CHAPTER 4

LABIAL TEETH STRUCTURE FOR HUMAN IDENTITY

4.1 INTRODUCTION

In this chapter proposed a model for teeth recognition to identify a person. The teeth image matrix of a person is matched against the teeth image matrix database. Developed algorithm is to recognize the teeth using image processing techniques. The proposed work is an application of pattern recognition which analyses the pattern of teeth images. A similarity criterion has been derived to match against the specified threshold value. This similarity measure has been used for person identification. The experiment results has been carried on 20 teeth images of the same person and 100 teeth images of different persons from our database and Labial Teeth Database of Color Imaging Lab - University of Granada – Spain. MATLAB 7.4 has been used for this purpose.

A reliable and automatic user authentication is becoming a necessity in our modern society. For that Biometric technology is available today. Biometrics offers convenient, achievable & secure solutions for personal security. Different biometric technologies may be appropriate for different applications. Multi -biometrics will improve the population "coverage" as well as the performance. Information security is potentially the biggest market. Biometric authentication is going to be the hot industry across the world in the future. Biometric-based authentication applications include
workstation, network, domain access, single sign-on, application logon, data protection, remote access to resources, transaction security and Web security. Trust in these electronic transactions is essential to the healthy growth of the global economy. Using this technology individually or integrating with other technologies such as smart cards, encryption keys and digital signatures, the biometrics is set to pervade nearly all aspects of the economy and our daily lives. Utilizing biometrics for personal authentication is becoming convenient and considerably more accurate than current methods (such as the utilization of passwords or PINs). This is because biometrics links the event to a particular individual (a password or token may be used by someone other than the authorized user), is convenient (nothing to carry or remember), accurate (it provides for positive authentication), can provide an audit trail and is becoming socially acceptable and cost effective.

Current methods like password verification have many problems (people write them down, they forget them, they make up easy-to-hack passwords) like ATM transaction, banking etc. and we can overcome these drawbacks using biometric authentication. Biometric authentication is a trustworthy technology for improved authentication as it provides accurate and secured access to information.

Since the fraud in our society grows, the pressures to deliver more and more authentication services also grow. With its multimodal concept, BioID guarantees a high degree of security from falsification and unauthorized access. It also protects the privacy rights of system users.

To catapult biometric technology into the main-stream identification market, it is important to encourage its evaluation in realistic contexts, to facilitate its integration into end-to-end solutions and to foster innovations of inexpensive and user-friendly implementations. We hope that a
pervasive, accountable use of biometrics technology will help to establish a more open and fair society.

4.2 PROPOSED MODEL OF TEETH RECOGNITION

In this proposed model, the typical architecture consist of preprocessor, dental recording, processing of image, matrix generation, storing of processed data in to database, search data, retrieval, comparison of processed data, makes decision and trigger authorization. During preprocessing Meta data of all the remaining records about individuals like name, age, employee number, etc. are filled. During dental recording, a high resolution camera needs to be attached with system to record face of the individual to capture. The distance between camera and human face should be less than 50cm. There should be face chin holder to capture teeth image very clearly. System will give instruction on the posture for taking face image with teeth exposed. This image will be extracted and trimmed to teeth only portion. The segmentation of the teeth is extracted from the whole face image using clustering technique. This algorithm groups the pixels into a number of clusters such that the intensity of pixels of a cluster has almost similar values. The algorithm also detects the skin part of human body present in the image. We have used a face detection system based on the algorithms by applying a series of operations like edge detector, morphological operator, filled region, and non-face. We have to record each image into matrix form into database for future processing. This image is getting resized for 256X256 for consistency purpose. Later, this will be converted into grayscale image. The image is again resized into 20X20 to enable captured data to record into database. There is an option to fix dynamically, fixed value of threshold or use the formula furnished. So we take 18X18 matrix data for calculation. It will be input for converting image into matrix format. Decision logic will be
used by creating multiple threshold values but whole experiment should have similar setup which means same camera and same threshold is used in this experiment. The block diagram of proposed model is shown in Figure 4.1.

There are different types of dental radiograph, Bitewing x-ray is taken at routine check-ups. Periapical x-ray: It shows entire tooth, including crown, root and bone, external picture as JPG. Panoramic x-ray: It gives broader overview of entire dentition. It shows not only teeth also sinus, upper and lower jawbone. X-ray based picture required special equipment related to medical purpose. Normal Tooth pictures can be taken using camera installed in experimental area with facility to take picture while user reading letters “EEEEEE” which gives wide coverage of user teeth. In our experiment we take this JPG images as input.

4.3 LABIAL TEETH DATABASE

Color Imaging Lab - University of Granada, Spain has images of human teeth, Labial Teeth and Gingiva Image photographic image database (LTG-IDB), developed at the Color ImagingLab at the Optics Department of the University of Granada in Spain. The LTG-IDB currently contains more than 90 photographic digital still of teeth images. Images in this database are available in raw image format (which is the unprocessed sensor data of the camera in a specific vendor dependent data format, in this case the Canon raw image format cr2), as well as JPEG and TIFF. The strengths of this database are the fixed, well-defined and well known parameters of image acquisition. We have downloaded these images to extract teeth image for testing purpose.
4.4 SIMPLE AGGREGATE METHODOLOGY

There are two major formulas used for executing proposed algorithm. One is to find the difference and other is to find similarity of the cropped matrix which is created around middle point of the image. As stated above, one uses percent difference when comparing two calculated or experimental values to each other. Typically, one is interested in the percent difference of two values pertaining to the same property or characteristic of an object or system (mass, velocity, charge, etc.) Typically, both values are calculated using different methods, theories, or devices. Just as with percent error, calculating percent difference is as follows.

\[
\text{Difference } \% D = \frac{1 - \hat{l}}{\hat{l}/(1+\hat{l})/2} \times 100
\]

(4.1)

\[
\text{Similarity } \%(S) = 100 - D
\]

(4.2)

where \(l1\) and \(l2\) correspond to the experiment values of interest.

Algorithm:

Step 1. Collect Meta data like employee id about the person’s image and store in database assign unique id for image.
Step 2. Read the RGB image.

Step 3. Extract teeth part.

Step 4. Resize the image into size $256 \times 256$.

Step 5. Convert the RGB image into gray-scale image.

Step 6. Resize the image into size $20 \times 20$ and store in database.

Step 7. Find $Threshold = \frac{(Gray\ Matrix\ Max\ value + Gray\ Matrix\ Min\ value)}{2}$

Step 8. Convert gray-scale image into binary image by using threshold value.

Step 9. Crop the binary image from row focused as $5X18$ in the middle.

Step 10. Count the number of one’s stored

Step 11. Take another RGB image from learning database and repeat steps 1 to 10.

Step 12. Calculate the percentage difference between these two images.

Step 13. $\text{Difference}\% = \left| \frac{\text{Image}_1 - \text{Image}_2}{\sqrt{\text{Image}_1 + \text{Image}_2}} \right| \times 100 \ldots (4.3)

Step 14. Find the similarity between these two images

Step 15. $\text{Similarity}\% = 100 - \text{Difference} \ldots (4.4)$

Step 16. Above steps with multiple images of the same person in the learning database. If Similarity is within Acceptance Range consecutively compared with multiple image of same person, images belong to the same person otherwise they belong to different persons.

Step 17. End.
Acceptance range is derived from difference of percentage between various sample images of the same person taken during the training time. Let us take for example a person is taken 10 images during the training. All these 10 images are cross compared with one another and the difference range is determined.

In the database, every image Meta data is stored. Meta data contains like name, age, employee number, etc. We may store up to 50 images or more of the same person. More number of learning data will give higher accuracy. Every trail data will be stored and kept for future use. The similarity has been calculated at random of two images of the same person. Average of the previous images similarity should be matching within threshold range; if not system will identify as different person. Based on this calculation authentication activity will be done. It is compared the pattern between the same person image and different person images. These patterns can be arrived only when you compare images in cross comparison. For the same person min and max range will be within certain limit but for different person’s image. Based on this observation the system can very easily make out if the image belongs to a particular individual or not. If the images match, the person is granted access to proceed with further steps else access is denied.

4.4 WORKING OF PROPOSED ALGORITHM

The following steps are carried using algorithm to calculate similarity % of two images.
<table>
<thead>
<tr>
<th>Description of Operation</th>
<th>First Image</th>
<th>Second Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGB Image</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td>gray image</td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td>The matrix of first gray-scale image</td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
</tbody>
</table>
| Calculate the Threshold                   | The maximum threshold value of image: threshold1 = 180  
The minimum threshold value of image: threshold2 = 2  
The average threshold value of image: threshold = 91 | The maximum threshold value of image: threshold1 = 185  
The minimum threshold value of image: threshold2 = 2  
The average threshold value of image: threshold = 94 |
| The matrix of binary-scale image is       | ![Image](image7) | ![Image](image8) |
Table 4.1 (Continued)

<table>
<thead>
<tr>
<th>Description of Operation</th>
<th>First Image</th>
<th>Second Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>The matrix of cropped image</td>
<td><img src="image1" alt="First Image Matrix" /></td>
<td><img src="image2" alt="Second Image Matrix" /></td>
</tr>
<tr>
<td>The number of ones in image are</td>
<td>150</td>
<td>148</td>
</tr>
<tr>
<td>Difference %</td>
<td>1.3423%</td>
<td></td>
</tr>
<tr>
<td>Similarity%</td>
<td>98.6577%</td>
<td></td>
</tr>
</tbody>
</table>

Toleration level acceptance criteria is defined based on learning images. While pattern regeneration compares the key data with multiple test data of same person, if similarity is above specified threshold value, Teeth images belong to same person; otherwise they belong to different persons. Once the person is identified using his Meta data his previous experimental data range is compared to ensure accuracy.

4.6 EXPERIMENTAL RESULT ANALYSIS

For analysis 20 teeth images are taken from same person and 100 teeth images of different persons. An experiment had been conducted to match the teeth images of a person against the teeth image database. The table has shown the results on the teeth image belonging to the same person. Both the images match against the similarity criteria. If they are more than specified threshold value, then they belong to the same person. Matching is critical and
tricky stage of dental biometric system which finds out difference between two dental processed data. Here we consider cropped data in matrix format for matching of the dental image. Conclusion can be made by matching one original image in order to increase the accuracy. Algorithm can create pattern of the same person image created using learning data. When comparison is made through all of the training data it is based on more number of sample. It will ensure the high accuracy of the result.

Table 4.2 Teeth Image of same person

<table>
<thead>
<tr>
<th>S No</th>
<th>Same person</th>
<th>Similarity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Image 1</td>
<td>Image 2</td>
</tr>
<tr>
<td>2</td>
<td>Image 1</td>
<td>Image 3</td>
</tr>
<tr>
<td>3</td>
<td>Image 1</td>
<td>Image 4</td>
</tr>
<tr>
<td>4</td>
<td>Image 1</td>
<td>Image 5</td>
</tr>
<tr>
<td>5</td>
<td>Image 1</td>
<td>Image 6</td>
</tr>
<tr>
<td>6</td>
<td>Image 2</td>
<td>Image 3</td>
</tr>
<tr>
<td>7</td>
<td>Image 2</td>
<td>Image 4</td>
</tr>
<tr>
<td>8</td>
<td>Image 2</td>
<td>Image 5</td>
</tr>
<tr>
<td>9</td>
<td>Image 2</td>
<td>Image 6</td>
</tr>
<tr>
<td>10</td>
<td>Image 3</td>
<td>Image 4</td>
</tr>
</tbody>
</table>

The similarity between two teeth images of same person was taken and calculated similarity using proposed algorithm. Randomly taken images are compared with each other images of the same person. We may observe the pattern in Figure 3 it may vary between 88 to 100%. The table needs to be compared for accuracy of the individual teeth image.
Figure 4.2 Similarity among same person teeth images vary within limits

In Table, We have taken set of teeth images belonging to different persons. The experiment results show that the teeth images of different persons and its similarity percentage.

Table 4.3 Teeth Image of different persons

<table>
<thead>
<tr>
<th>S No.</th>
<th>Different Persons Image No.</th>
<th>Similarity (%)</th>
<th>S No.</th>
<th>Different Persons Image No.</th>
<th>Similarity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Image 1 Image 2</td>
<td>74</td>
<td>11</td>
<td>Image 2 Image 15</td>
<td>51</td>
</tr>
<tr>
<td>2</td>
<td>Image 1 Image 3</td>
<td>27</td>
<td>12</td>
<td>Image 2 Image 16</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>Image 1 Image 4</td>
<td>1</td>
<td>13</td>
<td>Image 3 Image 11</td>
<td>79</td>
</tr>
<tr>
<td>4</td>
<td>Image 1 Image 5</td>
<td>45</td>
<td>14</td>
<td>Image 3 Image 14</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>Image 1 Image 16</td>
<td>20</td>
<td>15</td>
<td>Image 3 Image 15</td>
<td>65</td>
</tr>
<tr>
<td>6</td>
<td>Image 12 Image 13</td>
<td>50</td>
<td>16</td>
<td>Image 3 Image 16</td>
<td>38</td>
</tr>
<tr>
<td>7</td>
<td>Image 12 Image 14</td>
<td>22</td>
<td>17</td>
<td>Image 4 Image 11</td>
<td>79</td>
</tr>
<tr>
<td>8</td>
<td>Image 12 Image 15</td>
<td>69</td>
<td>18</td>
<td>Image 4 Image 12</td>
<td>94</td>
</tr>
<tr>
<td>9</td>
<td>Image 12 Image 16</td>
<td>42</td>
<td>19</td>
<td>Image 4 Image 13</td>
<td>45</td>
</tr>
<tr>
<td>10</td>
<td>Image 13 Image 14</td>
<td>68</td>
<td>20</td>
<td>Image 4 Image 14</td>
<td>17</td>
</tr>
</tbody>
</table>
The similarity between two teeth images of different persons are as shown in the above figures. We need to observe the patterns of which range from 1 to 95%. So the range difference cannot vary to this extend for the same person. The range observation system can easily make out this image belongs to different person.

![Graph showing similarity among different persons teeth vary outside limits](image)

**Figure 4.3** Similarity among different persons teeth vary outside limits

![Graph showing similarity comparisons of different data set images](image)

**Figure 4.4** Similarity comparisons of different data set images
Table 4.4 Matrices of teeth images belong to same person

<table>
<thead>
<tr>
<th></th>
<th>Original Image</th>
<th>Gray-scale Image</th>
<th>Gray-Matrix</th>
<th>Binary-Matrix</th>
<th>Sub-Image Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
<td><img src="image3.png" alt="Image 3" /></td>
<td><img src="image4.png" alt="Image 4" /></td>
<td><img src="image5.png" alt="Image 5" /></td>
</tr>
<tr>
<td>2</td>
<td><img src="image6.png" alt="Image 6" /></td>
<td><img src="image7.png" alt="Image 7" /></td>
<td><img src="image8.png" alt="Image 8" /></td>
<td><img src="image9.png" alt="Image 9" /></td>
<td><img src="image10.png" alt="Image 10" /></td>
</tr>
<tr>
<td>3</td>
<td><img src="image11.png" alt="Image 11" /></td>
<td><img src="image12.png" alt="Image 12" /></td>
<td><img src="image13.png" alt="Image 13" /></td>
<td><img src="image14.png" alt="Image 14" /></td>
<td><img src="image15.png" alt="Image 15" /></td>
</tr>
<tr>
<td>4</td>
<td><img src="image16.png" alt="Image 16" /></td>
<td><img src="image17.png" alt="Image 17" /></td>
<td><img src="image18.png" alt="Image 18" /></td>
<td><img src="image19.png" alt="Image 19" /></td>
<td><img src="image20.png" alt="Image 20" /></td>
</tr>
<tr>
<td>5</td>
<td><img src="image21.png" alt="Image 21" /></td>
<td><img src="image22.png" alt="Image 22" /></td>
<td><img src="image23.png" alt="Image 23" /></td>
<td><img src="image24.png" alt="Image 24" /></td>
<td><img src="image25.png" alt="Image 25" /></td>
</tr>
</tbody>
</table>

Table has list of images taken from same person and different persons with different variations. It has gray images and its matrix along with binary matrix to enable similarity calculation.
Table 4.5 Teeth images matrix belongs to different person

<table>
<thead>
<tr>
<th>Original Image</th>
<th>Gray-scale Image</th>
<th>Gray-Matrix</th>
<th>Binary-Matrix</th>
<th>Sub-Image Matrix</th>
</tr>
</thead>
</table>
Figure 4.5 Teeth structure verification being used in ATM machine

The feature extraction stage uses linear filter to enhance the images and knowledge based method to segment the dental work and store the features in the database for identification.

4.7 EDGE DETECTION METHOD

The contours of the teeth are important features in dental biometrics. They can be utilized as cues for identifying the individuals. The extraction of other features (e.g., the dental work) also needs the contours of teeth as reference. However, without the proper guidance of tooth shape knowledge, these methods are subject to errors when the tooth contours are fuzzy and only partially visible. To extract the contours from these images, we propose a method based on edge detection, and an extraction method by using binary template and knowledge based model. The method is developed using Matlab 7.5. The accuracy and robustness of this method allow its usage
in biometric identification system. Matching results show the contours extracted with this method perform better than the traditional method.

Dental biometrics about teeth, including tooth contours, relative positions of neighboring teeth and shapes of the dental work (e.g., crowns, fillings, and bridges). The proposed system has two main stages: Feature extraction and matching.

The feature extraction stage uses linear filter to enhance the images and knowledge based method to segment the dental work and store the features in the database for identification.

The matching stage has three sequential steps: Tooth-level matching, computation of image distances and subject identification. Here only features extraction is addressed.

4.8 FACE AREA DETECTION

Before starting the search for face features the face area has to be found in which the face features are located. An algorithm (Froba et al 2002) is described which marks possible eye positions with high robustness and acceptable accuracy. The desired face area is defined by applying head and face relations which are described in (Farkas 1995) to the possible eye positions. The half distance of the possible eye positions can be interpreted as eye width or length of the eye fissure. Furthermore the eye width can be used as a unit for face feature relations.

4.9 FACE DETECTION

Feature points like iris-pupil centers, eye corners, nose tip, chin outline, cheek outline, eyebrows and mouth corners are used to adjust a generic head model to an image of that person and to extract a texture map for
the model. For a practical system, this feature detection has to be done automatically without any manual interaction. The following sections describe algorithms for iris-pupil centers, iris outlines and mouth corners detection.

4.10 EYES DETECTION

Presented a novel approach is for iris-pupil centers detection within the face area. This approach is based on the knowledge of the iris and pupil. The iris is a circle which can have partly occlusions of the upper and lower lid. Mostly the upper lid is the reason for such occlusions. The iris and pupil are both dark compared to the white of the eye ball and to the luminance values of skin color. There are mostly two eyes found within a face with the same diameter for the iris. The locations of the eyes are described in relations to the other face features like mouth, and nose, but also to head weight and height. These relations are called anthropometric information. First the iris-pupil area and afterwards the iris-pupil center detection are explained.

Eye area Search: This part of the iris-pupil centers search is used to mark a position within the iris-pupil area. Key elements are iris-pupil template and the inverse version of this template as well as the 90 degree rotated vertical versions of the described templates. The iris-pupil template is a filled circle surrounded by a box. The filled circle represents the iris and pupil as one part. The horizontal version of the template has left and right areas, which represent parts of eyeball area. The vertical version has upper and lower areas, which represent parts of upper and lower eye lid. The purpose of these templates is to extract desired values of the luminance, and first order gradient data, but also for calculating the correlation of the shape after extracting the data. Such templates have only the diameter of the filled circle (iris-pupil area) as a free parameter which is adjusted at the beginning of the search within the face area. The diameter is determined from the eye width as unit
for facial feature relations. The eye width to eye height relation described can be expressed as 1: 1/3 of the determined unit eye width. The eye height is interpreted as iris diameter and is therefore used to create the iris-pupil templates. The width of the left and right eyeball areas as well as the upper and lower lid areas are adjusted to the iris diameter. Because of the dependency of the possible eye position found by (Froba et al 2002) and anthropometric relations described by (Farkas 1995) the desired templates are generated according to the determined size of the face area within the scene. Therefore these templates can be scaled automatically and depend on the size of the face area.

The algorithm consists of three steps: First, a search using the templates, second combination of both search results. Third step is applying anthropometric information to the combined search results.

- Step one is done for each pixel (horizontal, vertical) within the face area. Cost functions used together with the corresponding templates consist of the following elements:
  - The luminance values of the iris-pupil filled circle and the surrounding areas are estimated for each search position in order to minimize the difference of template and search image,
  - Correlation of synthesized iris-pupil template parts with the search image
  - Horizontal gradient values along the horizontal iris-pupil template outline and vertical gradient values along the vertical iris-pupil template
  - Luminance value variation inside the iris-pupil area,
  - average of luminance values inside the pupil-iris area, and
  - lowest luminance value inside the iris-pupil area.
Step one generates two 2D error images. Step two starts with excluding regions of the error images found only by one search (horizontal or vertical template). Both error images are combined by simple addition after normalization. Prospective iris-pupil centers are extracted by analyzing the combined result for high density regions. The third step arranges these regions using anthropometric information. Prospective iris-pupil area combinations for left and right iris-pupil centers are the output of this part.

Eye area Center Search: In order to refine the iris-pupil center positions and to obtain the iris outline in a second step, deformable iris outline templates are introduced. These templates can be changed in diameter and geometry. Taken into account that in most cases the iris is partly covered with the upper lid makes it necessary to change the geometry of the iris outline template. The iris outline template is not a filled area like the iris-pupil template because of the possible light reflection(s) within the iris-pupil area. A cost function which is defined by property descriptions of the iris is used with the described iris outline template. The algorithm consists of two steps. First, the iris outline template is only changed in iris diameter and position. The iris diameter can be changed in both directions; this means a bigger or smaller iris is possible. The position found by the part one of the iris-pupil center search can be shifted within the initial iris diameter. Second, the geometry changes are applied using the previous determined iris diameter. The used cost function consists of the following elements:

- Absolute value of the horizontal and vertical gradient values along the specified iris outline,
- size of the iris outline (circumference), and
- the average of the luminance values inside the iris outline.
4.11 MOUTH IDENTIFICATION

Before extracting specific mouth features like mouth corners and mouth inner lip line, the mouth itself has to be located within the face area. For this purpose eye location and a mouth template as well as the inverse version similar to the iris-pupil template are used. Note this template has the same size as the vertical version of the iris-pupil template because of the given anthropometric information. Therefore this template does not represent a whole mouth. The mouth templates are used to determine possible mouth locations. Analyzing the possible regions with the anthropometric location of the mouth marks the position of a mouth region. Within the found mouth region highest second order gradient values of the luminance values are connected to the initial mouth inner lip line. The mouth corners and inner lip line search region is framed by applying vertical the upper and lower lip height along the initial line and by extending the left and right search region boundaries to the maximum possible distance given by the binocular line. The lowest luminance values are connected in this procedure to the possible mouth inner lip line. In order to specify the mouth corners a color plane in the RGB color space is used to separate mouth from skin color pixels of the mouth line. Samples of the mouth and the skin color have to be extracted from the color image for positioning of the separation plane. Skin color pixels are found by excluding regions with high gradient values of the face area. Morphological operations like dilatation are applied as well. Mouth color pixels are extracted from the inner lip line.

The positioning of the separation plane consists of the following steps:

- Separation vector centered by mean values of skin and mouth pixels,
• Normal on the separation vector towards mean skin position, and
• Rotation around the separation vector for maximum skin color data enclosure.

In order to separate skin from mouth pixels the normal of the plane is used for color space transformation. Positive results are pointing to the skin color space and negative results to the mouth color space. The usage of this method for separating skin and mouth color pixels along the found inner lip line marks the mouth corners.

4.12 TOOTH EXTRACTION

A tooth includes two parts: the upper part is called the crown, which is above the gum line, and the lower part is called the root, which sits in the bone below the gum. Because of the bone and the soft tissue, the root of the tooth is not very visible in the image. Since the crown has a higher contrast with the background than the root, we extract the shape of the crown only.

![Figure 4.6 Tooth structure](image)

To simplify the shape extraction, we manually select a rectangular region R and a point c in the input image I. R is a region containing the tooth and the point c is inside the crown of the tooth, which is called the Crown Center. First, we compute the gradient image, $|\Delta I|$ of the input image I, as
\[ | \Delta I(x, y) | = \text{Sqrt}((I(x, y) - I(x, y-1))^2 + (I(x, y) - I(x-1, y))^2) \quad (4.5) \]

Due to the proximity of the neighboring teeth, there is some interference between the edges of a tooth and the edges of adjacent teeth. To solve this problem, we define an auxiliary image \( M \), by

\[ M(x, y) = B(x, y) | \Delta I(x, y) | \quad (4.6) \]

where

\[ B(x, y) = \begin{cases} 0 & \text{if } \Delta I(x, y).E(x, y) < 0 \\ 1 & \text{otherwise}, \end{cases} \]

and \( \Delta I(x, y) \) is the gradient direction vector at \((x, y)\), \( E(x, y) \) is a vector from Crown Center \( c \) to \((x, y)\), and ‘.’ denotes the dot product. Note that when \( E(x, y) \) and \( \Delta I(x, y) \) form an acute angle, \( B(x, y) \) equals 1; otherwise, \( B(x, y) \) equals 0. As a result, the effect of the edges of the neighboring teeth in computing the gradient is greatly decreased.

From the crown center, it make a radial scan of the crown. The edge of the crown should be somewhere along this radial line. It sort all the points on the radial line in terms of \( M(x, y) \) and record the three largest ones. If drawn a sufficiently large number of radial lines, then a list of edge candidates is produced. Let \( M \) be the mean of all the recorded \( M(x, y) \) values. To define the reliability, \( R(x, y) \), of each edge candidate \((x, y)\) by

\[ R(x, y) = \begin{cases} e^{-\alpha(M(x, y) - M)^2} & \text{if } M(x, y) < M, 1 & \text{if } M(x, y) \geq M, \end{cases} \quad (4.7) \]

where \( \alpha \) is a constant to prevent \( R(x, y) \) from decaying too fast. Along each radial line, the point with the largest reliability is selected to be an edge point.
4.13 PRINCIPAL COMPONENT ANALYSIS (PCA)

Principal Components Analysis (PCA) offers a method to identify and rank the low-level features according to the amount of variation within the image data explained by each feature (Horstemke & Raicu 2007). PCA uses the covariance between the features to transform the feature space into a new space where the features are uncorrelated. First, the covariance matrix for the feature data is calculated and then, the eigenvectors (principal components) are extracted to form a new linear transformation of the original attribute space:

\[
P C_j = \alpha_1 f_1 + \alpha_2 f_2 + \alpha_3 f_3 + \alpha_4 f_4 + \alpha_5 f_5
\]

(4.8)

where \( j \) stands for the \( j \)th principal component \( (j = 1, \ldots, 5) \) and \((\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5)\) are the features contributions to forming the component. The features with large loadings (weights) contribute more to the principal component of the data, the features with lower loadings (weights) can be considered noise. Using both the loadings (weights of the original features) and the amount of variance explained by the principal components, the importance of the individual features can be compared and ranked.

After ranking each eigenvector (principal component) for the amount of dataset variation they explain, the top ranking eigenvectors are selected to represent the entire dataset. In our proposed approach considered the only first principal component for further analysis. That is, instead of applying the snake on the original gray-level image, then apply the snake on the first principal component image formed by replacing each pixel’s intensity by its representation in the PCA space:

\[
\begin{bmatrix}
PC_1(1,1), \ldots, PC_1(1,n) \\
\vdots \\
PC_1(n,1), \ldots, PC_1(n,n)
\end{bmatrix}
\]

(4.9)
4.14 GRADIENT VECTOR FLOW (GVF) SNAKE APPROACH

Snakes or active contours were first introduced by Kass et al (1987) to locate the boundaries of an object of interest. Since then, snakes have been used in many applications, such as edge detection, shape modeling and object tracking. The traditional snake approach is based on the image energy function and attempts to conform to an energy minimization solution by deforming to certain internal and external forces:

\[ E(X) = S(X) + P(X) \]  \hspace{1cm} (4.10)

where \( S(X) \) and \( P(X) \) are the internal and potential energy functions respectively. \( S(X) \) is generally represented by

\[ \frac{1}{2} \left[ \alpha \left| \frac{\partial X}{\partial s} \right|^2 + \beta \left| \frac{\partial^2 X}{\partial s^2} \right|^2 \right] \]  \hspace{1cm} (4.11)

where the first term represents resistance to stretching and the second term dampens bending. These two terms are called tension and rigidity. \( P(X) \) is computed by

\[ \int_{0}^{1} P(X(s)) \, ds \]  \hspace{1cm} (4.12)

where \( P(X(s)) \) is calculated from the image data and takes smaller values at object boundaries and other features of interest.

The problem associated with the traditional snake approach is that the suggested external forces are faulty when it comes to converging to desired concave boundaries. Also, another inherent problem with snakes is that the initialization of the snake heavily influences the outcome of its deformation.
Xu & Prince 1998 introduced the gradient vector flow (GVF) in order to solve these two problems associated with snakes. Using a gradient edge map derived from the image, a diffusion model was applied to deform the snake such that it was able to converge to concave boundaries. Furthermore, the map did not rely on initialization by an expert user as long as the map is automatically initialized within the vicinity of organ of interest. Therefore, the GVF model was defined by the following equation:

\[ x_t(s,t) = \alpha x''(s) - \beta x'''(s) - v = 0 \]  \hspace{1cm} (4.13)

where \( \alpha x''(s) - \beta x'''(s) \) is the internal force that resist to stretching and bending while \( v \) is a new static external force field that pulls the snake towards the desired object. The snake is iteratively deformed using the parameters \( \alpha, \beta, \kappa, \mu, \) and \( \gamma \) (tension/elasticity, rigidity, external weight force, noise filtering, and viscosity) which returns a new set of points that represent the deformation of the snake after a set number of iterations. The GVF model is defined by the above equation and applied on the matrix defined by Equation (4.9).

4.15 EXPERIMENTAL RESULTS

Computers of the future will interact with us more like humans. The key element of that interaction will be their ability to recognize human beings and even understand their expressions. Proposed system serves an integral part in establishing smart environments, where computers are employed everywhere and it is suitable for any application where people require access to a technical system: computer networks, Internet commerce, banking systems, and ATMs.
In addition, this system secures access to rooms and buildings. Depending on application, the proposed system authorizes people either through identification or verification.

In identification mode, the system identifies a person exclusively through biometric traits. In verification mode a person gives his name or a number, which the system then verifies by means of biometric traits. The correct extraction rate and the results are show in Table 4.6.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Test Scenario</th>
<th>No. of Samples</th>
<th>No. of Correct extraction</th>
<th>%</th>
<th>Mean false extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSM and GVF</td>
<td>Day</td>
<td>125</td>
<td>120</td>
<td>96</td>
<td>4.8%</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td>125</td>
<td>118</td>
<td>94.4</td>
<td></td>
</tr>
<tr>
<td>Proposed Method</td>
<td>Day</td>
<td>125</td>
<td>123</td>
<td>98.4</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td>125</td>
<td>122</td>
<td>97.6</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.7 Stages of image extracted from human face to teeth
(a) Captured (b) Binary image (c) Feature identification (d) Teeth extracted
Figure 4.8 Simulator illustration of door authentication using teeth

4.16 SUMMARY

In this chapter, the models of image processing techniques have been used to match the pattern of teeth image against the teeth image database. If the similarity between two teeth images is above the specified threshold value, then they belong to the same person otherwise they belong to different persons. The results conclude that the accuracy of the proposed system is more than 90% when the teeth images belong to same person. The proposed system is accurate when the teeth images belong to different persons because consistency is missing. The proposed algorithm for dental image registration uses the phase-based image matching. Experimental performance evaluation demonstrates efficient performance of proposed algorithm.

Algorithm is developed as semi-automatic on JPG images because during the cropping stage can define the size of the matrix for maximum accuracy. Threshold point also selected manually, these can be automated based on the usage and alignment to the application and infrastructure. In this method collection of sample image is user friendly. It is very simple image when the individual is reading letters “EEEEEE” face snap is taken. This can be used in most of common corporate and restricted areas where their data is present always. It can be used as additional parameter to identify a person in voter’s database, National security database, employee records. Even this can
be used as key to open doors, office, Bank, schools attendance purpose addition to thumb impression reading. This method is used in ATM simulator design as additional static parameter for identifying banking customer during transactional based security authorization. Front elevation of the radiograph and X-ray images of teeth of cadavers can be compared with this image to get comparison results for the purpose of forensic analysis.

In a test involving more than hundred persons for three months, the proposed system reduces the false-acceptance rate significantly below 2 percent, depending on the security level. The higher the security level, the higher the false-rejection rate. Thus system administrators must find an acceptable false rejection rate without letting the false-acceptance rate increase too much. The security level depends on the purpose of the biometric system implementation.