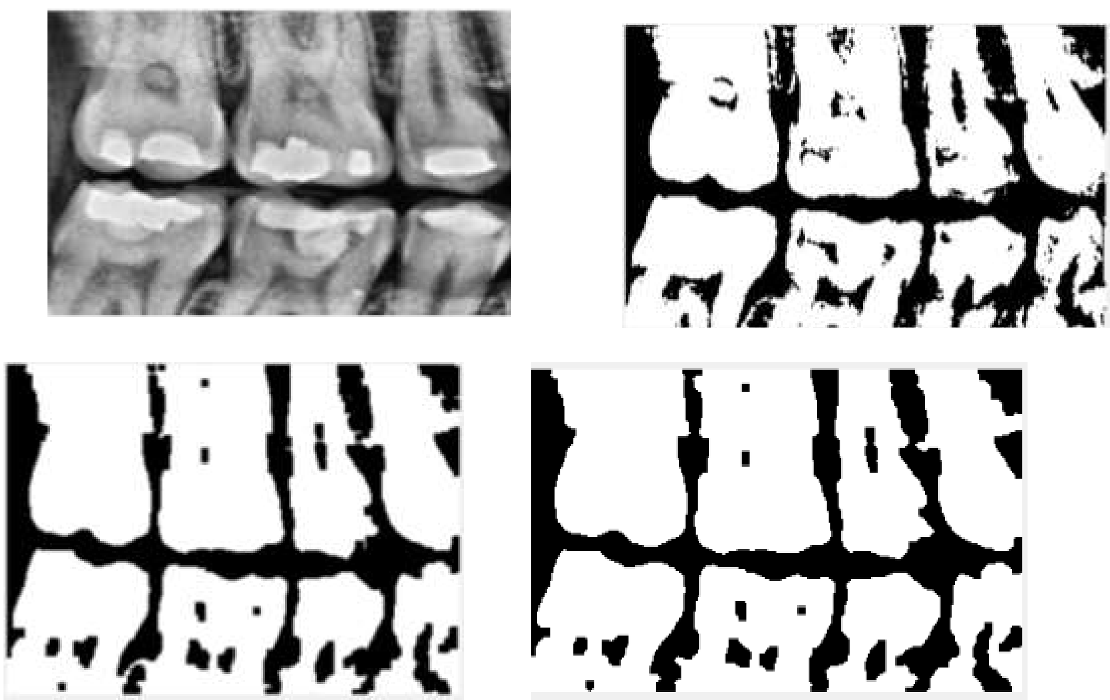

Figure (8) Image segmentation steps.

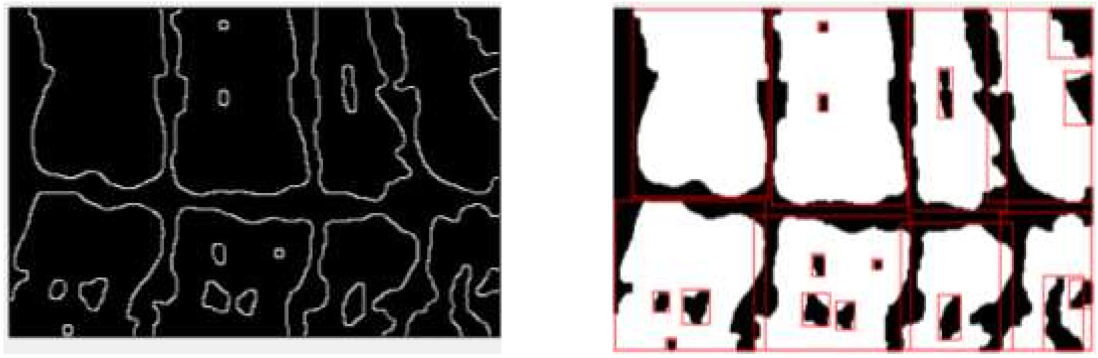

Figure (9) Teeth edge detection

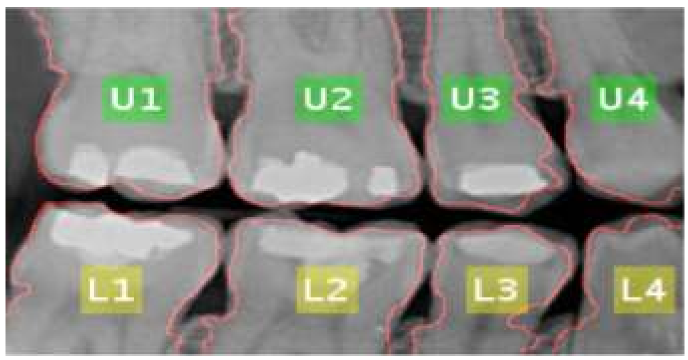

Figure (10) Teeth edge coloring, small objects removing and labeling.

Finally, Table (2) includes the three features of the considered teeth. It is shown that the missing tooth has all zero values for the underlying feature. This is to keep the sorting in right way and give an indicator that this is a missing tooth.

Table (1). Bite-wing Features.

	Left Side			Right Side		
	Standard Deviation	Euler Number	Area	Standard Deviation	Euler Number	Area
1	77.43656202	2	1392332	94.7982725	1	662118
	81.74313324	1	2707200	86.36347233	4	1354614
	63.54367503	1	265916	42.9746489	0	304422
	62.50915461	1	2480954	82.90833925	-4	904124
2	64.54959034	1	1011076	55.83322006	1	648136
	60.2941442	0	1672832	64.83888472	2	328086
	56.08191638	5	926452	79.43976217	-1	828092
	50.9973734	3	637444	86.28298778	1	2118830
3	81.06218958	2	1113722	78.75666437	1	796224
	82.7132029	3	1149002	56.9870911	8	542276
	64.82817667	-2	419896	73.18775018	-1	328424
	77.26259959	-5	368056	71.78040964	1	585732
4	97.8014964	1	2898282	55.98390339	1	1159752
	72.89922753	-1	266870	64.05611997	3	824156
	76.24608994	2	524582	83.62491383	-1	1925904
	66.19956912	-2	649200	94.51665713	-2	4103976

Figure (11) Image enhancement of missing tooth

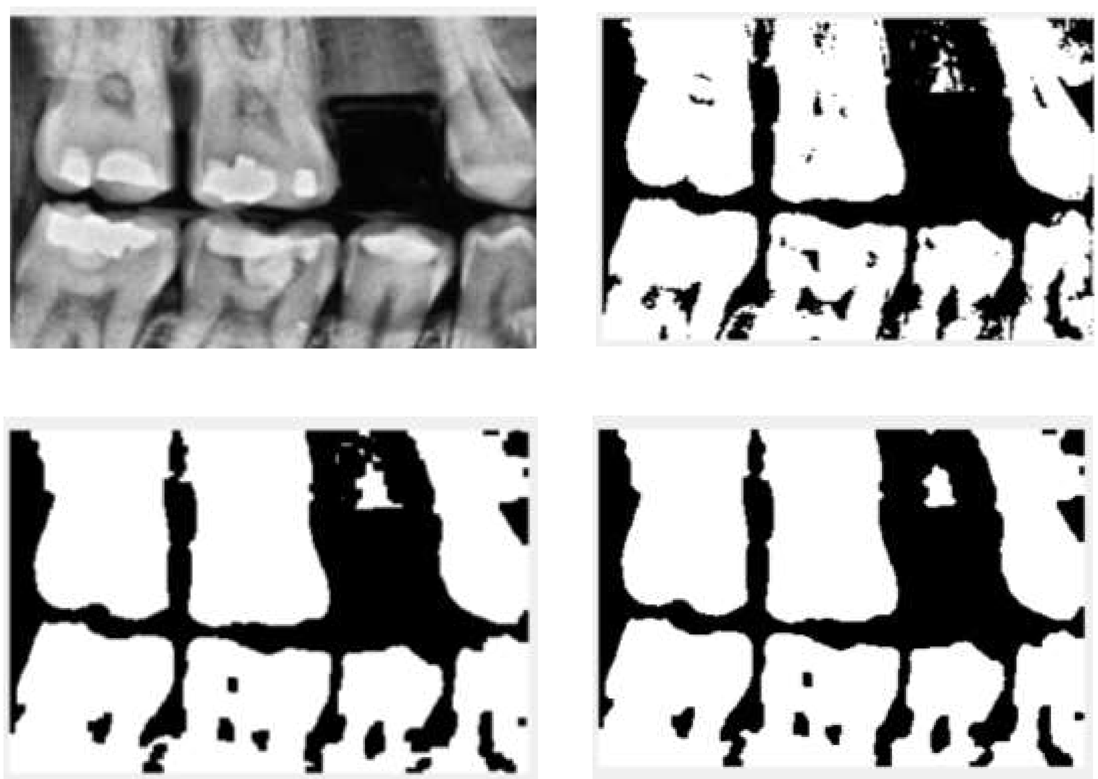

Figure (12) Teeth segmentation

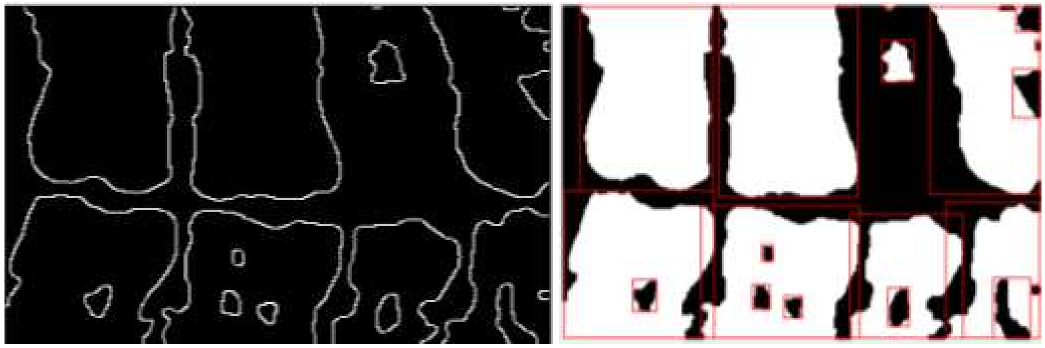

Figure (13) Teeth edge detection

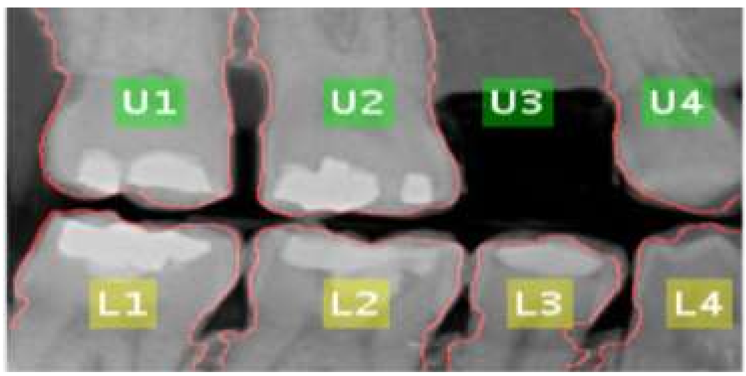

Figure (14) Edge coloring, objects removing and labeling with missing tooth

Table (2). Missing tooth bite-wing features.

	Left Side			Right Side		
	Standard Deviation	Euler Number	Area	Standard Deviation	Euler Number	Area
1	72.08706	1	2493932	67.34652	-4	2160164
2	60.67287	0	2551552	63.30041	-8	1795760
3	0	0	0	61.63551	3	961842
4	60.76957	-1	1321390	51.93992	12	806678

CONCLUSION

An accurate teeth edge detection method for dental X-Ray images is proposed. This method adopted three stages algorithm Witten in MATLAB environment. These stages are image enhancement, teeth segmentation and edge detection with feature extraction. Three features are selected to be the identity for each teeth individually: Area, Euler Number and Standard Deviation. These features are extracted and exported as a file with distinct extension types. Throughout the processing of dental images of type bit-wing, different traditional algorithms and methods have been considered to obtain the required goal. It is important to mention that the proposed method considered the missing teeth X-Ray images and tackled this issue by assuming them as individual objects. The obtained results show a satisfied accuracy of edge detection in the proposed method. These results are for normal and missing teeth images.

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