An Effective Shape Extraction Algorithm for Dental Radiographs using Contour Information

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Abstract
The purpose of Forensic Dentistry is to identify the persons based on their Dental records. In this paper, a prototype for Dental CT image shape extraction technique is presented. The main goal of this approach is to make use of the result of this methodology as an initial step in an automated Dental identification system. The proposed algorithm consists of three stages. The first stage is pre-processing. The second one involves the integral projection method for partitioning the upper, lower jaw and individual tooth separately. The third stage is applying connected component labeling to the partitioned result to extract the shape. Experimental results show that this algorithm achieves robust, high accuracy and requires less computation time.

Keywords
Teeth segmentation, Dental CT, Homomorphic filtering, Integral projection, connected component labeling

I. Introduction

Biometrics meant by uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits. Forensic odontology is the application of dentistry in legal proceedings deriving from any evidence that pertains to teeth. The application involves individual identification, Mass disasters and Bite mark analysis. The ultimate aim of forensic odontology is to identify the person when other means of identification like fingerprint, DNA, iris, hand print, leg print, etc… are not available. The purpose of selecting the Dental record is that the teeth can withstand decomposition, heat degradation; water immersion, and desiccation etc.., Dental patterns are unique for every individual. Dental identification can be confirmed in a matter of hours, usually done by a human expert. And identification rates are highest among people from nations where dental and healthcare systems are of high quality .There having been many major disasters throughout the history. As per the survey, some major disasters of world like the World Trade Center attack in 2001 killed 2,819 people, Swissair Flight 111 crash in 1998 off the coast of Nova Scotia killed 229 people; Oklahoma City Bombing in 1993 killed 168 people. Biometrics have been the most effective and strongest means of identifying victims of such mass disasters. Experts used many methods to identify the victims of this disaster – Such as fingerprints, dental records, DNA, and physical identification. Out of all, dental identification is proved to be the best in critical condition. A survey and analysis paper says that in the world trade center attack - of the total death certificates issued, 188 were identified using dental records. In Swissair Crash of Flight 111 – of the 229 victims – Over 90 individuals were identified using dental x-rays. Similarly in Tsunami - 2004, around 60% identification is done using dental images. So, this work is focused with dental records. This work aims to produce an initial stage algorithm for Forensic dentistry. There are several approaches for dental radiograph segmentation [1-7]. Anil.K.Jain and Hong Chen, were dedicated a concept of semi automatic contour extraction method for shape extraction and pattern matching [2]. The shortcomings in their approach are if the image is too blurred their algorithm is not applicable and slight angle deviation in the Ante-mortem and postmortem images are not handled with this approach. P.L.Lin a, Y.H.Lai b, P.W.Huang presented an algorithm to classify and numbering teeth in bitewing images. They used Bayesian classification to classify molars and premolars teeth and assign an absolute number to each tooth according to the common numbering system used in dentistry. Another approach used Fourier descriptors of the teeth contours as features in the Bayesian classification [9]. The success of this algorithm is found to be limited, for maxillary teeth. So in this work, an image enhancement method that involves frequency domain filters like Butterworth filter followed by homomorphic filtering is used. It is proven from the fig. 2, that frequency domain filters provide better results than the combination of morphological and homomorphic filter as in the previous approach [3]. It improves both contrast and illumination evenness of the radiographs simultaneously. Then teeth shape extraction is carried out by connected component labeling [4, 5]. Hence even the blurred images can also be considered. Iterative thresholding and integral projection are adapted to isolate teeth to regions of interest (ROIs) followed by contour extraction of the tooth from each ROI.

II. Proposed Methodology

The algorithm involves three stages. They are Pre-processing stage, Integral projection and connected component labeling.

A. Pre-processing

Dental radiographs always suffer from problems like noise, low-contrast and uneven exposure. In order to improve both contrast and intensity illumination evenness simultaneously, this algorithm uses an image enhancement method that uses frequency domain filters like Butterworth and homomorphic filters [1-4]. Homomorphic filters are widely used in image processing for compensating the effect of non-uniform illumination in an image .The pre-processing stage consists of two steps. In the first step, the input image is subjected to Butterworth high pass filter to provide uniform sensitivity to all the frequencies. In the second step, it is processed with homomorphic filter to get uniform illumination in the image. The transfer function of Butterworth filter is defined as:

$$G^2(w) = |H(jw)|^2 = \frac{G_0^2}{1+\left(\frac{w}{wc}\right)^{2n}} \quad (1)$$

Where n is the order of the filter. Here order 2 is considered for better performance.

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B. Homomorphic filtering

Homomorphic filters are widely used in image processing for compensating the effect of non-uniform illumination in an image. In theory, an image function I(x, y) may be characterized by the multiplicative combination of an illumination component i(x, y) and a reflectance component r(x,y).

$$I(x,y) = i(x,y) \times r(x,y) \tag{2}$$

Also teeth, pulps, and gums in a dental radiograph should each have similar reflectivity [1]. Thus, a homomorphic filtering method to suppress the uneven illumination effect while preserving the intensity discrepancies among all the components in the radiograph is used here. For a given dental radiograph image I(x,y), first take the Fourier transform of the logarithm of I(x,y) to get the sum of its low-frequency illumination component and high-frequency reflectance component :

$$I(u,v) = F(\ln(i(x,y))) + F(\ln(r(x,y))) \tag{3}$$

Apply a Gaussian low-pass filter to remove its detailed components and retain its illumination distribution

$$I'(u,v) = I(u,v) \times G(u,v) \tag{4}$$

Where,

$$G(u,v) = \frac{1}{\sqrt{(2\pi\sigma)}\, e^{-(u2+v2)/2\sigma^2}} \tag{5}$$

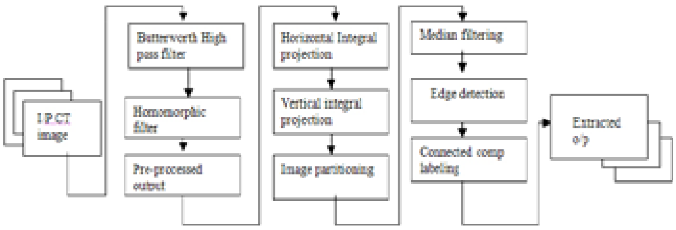


Fig. 1: Block diagram of the proposed algorithm

Take inverse transform I' for back to spatial domain and antilogarithm to obtain a homomorphic view of illumination.

$$I'(x,y) = \ln'(F'(I'(u,v))) \tag{6}$$

C. Integral projection

First sum the intensities of pixels along each row parallel to the x-axis. Since teeth have high intensity and the gap between the upper jaw and the lower jaw has lower intensity, this difference helps to split the upper jaw from the lower jaw using brightness density. So, integral projection of brightness is an apt one throughout this algorithm [9]. Assume proj(y) is the accumulative intensity of pixels in each row of the image function f(x,y), (0≤ x≤w-1) & (0≤ x≤h-1) .Then the series ,

{proj(y0), proj(y1),........proj(yH-1)} forms a graph of integral intensity. From mathematics perspective, the projection function is defined as:

$$\mathrm{Pr}oj(y) = \sum_{x=0}^{w} f(x,y) \tag{7}$$

Since the teeth usually have a higher gray level intensity than the jaws and other tissues in the radiographs due to their higher tissue density, the gap between the upper and lower teeth will form a valley in the y-axis projection histogram, which is called as the gap valley [2]. Consider the user initializes the estimated position, y^, of the gap between the upper and lower jaws. Let v_i; i = 1, 2,...., m be the valleys detected in the projection histogram where D_i being the depth of v_i , and y_i being the position of v_i . Among all these valleys, only one of them is the gap valley. Let $p_{vi}(D_i, y_i)$ be the probability that v_i (with attributes D_i and y_i) is the gap valley. Then, assuming the independence between D_i and y_i, this probability is computed as

$$p_{vi}(D_i,y_i) = p_{vi}(D_i).p_{vi}(y_i) \tag{8}$$

$$p_{vi}(D_i) = c\,(1 - D_i/\max_k.D_k) \tag{9}$$

$$P_{vi}(y_i) = \frac{1}{\sqrt{(2\pi\sigma)}}\, e^{(y-\hat{y})^2/2\sigma^2} \tag{10}$$

After finding the gap valley, the vertical line is drawn by obtaining integral intensity. Horizontal integral projection followed by vertical integral projection is applied to separate each individual tooth. The horizontal integral projection separates the upper jaw from the lower jaw, while the vertical integral projection separates each individual tooth.

D. connected component labeling

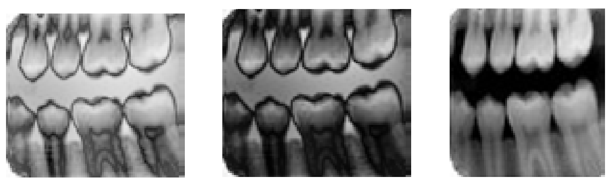
The partitioned image from the previous stage is subjected through median filter to remove some unwanted information even after pre processing and then edge map is created using canny operator [8]. Then it is convolved with the following proposed mask to trace the shape of the desired dental pattern.

$$Mask = \begin{bmatrix} 00000 \\ 01110 \\ 01110 \\ 01110 \\ 00000 \end{bmatrix} \tag{11}$$

By applying connected component labeling, the pixels with the same class label are grouped into regions. Here 8-connectivity is used to trace the boundary of the teeth.

III. Results And Discussion

The algorithm is developed in Matlab-R10b, and it is tested with the database of approximately 100 images. The sample input image taken for analysis is shown here which is of size (96,159). The following are the results shown for the pre processing steps. Fig. 2(a) shows the input image.



a b c

Fig. 2:(a). Input image (b). Butterworth filtered (c). Homomorphic filtered

The output 2(b) is the Butterworth high pass filtered output and then it is subjected to the homomorphic filter to get the uniform contrast output. The fig. 2(c) obtained shows that the output obtained preserves all the edges of the image and it seems better than the morphological operations that were shown in our earlier work. Moreover it is justified by the similarity measures like Average difference, Structural content, Normalized Absolute Error and Normalized Cross correlation etc... It is tabulated here in Table 1 for the test image taken.

Table 1 : Quality factor table

Quality factor Table for Image-1 (Dent17)		
Quality Factor	Before Homomorphic filtering	After Homomorphic filtering
Average Difference	-0.0021	-170.8499
Structural content	0.7726	0.1983
Normalized absolute error	0.3122	1.3080
Normalized cross correlation	1.0969	2.2131

In the Table, the first column before homomorphic filtering refers to the output obtained with morphological operations. The second column refers to the output with homomorphic filter. From the table it is clear that the similarity measures like Average Difference, Structural Content and Normalized cross correlation are seems to be better even though the error is marginally higher.

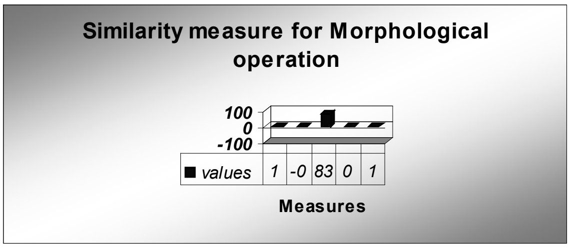


Fig. 3: Similarity measure plot for Morphological operation

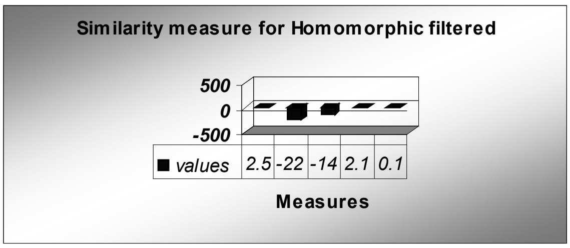
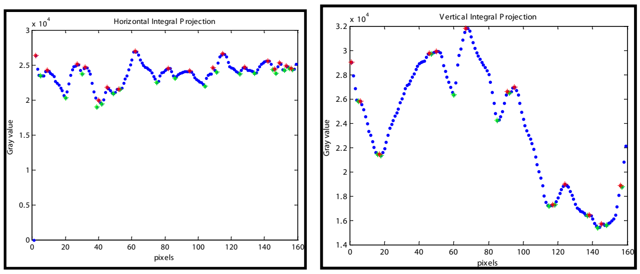


Fig. 4: Similarity measure plot for Homomorphic filter operation

Fig. 3 and 4 are the pictorial representation of the same. The similarity measures are obtained for several images and similar concept was observed for all. So homomorphic filter is chosen for pre processing here. To partition the given input image initially observe the horizontal projection to obtain the gap valley. It is observed that the integral projection of actual input image is seemed to be little differing from the pre processed image. fig. 5(a) and 5(b), shows the horizontal and vertical integral projection of the pre processed image respectively. With the use of these projections the image in fig. 1(b), is shown in fig. 6.The coloured dots on the top peak and the bottom peak values to easily trace the gap between the teeth. It is observed by the peak value detection logic.



a b

Fig. 5:(a). Horizontal Integral Projection, (b). Vertical Integral projection

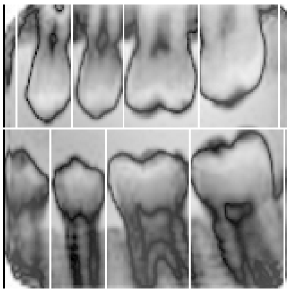
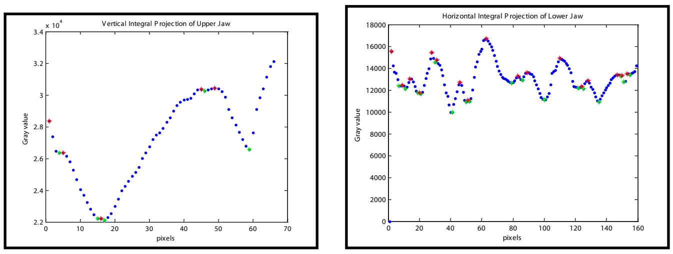


Fig. 6: Partitioned Pre processed image

The upper jaw and the lower jaw can be separated or cropped by knowing the intensity projections. The horizontal and vertical projections of the upper jaw are shown in the fig.7(a) and 7(b).



a b

Fig. 7:(a) Horizontal Integral projection of upper jaw, (b). Vertical Integral projection of the upper jaw

Using the integral projections, the upper jaw is partitioned as shown in the fig. 8 (a), 8(b) & 8(c)

a b c

Fig. 8:(a). Original upper jaw, (b). pre processed upper jaw (c). Partitioned upper jaw

Similar way the lower jaw alone can be cropped and then partitioned which may helpful for matching dental radiographs for person identification application. The horizontal and vertical integral projection of the lower jaw can be obtained and the partitioned and is shown in fig. 9.(a) and 9(b). The corresponding partitioned result is shown in fig. 10(c). The original lower jaw and the pre processed results are shown in fig. 10(a) and 10(b).

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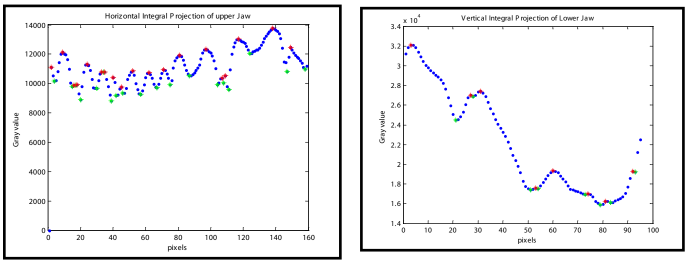
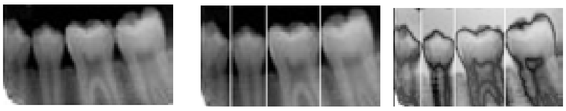


a b

Fig. 9: (a). Horizontal Integral Projection of lower jaw (b). Vertical Integral projection of lower jaw



a b c

Fig. 10:(a). Original lower jaw (b). pre processed lower jaw (c). Partitioned lower jaw

The partitioned image is median filtered first and convolved with the proposed mask and by applying connected component labeling the regions which are similar is grouped together as shown in the fig. 11(a) and 11(b)

a b

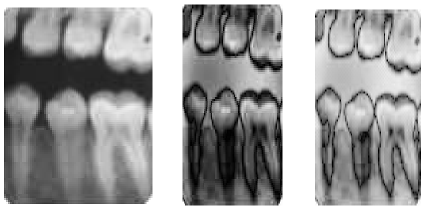
Fig. 11:(a). edge map (b). convolved with the mask

To trace the boundary sharper the edge map is convolved with the proposed mask and the resultant image is shown above. Using connected component labelling the pulp region which is picked up as an edge can be removed as shown here.

a b c

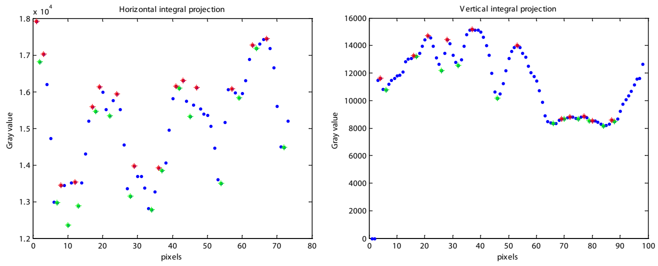
Fig. 12:(a). segmented (b). segmented upper jaw (c). segmented lower jaw

The algorithm is tested for several other images also. It holds good for other images. Another sample image Dent11 of size (98, 74) was taken and is shown in fig. 13(a), 13(b) & 13(c) are the Butterworth filtered and Homomorphic filtered outputs. Their horizontal and vertical integral projections of the pre-processed output are shown in the fig. 14(a) and 14(b).



a b c

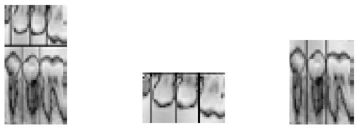
Fig. 13:(a). original Image (b). Butterworth Filtered (c). Homomorphic filtered



a b

Fig. 14:(a). Horizontal Integral projection of the pre-processed o/p. (b). Vertical Integral projection of the pre-processed o/p

The corresponding partitioned outputs are shown in fig. 15 (a) and 15(b)



a b c

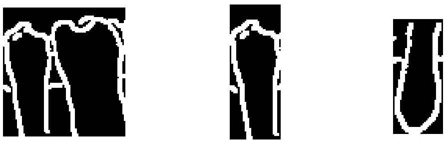
Fig. 15:(a). partitioned whole image (b). upper jaw (c). Lower jaw

The outputs of connected component labelling are shown in fig. 16(a), 16(b) & 16(c).

a b c d e

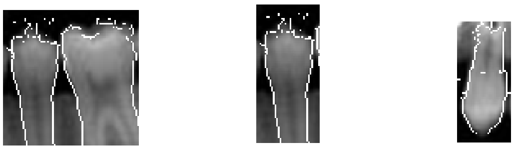
Fig. 16:(a). Edge map (b). connected component labelling output (c). segmented upper jaw (d). segmented lower jaw (e). single tooth

The results obtained using this technique is compared with the semi automatic contour extraction output. For person identification while matching [5-10] post mortem and ante-mortem images, instead of matching the whole image, if a single part like either a jaw or a single tooth is compared then the better results may be expected. The results shown in fig .17(a), 17(b) & 17(c), are obtained for the input image1 using this method and fig. 18 (a), 18(b) & 18(c), are the results of semi automatic contour extraction method which was shown in our previous work [3]. For shape matching purpose similarity measures are obtained for both these outputs by matching it with the original image



a b c

Fig. 17:(a). Left and middle teeth of lower jaw (b). Left lower tooth (c). leftmost tooth of upper jaw



a b c

Fig. 18:(a). Left and middle teeth of lower jaw (b). Left lower tooth (c). leftmost tooth of upper jaw

Fig. 19(a) is another sample image Tooth4 of size (171, 98), 19(b) is the contour extracted by Semi –automatic extraction method, 19(c) is the result obtained by connected component analysis.

a b c

Fig. 19:(a). Sample image Tooth4, (b). contour extracted by semi automatic contour extraction method (c). Connected component output

The results obtained are evaluated using the similarity measures and are listed in the Table 2.

Table 2 : Similarity measures

Sample Images	Connected Component Analysis output			Semi automatic contour Extraction output		
	NCC	SC	CT (Sec)	NCC	SC	CT (Sec)
Tooth 4	1.358	1.4	11.95	0.89	1.003	12.44
Tooth8	0.561	0.49	11.95	0.99	0.771	12.44
Tooth10	0.417	0.91	11.95	1.01	0.838	12.44
Tooth21	0.366	1.16	11.95	0.99	0.912	12.44
Tooth 4	1.358	1.4	11.95	0.89	1.003	12.44

In the Table 2, the similarity measures like Normalized Cross Correlation (NCC) and Structural Content (SC), Computation Time (CT) are tabulated for few sample images. It is observed that the computation time is comparatively less in this method. Even though NCC value seems to be good in semi automatic contour method, the structural content in the output is higher in the proposed technique.

IV. Conclusion

Here is a simple and efficient shape extraction algorithm of dental radiograph is introduced. It handles three stages like pre-processing, integral projection and the connected component labeling. Here it is proven that the homomorphic filters used simultaneously normalizes the brightness across the image and increases contrast rather than simply using morphological filters. From the Table 1, it is clear that the structural content and the average difference between the original and the pre-processed images seems to be better after homomorphic filtering rather than simple morphological operation. Using connected component labeling single tooth can also be extracted to make the matching process still efficient. From the Table 2, it is observed that the structural content of the output still remains better after shape extraction using connected component labeling only. The main goal of this work is to make use of this result for person identification using dental patterns. This algorithm fails to holds good for the dental pattern which is not perfectly aligned with the vertical strips (i.e.) if it is occluded. So this can be enhanced further by projecting curved lines by using angle and distance approach.

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