Person Identification Technique Using RGB Based Dental Images

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Abstract. Dental signature captures information about teeth, including tooth contours, relative positions of neighboring teeth, and shapes of the dental work. However, this is complicated as dental features change with time. In this paper, we proposed a new, safe and low cost dental biometric technique based on RGB images. It uses three phases: image acquisition with noise removal, segmentation and feature extraction. The key issue that makes our approach distinct is that the features are extracted mainly from incisor teeth only. Thus the proposed solution is low cost besides being safe for human.

Keywords: HSI color format · Wiener filtering · Opening · Watershed · Snake

1 Introduction

Person identification based on human teeth is very popular in the world. Generally, dental records have been used to identify the victims of disasters like 9/11 terrorist attack, Asian tsunami [1] etc. According to these facts there are many advantages of using dental biometrics. It is very possible to identify an unidentified (mutilated) body by comparing the post-mortem (PM) records against ante-mortem records. This will produce the closest match of multiple identities [2]. Dental biometric system based on radiograph images are also able to identify the correct person from a large set of database where manual method fails. Dental biometrics is worked upon the radiograph images. Frequently taken x-ray is very injurious to our health. The radiation of used X-Ray changes our DNA structure that leads to cancer [3]. One question naturally comes to our mind that can we use dental biometric on living people? The answer is 'yes' off-course we can by taking the RGB based dental image. The other reasons for choosing dental biometrics are as follows

1. It is very precise and correct.
2. We don't need an expert to treat and compare the result.
3. It is not easy to replicate the dental signature.

The primary contribution of this research work is to propose a three phase novel technique for RGB dental image based authentication and verification using biometrics. Our proposed method takes the RGB images of human teeth, extract the features

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[1] like shape; contour; length etc. Depending on the features system will take the decision whether record is matched or not. This will be the extended version of this re-search work. There are so many good biometrics methods other than dental are exist. Among them retina scan is invasive in nature and it is injurious to our eyes. For finger print, iris detection [4, 5, 6, 7] special type of device set-up is needed where as dental image can be taken by any kind of camera. Hence to identify a person at any place is possible by only carrying the camera and this application. However this system does not require any extra high cost device like retina scan requires Topcon retinal camera and its cost is $15,995. Hence it is very less cost device comparative to other biometrics devices. This method is safe to our health. For this reason dental signature based biometrics method is helpful. Here we extracted the features of five incisor teeth. Hence we can say that RGB based dental biometrics is advantageous with respect to speed, storage requirement and human health.

2 Related Review Work on Dental Biometrics

Before starting of this work, we have gone through many good dental biometrics methods. Most of these methods work upon the dental radiographs. Here some of them are explained shortly. Anil K. Jain and Hong Chen dedicated a concept of semi-automatic contour extraction method for shape extraction and pattern matching [8]. The main problems in their approach are if the image is too blurred, their algorithm will not work and slight angle deviation in the database image and incoming images may not be handled with this approach. Said et al. [9] offered a mathematical morphology approach, which used a series of morphology filtering operations to improve the segmentation. Morphological filters like top hat and bottom filters are used for tooth segmentation. Nomir and Adbel-Mottaleb introduced a fully automated segmentation technique [10]. It starts by applying iterative thresholding followed by adaptive thresholding to segment the teeth from both the background and the bone areas. After adaptive thresholding, horizontal integral projection followed by vertical integral projection is applied to separate each individual tooth. And this method can achieve the position of each tooth precisely. All of the above method works on the radiograph dental images where as our proposed method works on dental RGB image.

3 Proposed Method

This research work describes up to the dental biometrics features extraction procedure. Fig 1 shows the entire system. Image acquisition and filtering is the first step. For de-noising Winer filter is used. In the first phase of this method conventional methods are used that are described in the next sub sections in short. In the segmentation phase only the tooth region are segmented based on morphological operations. Segmentation of individual tooth is done by using the 'watershed' and 'snake' algorithm. In the last step the features like volume, size, area etc are extracted from the incisors teeth.

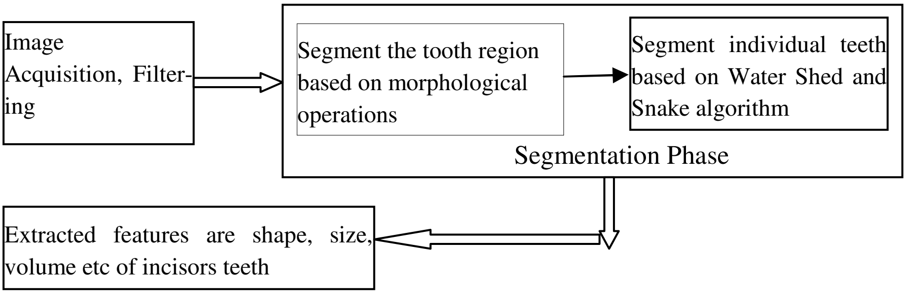

Fig. 1. Block diagram of the system.

3.1 Image Acquisition and Filtering

We worked upon freely available database named 'Labial Teeth and Gingiva Image Database' [11]. Here dental images are different for resolution, file format and image scene type. Due to easiness of our research work we transform each image into jpeg format. All the rest of the works are based on these jpeg images. The qualities of the images that are obtained from the sensor camera are not so good, some noises exist. To remove these noises we used 'Winer' filter.

3.2 Segmentation

Segmentation phase contains two sub phases. The phases are 'Segment the tooth region based on morphological operations' and 'Segment individual teeth based on Water Shed and Snake algorithm'. The next subsections describe how the teeth are extracted finally.

Information Extraction

It is not so easy to extract only tooth region from the entire input image. The input image contains white space surrounded by the green color, lips, some part of face etc. These regions should be eliminated from the ROI. It is very challenging to separate the teeth and non-teeth region based on Red, Green and Blue component. Sometimes it fails to find the exact ROI due to the variation of white color that present in the teeth. Hence we have used HSI color model [12]. The meaning of HSI color model is Hue (H), Saturation (S) and Intensity (I). The HSI color model described more exact color than the RGB color. Though HIS color model is non-uniform in perception, still it is one of the most popular color models for color image processing. The another advantage of using HSI color model is that it has human-intuitional advantages such as color image enhancement, fusion, skin area detection, segmentation, color based object detection etc. The RGB to HSI color model conversation is done by using the following equations:-

$$H = \begin{cases} \theta & if\ B <= G \\ 360^0 - \theta & otherwise \end{cases} \quad (1)$$

Where

$$\theta = \cos^{-1}\left\{\frac{\frac{1}{2}[(R-G)+(R-B)]}{\sqrt{(R-G)(R-B)+(R-B)(G-B)}}\right\}$$

$$S = 1 - \frac{3}{(R+G+B)} * [\min(R,G,B)] \quad (2)$$

$$I = (R+G+B)/3 \quad (3)$$

Where, H stands for Hue i.e. pure color, S for saturation, i.e. the degree by which the pure color is diluted using white light and I for intensity i.e. Gray level. Fig 2.a shows the corresponding saturation image of the input image in fig 3. Saturation component contains a lot of information for both tooth and background region. So it is very difficult to extract only teeth region from background from saturation component. As a consequence hue and intensity components are used to segment ROI and after that saturation component is used for feature extraction.

Fig. 2. Input Image

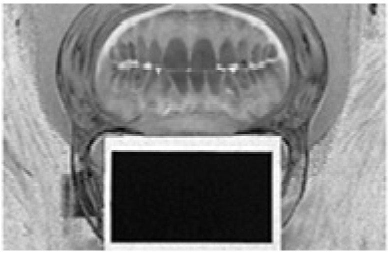

Fig. 2a. Corresponding saturation Image

Region of Interest (ROI) Extraction

After information extraction, the initial segmentation is done based on the hue and intensity component of the image. In this phase the hue and intensity component are multiplied pixel-wise. Now this is converted into binary image using self updating threshold method [13]. It stores the intensities of the pixels in an array. The threshold is calculated by using total mean and variance. Based on this threshold value each pixel is set to either 0 or 1. i.e. background or foreground. Thus here the change of image takes place only once. Suppose f(i,j) is the gray-scale value at pixel (i, j), and Ti is the segmentation threshold value at step i. To obtain a new threshold value, we have to threshold the original image using Ti to separate the image into teeth areas and non-teeth areas, where μ_i^0 and μ_i^1 are the mean gray values for the two areas.

$$\mu_i^0 = \left(\sum((i,j) \in f(i,j)) / no\_pixel\right) \quad (4)$$

$$\mu_i^1 = \left(\sum((i,j) \in background - f(i,j)) / no\_pixel\right) \quad (5)$$

The threshold value for step i+1 can be obtained as

$$T_{i+1} = (\mu_0 + \mu_1)/2 \quad (6)$$

Procedure: Binarization
Assumption: Null
Input: Teeth image
Output: Binary image of the given teeth image

Step 1. Select an initial estimate of the threshold T.
Step 2. Calculate the mean grey values $\mu 0$ *and* $\mu 1$ *of the partition, R1, R2.*
Step 3. Partition the image into two groups, R1, R2, using the threshold T.
Step 4. Select a new threshold as T= $(\mu 0 + \mu 1)/2$ \
Step 5.Repeat step 2-3 until the mean value $\mu 0, \mu 1$ *values in successive iteration are equal.*
Step 6. End

Fig. 3a. Output after using Binarization.

Fig. 3b. After applying *Fainting_Nameplate*

In Fig3.a the name plate portion of the image is mostly visible. This is not required at all, hence to remove this unwanted region we used the following procedure remove_nameplate.

Procedure: Fainting_Nameplate
Assumption Presence of the Nameplate as specified in [11]
Input: hue and intensity image of the given teeth image, threshold_value obtain in Binarization algorithm
Output: Teeth image where Nameplate area is filled with threshold_value

*Step 1 temp= image(hue)*image(intensity) // Pixel wise multiplication of hue and saturation and store it into temp variable.*

Step 2 Take the size of temp and store them in two different variable, [r, c] = size(temp).
Step 3 Start loop i=1 to r
Start loop j=1 to c
if(g(i,j)>=1)
temp2(i,j)= threshold_value / Ti+1;
End Loop
End Loop
Step4 End

Again we used procedure Binarization upon Fig 3.b to get the image where teeth region and name plate both are present. Next task is to remove the name plate region. It is done by subtracting fig 3.a from fig 4.a, shown in fig 4.b.

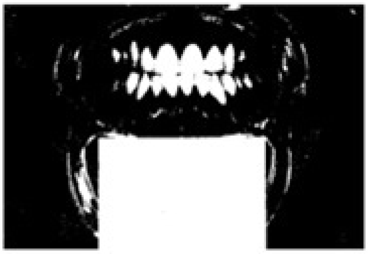

Fig. 4a. After applying 2 times Binarization

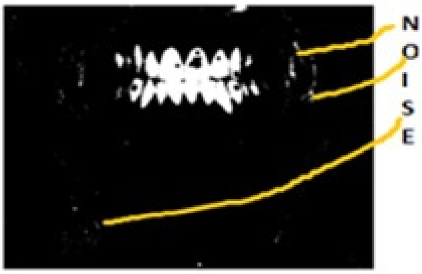

Fig. 4b. Only teeth region with noise

In fig 5.b some noise are present. Noises have been removed using erosion followed by dilation [12] technique. Erosion erodes contours so small contours are removed but it also shrinks the desired contours. Dilation recovers the looses areas. Now the contours contains only tooth region. Algorithm3 is used to find the final ROI which is a subset of input image. Algorithm 3 accepts the saturation components (Sat_Mat) and binary mask (B_Mask) of tooth region which is cleaned by erosion and dilation techniques. The dilation of A by B, denoted, is defined as the set operation.

$$A \oplus B = \left\{ z \mid \hat{B}_z \cap A \neq \phi \right\} \tag{7}$$

Where Ø is the empty set and B is the structuring element. In words, the dilation of A by B is the set consisting of all the structuring element origin locations where the reflected and translated B overlaps at least one element of A. The erosion of A by B, denoted, is defined as

$$A \ominus B = \{ z \mid (B)_z \cap A^c = \phi \} \tag{8}$$

Here, erosion of A by B is the set of all structuring element origin locations where no part of B overlaps the background of A.

Procedure: Find_ROI
Assumption: Nameplate should be removed from the binary image.
Input: saturation matrix, binary matrix after applying Remove_Nameplate
Output: exact teeth image

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Step1: // Averaging is required to suppress the detail information
    (Avg_Sat_Mat)40*40 = average_filter(Sat_Mat)40*40
Step2:   for all point in b_mask where b_mask(row,col)==1
            V_Point (index,1)= row
            V_Point(index,2)=col          // Storing row and col-
    umn
Step3: ∀(I,j) do
    {
    Avg_Sat_Mat(V_Point.row,V_Point.col)=
    Sat_Mat(V_Point.row,V_Point.col)
    }
    //End Loop
Step4: // Avg_Sat_Mat contains detail information about the tooth
region and          suppress information for background.
     Max_row = max(V_Point1st column)
        Min_row=min(V_Point1st column)
    Max_Col=max(V_Point2nd column)
    Min_Col=min(V_Point2nd column)
Step6:              ROI_sub_image =
            Avg_Sat_Mat[(Min_row,Min_row+1,.....,Max_row),
            (Min_Col, Min_col+1,....,Max_col)]
Step7: End
```

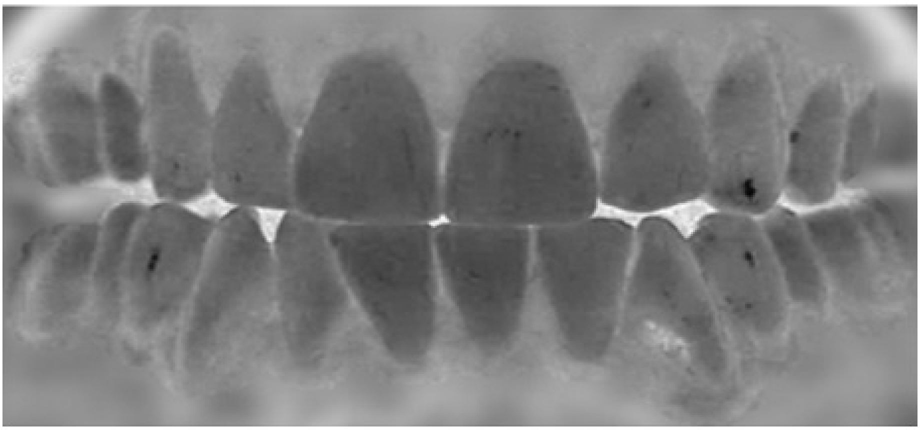

Fig. 5. The actual ROI after applying *Find_ROI* on fig 5.b

Segment Individual Tooth

In this step the individual teeth are segmented using mainly watershed [14] and snake active contour model [15] followed by some morphological preprocessing. Fig 5 is converted into its equivalent binary image using algorithm1 shown in Fig 6. Now we have segmented each contour using opening operation [12] shown in Fig 7.

Fig. 6a. Binary image of Fig 5

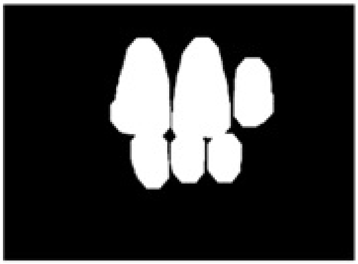

Fig. 6b. After applying Opening on Fig 5

In dental biometry it is not required to find the features of all the teeth. We have taken five incisors tooth for which features have been extracted. These teeth are shown in Fig 8. After opening operation we have pointed out the incisors tooth.

Fig. 7. After applying Watershed incisor are segmented

Fig. 8. Segmented contour after label matrix are Technique.

Now each contour has been identified by applying the label matrix technique [12] shown in Fig 8. The boundary of the contour is detected by using boundary detection algorithm as follows.

Procedure: Find_boundary
Assumption: Input image contains only single teeth.
Input: Teeth image after applying Watershed algorithm
Output: Boundary points of the teeth region.

Step 1 Set A to be empty ; From bottom to top and left to right scan the cells of T until a black pixel, s, of x is found.
Step 2 Insert s in A ; Set the current boundary point x to s or x=s
Step 3 Move to the pixel from which s was entered. Set c to be the next pixel in M(x).
Step 4 While c not equal to s do
If c = 0
insert c in A
set x=c
Move the current pixel c to the pixel from which x was entered
else
add the current pixel c to the next clock-wise pixel in M(x)
end if
End While
Step 5 End

The label matrix technique has used for getting the approximate boundary points of the tooth. After that snake active contour algorithm has been used to detect the exact individual tooth region as shown in Fig 9, Fig 10.

Fig. 9. incisors_central_1 Contour

Fig. 10. incisors_central_2 Contour

In the last phase the features are extracted teeth wise. We have extracted features of the incisor teeth from right maxilla, left maxilla, right mandible and left mandible. The binary contour of each tooth (teeth_contour) is given as the input of the system. The algorithm returns the features of the teeth.

Procedure: Feature_Extraction
Assumption: Input image must contains only one teeth.
Input: Individual tooth image

Output: Features like height, width, CG_Row (CG_Row and CG_Col points are the row and column value of the centre points of a tooth) etc

Step1 Determine the position of each segmented teeth; i.e. upper jaw or lower jaw. In teeth_contour find the number of pixel whose value is 1 for each row. Store the result in jaw_vector_array. If (jaw_vector(i) <= jaw_vector(i+1)) is true for almost all element of jaw_vector then that tooth belongs in the upper jaw.

Step2 // finding the width and height of each teeth.

Width = maximum _value(jaw_vector)

Height = number of non zero elements in jaw-vector

The ratio of these two is independent to zoom.

Step3 //find volume of each teeth

$$Volume = \sum_{i=1}^{i=sizeof(jaw\_vector)} jaw\_vector(i)$$

Step4 // find the CG co-ordinate for each teeth contour

$$CG\_row = (\sum row\_no\_nonzero\_pixel) / total\_pixel\_positions$$

$$CG\_col = (\sum col\_no\_nonzero\_pixel) / total\_pixel\_positions$$

Relative positions of CG points vary with the width of the teeth. CG points are helpful to determine the relative position.

Step5 Stop

4 Result

After applying procedure Feature_Extraction we got the following data for five teeth that mentioned in the table given below. This method can be applied on all of the remaining tooth. If we apply this algorithm to all 32 teeth then processing time will be much more higher than the proposed method and storage space requirement will be again coonsiderably high. However that case accuracy will be much higher. Similarly we can find the features of the tooth. Here for simplicity we have mentioned the features of incisors_central_1, incisors_central_2, incisors_central_3, incisors_central_1 and incisors_lateral (discussed in introduction).

Table 1. The calculated featured of individual teeth

Teeth Name	Width	Height	Volume	CG-Row	CG-Col
incisors_central_1	208	256	38100	240	427
incisors_central_2	196	256	36965	243	615
incisors_central_3	156	245	32145	495	625
incisors_central_4	150	244	31120	495	480
incisors_lateral	157	242	31560	493	405

5 Discussion and Conclusion

In this research work we proposed a system by which the features of the incisors tooth have been extracted. We have worked upon Labial Teeth and Gingiva Image Database [20]. We have applied the algorithm upon 270 data from set 1 to set 6 in Labial Teeth and Gingiva Image Database. Our proposed method can correctly find out the features from these sample dental images. In the next phase of this research work these features will be matched with the database. To extract the tooth contour from the entire tooth region we have used watershed and snake algorithm. Sometimes it happens that these methods are unable to detect exact tooth contour due to the less 'gap-valley' area. Even if the proposed dental biometrics approach is a low cost solution, dental signatures do change with time. A dental signature change due to accidents, dental work and as human grows up. Hence biometrics method based on dental signature is not 100% accurate. Our future plan is to develop low cost, multimodal biometrics method based on dental signature and ear pattern which will be more accurate towards identifying a person.

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