Journal of AL-Qadisiyah for computer science and mathematics Vol.10 No.3 Year 2018
ISSN (Print): 2074 – 0204 ISSN (Online): 2521 – 3504

Identification based Dental Image

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Recived : 27\8\20178 **Revised : 2\9\2018** **Accepted : 6\9\2018**

Available online : 26/9/2018

DOI: 10.29304/jqcm.2018.10.3.438

Abstract

Identification (matching) system is a recognition and classification form that helps in identifying the identity depending on his/her dental X-Ray image. This work displays a new method to identify a person from his/her dental X-Ray image that is widely used in forensic, border organization, parenting selecting and investigations. The goal of this paper is to design an efficient identification model depending on dental X-Ray image of identities and that can be useful to identify the unknown Individuals who died. The techniques that used were image processing and features extraction techniques which had been added to improve the goal. The best result attained from the dental X-Ray model was 89% as an identification rate.

Keywords: dental X-Ray; identification; recognition; image processing; features extraction

1. Introduction

The goal in identification systems is to determine the identity of an individual from a large set of possible identities. The system depends on the templates of the users that have been inserted into the database at the enrollment process to extract the desired features to be used for the identification process. In this process, the system decides whether there is a matched identity or not [1][2][3]. Biometric identification system became an industrial implement for person's matching. The increasing needs for this system has a significant importance for the security because there is massive information that the identities wanted to be protected from the other damages or hacking. Because of its reliability and accuracy, biometrics became an important tool for the security [1][4][5]. Dental identification process applied in case of the totally damaged, burned bodies. This biometric measurement is useful tool in forensic identification in case that the system couldn't recognize the identity from his/her face if it was smashed or burned, so it would be difficult to be identified by face. Here dental biometrics would be represented as a positive tool for identifying a person from his/her dental besides another biometrics such as finger-print, iris…etc. Besides the forensic identification, dental biometrics can also be used in security authentication [6][7]. The aim of paper is identifying a person from many persons by collecting their biometric traits in a database. The biometric trait that employed on in this paper is Teeth measurement. the aim of this paper comes true when the designed identification system verify persons depending on his/her biometrics traits without humans entry in decision making. this decision making based on a table that contains the calculations of the similarity or the differences between the traits of each person which is got through different stages to calculate these results. each stage has its importance to get the desired result. There are some of the past researches that are related to the subject of the paper and it is explained as the following:

[M.Cr. 2016], Proved an accurate edge detection method for dental X-Ray which is canny edge detection algorithm. It has been tasted of different bite wing dental X-Ray images for the upper, lower teeth and it also took in consider the missing teeth as an object to ensure an accurate result. The stages of the system included an image enhancement, teeth segmentation and edge detection with feature extraction. Three features are selected to be the identity for each tooth individually: Area, Euler Number and Standard Deviation.

The preprocessing stage works on bite wing X-Ray images and gives an accuracy results. The results that obtained were for normal and missing teeth. The problem was dental X-Ray suffers from the accuracy due to different issues, such as segmentation and teeth edge detection. Additionally, dental X-Ray images could be changed according to the shoot and weather conditions [7].

[S.Dh. 2017], Presented a full system for human identification by using dental biometric traits with full actions such as searching, matching and insertion. The database was a collection of a bite wing dental X-Ray with high resolution to be compared with the other types. The system performance evaluated according to its capacity, accuracy, and time complexity by using different dental X-Ray images samples [10].

[L. Ka.2017], Proposed a dental biometric to identify human. It is an important tool for forensic identification in case of the totally damaged face, in this case biometric identification is the most promising way to authenticate humans with high level of accuracy rate. The data tested on two types of database such as dental radiographs and colored teeth images. One of the problems that the researchers was face is the bad quality of the Images which create difficulties at every stages of features extraction and matching [6].

2. Proposed Method

The typical design of verification and identification model consists of many stages as shown in fig (1).

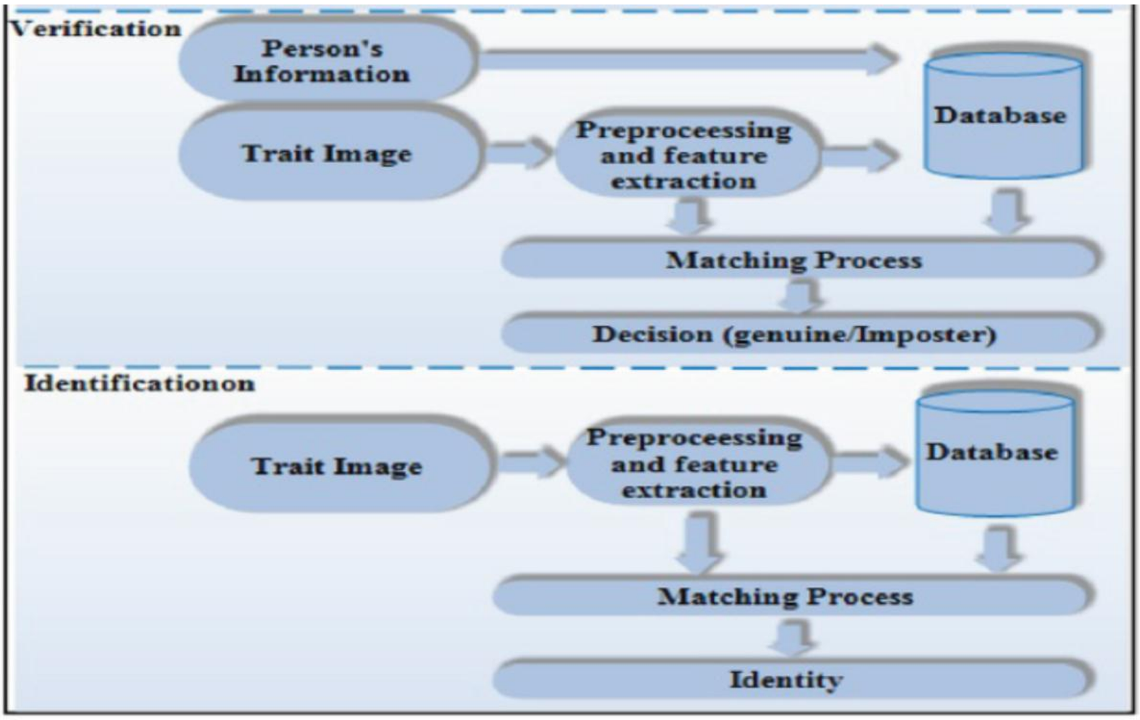

Figure (1): Verification and Identification Process

- **Preprocessing Stage**: It has an effective role on the system performance.
  This role contributes in minimizing the problems that will be found in the image which is enhancing the image quality by filtering the image from noise and dirt that might happen in the capturing stage (the acquisition device). The preprocessing methods differ from one trait to another and according to the traits nature.

- **Feature Extractions**: This stage contributes in extracting the outstanding features of the biometric measure using different methods to find out the distinguishable feature of these measurements.

- **Matching**: The result of the matching phase can be gotten from the ability of the minimum distance which is used to calculate the lower value of the test sample and compare it with the saved one to get the nearby matching result.

- **Experiment Results**: It is depending on the used biometric measurements which is employee some as a training sample and another as a testing one, so it differs from one system to another in computing the recognition rate.

In our proposed system the database constructed by Microsoft SQL server 2008 that contains the person’s info (name, mother name and age), besides the extracted features of the dental X-Ray images which are mean($\bar{g}$), Standard Deviation (STD), variance, PCA feature that we got it from Principal Component Analysis algorithm (PCA) and the minimum distance. The proposed dental model divided into two phases: enrollment phase that contains preprocessing stage, feature extraction stage, while the identification phase including preprocessing stage, feature extraction stage and the matching /identification stage. Fig(2)illustrates the proposal dental model structure.

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ISSN (Print): 2074 – 0204 ISSN (Online): 2521 – 3504

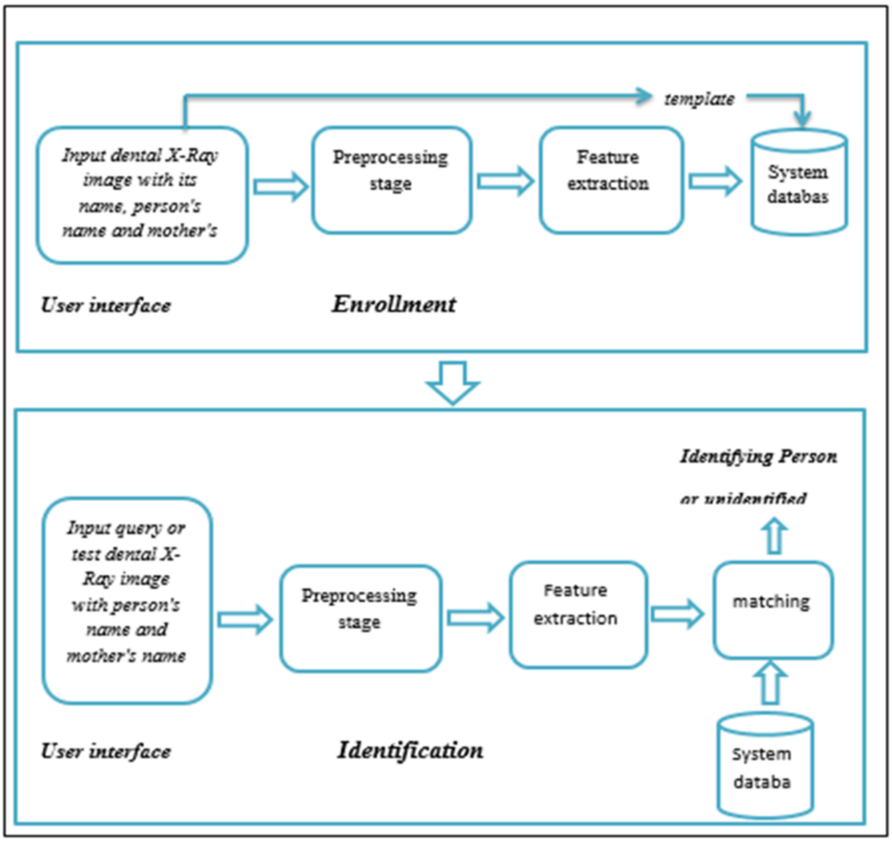

Figure (2): Stages of Two Phases of Identification Dental Model

The enrollment phase is sequence of processes, firstly the user reads the X-Ray image with Joint Photographic Experts Group (JPEG) format, then passes through the preprocessing stage that contains some steps such as image resizing by scale factor, converting into gray scale, filtering the image with median filter and image histogram with Contrast Limited Adaptive Histogram Equalization (CLAHE), then passes through features extraction stage that consists of steps like PCA feature, $\bar{g}$, STD, variance and minimum distance where these extracting features are inserted into the Dental Features Table (DFT) database. The work of this process inserts the features into the database only without identification. Fig (3) illustrates the dental enrollment phase.

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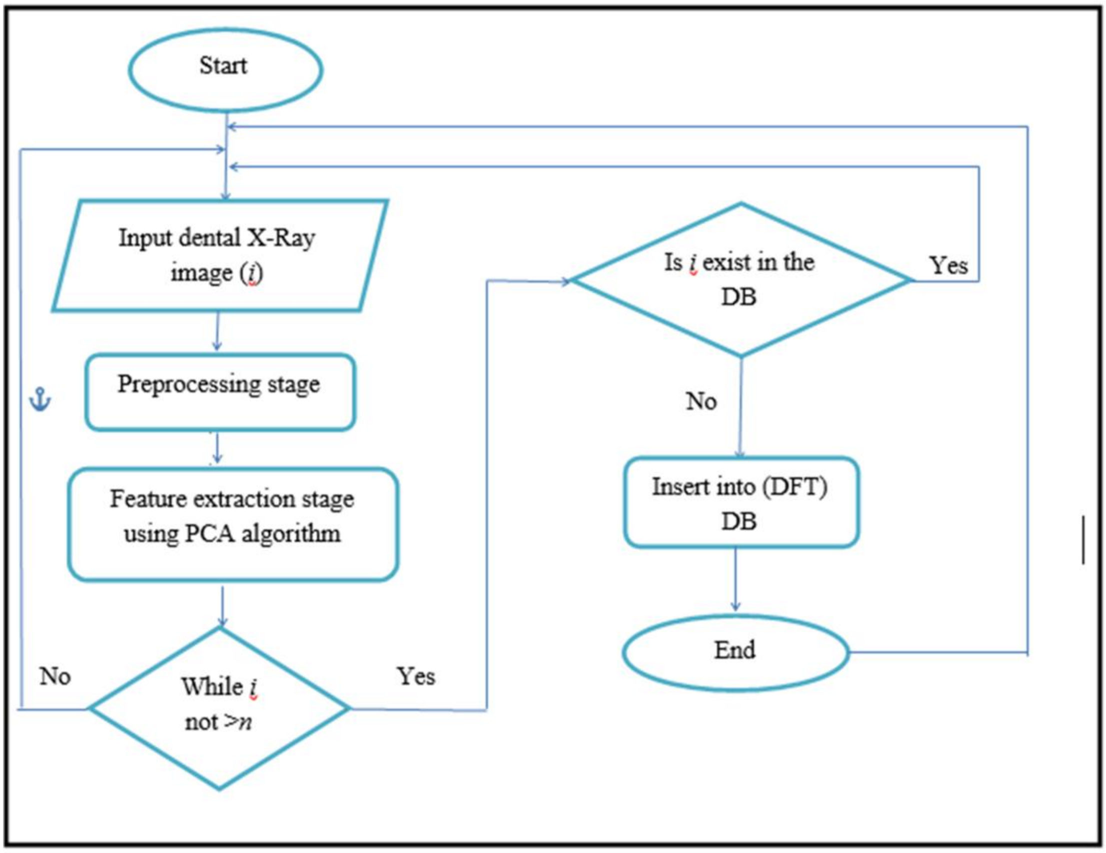
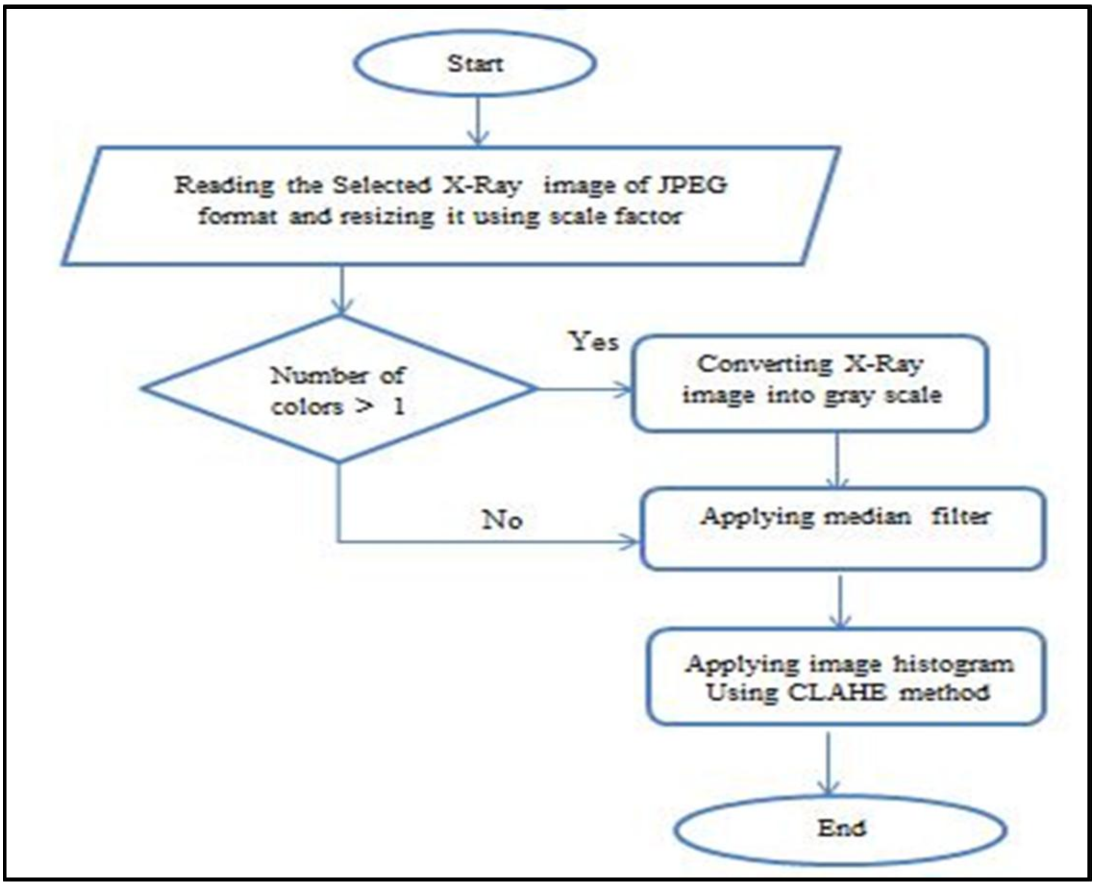


Figure (3): The Dental Enrollment Phase

The preprocessing Phase summarized as the following:

- The input X-Ray image will be preprocessed starting from resizing all the selected X-Ray 's at the same size by scale factor.
- Checking the X-Ray to convert it into gray scale image.
- Apply median filter to filter the image from salt and pepper noise by using "imnoise" function in matlab program, if it exists in the image.

Apply image histogram using CLAHE method Which help to get best results in the features extraction stage. Fig (4) illustrates the preprocessing stage.



Figure(4): Dental Preprocessing Stage

The output result of the previous stage treated as an input for the features extraction stage, to extract the outstanding feature of the specific X-Ray by using PCA algorithm which is used to select a collection of X-Ray images as a training matrix. It would select the prominent traits of each X-Ray in the training matrix, and then eliminate these traits to the strongest one to be the wanted feature after comparing the training matrix with the test X-Ray image to decide which one is the strongest trait to be added to the PCA feature column in the database. PCA algorithm summarized as the following:

- Reading n of 2D images to convert it into 1D images (vector).
- Put them in the training matrix which is contains all the selected X-Ray images vectors as shown in the formula below:

Training matrix= $[x_1, x_2, x_3, \ldots, x_n]$

- Calculating mean value (ḡ) for the training matrix rows as shown in eq (1):

  $\bar{g} = 1/k \sum_{i=0}^{k} x_i$ ....(1)

- Calculating Covariance equation (Cov) depending on the previous results from the formula and eq (1) as shown in the eq (2). Fig (5) illustrates PCA algorithm process.

Cov= $(x_k - \bar{g})(x_k - \bar{g})T$ ....(2)

Each **x** represents an input X-Ray image vector (1D) with **k** length. **n** represent the number of the input X-Ray images. **ḡ** represent the mean value of the training matrix for each row.
K represents the row length of the input vector. **Cov** is the covariance matrix that used to make the dimensions of the training matrix in the above formula symmetrical to use the diagonal as variance of x. **T** is the transpose of the matrix $(x_k - m)$which is made the row as a columns and columns as rows.

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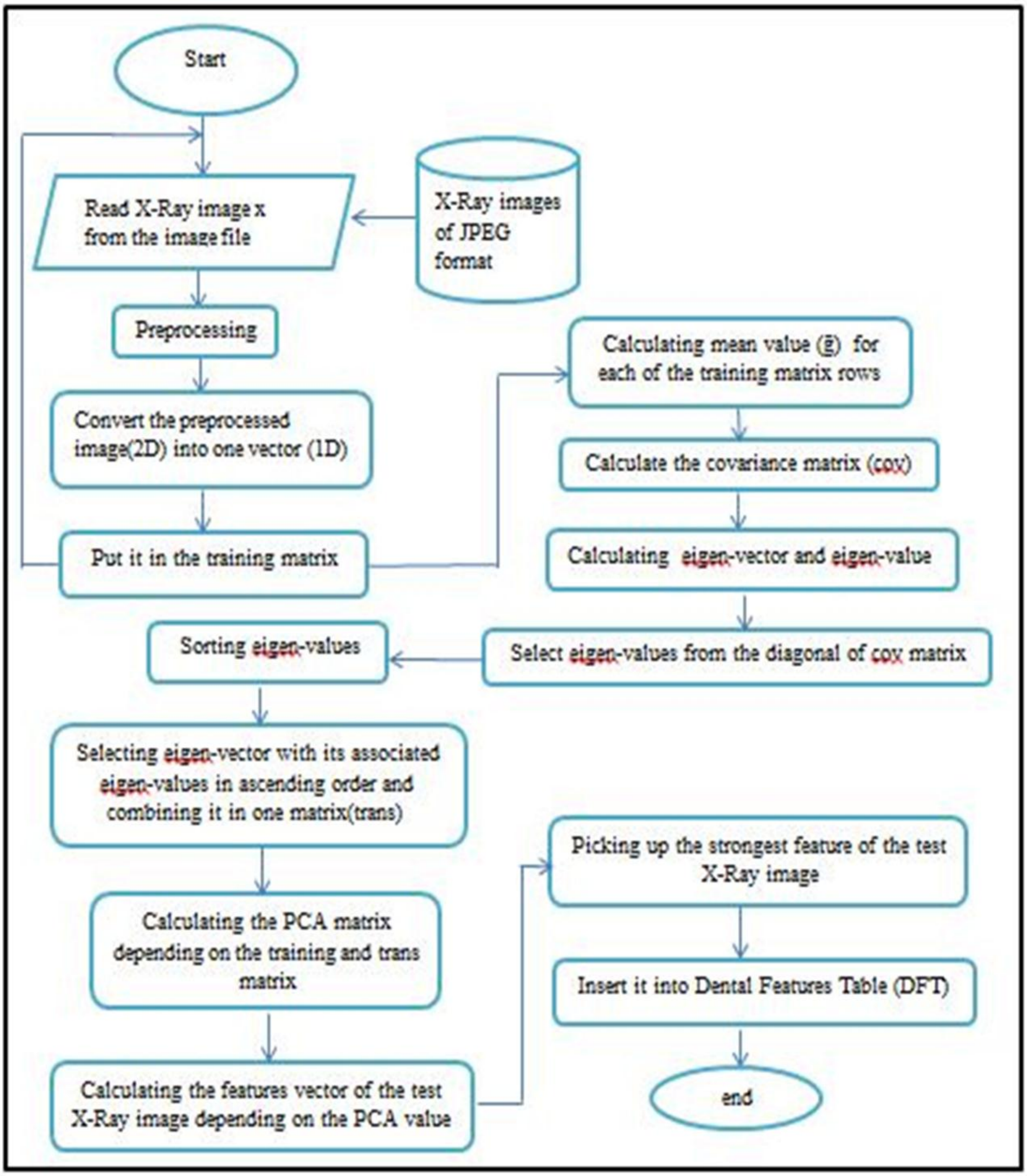

Figure (5): Features Extraction Stage using PCA Algorithm

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ISSN (Print): 2074 – 0204 ISSN (Online): 2521 – 3504

Features extraction stage that depending on the PCA algorithm to extract the prominent feature to insert it into DFT is not the only feature to be extracted, but also there is more such as extracting the mean of the whole X-Ray image as illustrated in eq (1), the variance of the image is also one of these features. The variance defined as the squared difference from the mean as illustrated in eq (3), STD defined as the measure of how spread out pixels numbers are, as shown in eq (4) and the Euclidian distance of the test image is illustrated in eq (5).

$$\boldsymbol{\sigma^2} = \frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{g})^2 \quad \text{………(3)}$$

$$\boldsymbol{\sigma} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{g})^2} \quad \text{………(4)}$$

$$\textbf{Distance} = \frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)^2 \quad \text{………(5)}$$

$\boldsymbol{\sigma^2}$ Represents variance, $\boldsymbol{\sigma}$ represents STD, $\mathbf{X_i}$ displays each pixel value of the image, $\bar{\mathbf{g}}$ represents the mean value, and **N** shows the total number of pixel values. x_i , y_i represents different pixel point in the X-Ray image to give the minimum distance between two outstanding pixels in the image.

DFT was constructed by using Microsoft SQL Server 2008. This table not specified with a specific size which means that the data space of the table is unlimited to a specific size. It contains 10 columns including person-id and age of numeric datatype of size 4 digits, person's name, mother's name and image name of char datatype of size 10 digits, pca value, mean value, variance value, STD value and distance value of float datatype of different sizes according to the image feature using Microsoft SQL Server 2008. These values considered as the features of the dental X-Ray image of each person which are inserted by the user into the DFT as shown in fig (6). Besides the ability of inserting to the table, there are ability of searching, deleting and editing functions. Algorithm (1) shows the way of calculating the test X-Ray other features such as mean, STD, variance, distance.

personid	name	mothersname	imgname	age	pca	mean	variance	STD	dis
1	g	gg	g3	47	16079.3656770...	0.51456747373...	0.07972479503...	0.28235579511...	4.47213595499...
2	a	aa	a1	56	3211.90074716...	0.51865555231...	0.08105294432...	0.28469798791...	84.7230783199...
3	a	aa	a2	56	7407.33959735...	0.64237373739...	0.13620530104...	0.36906002363...	93.2308961664...
4	a	aa	a3	56	18330.7178177...	0.51866754827...	0.08128367452...	0.28510291917...	123.065023463...
5	a	aa	a5	56	3405.69103111...	0.51696001725...	0.08094532944...	0.28450892682...	84.7230783199...
6	l	ll	l1	50	4993.35961957...	0.48010738713...	0.08510322910...	0.29172457747...	4.12310562561...
7	b	bb	b1	21	5245.83994389...	0.51441145114...	0.07728642405...	0.27800435977...	4.12310562561...
8	b	bb	b2	21	38.0803201623...	0.51296262777...	0.07746991979...	0.27833418725...	2
9	b	bb	b3	21	5231.10429058...	0.51550895510...	0.07702292860...	0.27753004991...	3.60555127546...
10	b	bb	b4	21	12172.5545155...	0.55044049690...	0.09934207955...	0.31518578577...	2.23606797749...
11	b	bb	b5	21	5069.22345655...	0.51556931184...	0.07566638005...	0.27507522618...	2.23606797749...
12	d	dd	d5	52	5200.96265744...	0.51769971045...	0.08068258303...	0.28404679726...	6
23	e	ee	e2	41	3333.44503034...	0.52583515054...	0.07568774295...	0.27511405445...	2.23606797749...
19	g	gg	g1	47	4066.57353408...	0.51494023387...	0.07954596312...	0.28203893901...	2
20	g	gg	g2	47	3936.68453426...	0.51405114396...	0.07999990367...	0.28284254219...	2.82842712474...
21	g	gg	g4	47	4076.96921236...	0.51539929365...	0.07969149495...	0.28229682065...	2.23606797749...
22	g	gg	g5	47	4579.83189605...	0.53145727917...	0.08759863476...	0.29597066537...	2.23606797749...
24	e	ee	e3	41	69.3411615477...	0.51759370676...	0.07477849197...	0.27345656322...	3.60555127546...
26	e	ee	e5	41	4043.64346527...	0.52339180243...	0.07698624534...	0.27746395323...	9.05538513813...
25	e	ee	e4	41	3968.99230212...	0.51866999987...	0.07557742977...	0.27491349507...	9.05538513813...
28	d	dd	d2	52	4929.95450410...	0.51548740812...	0.08069091219...	0.28406145848...	3.60555127546...
31				57	13727.8341332...	0.51507805054...	0.08165928394...	0.28576088596...	90
13	a	aa	a4	56	4274.60067008...	0.51512656353...	0.08001568990...	0.28287044721...	85.1645466141...
27	d	dd	d1	52	5195.52427990...	0.51773861028...	0.08060943119...	0.28391800083...	149.013422214...
14	l	ll	l5	50	159.722779996...	0.48010806575...	0.08510297238...	0.29172413748...	4.12310562561...
15	l	ll	l4	50	[illegible]	[illegible]	[illegible]	[illegible]	2.23606797749

Figure (6): Dental Features Table (DFT)

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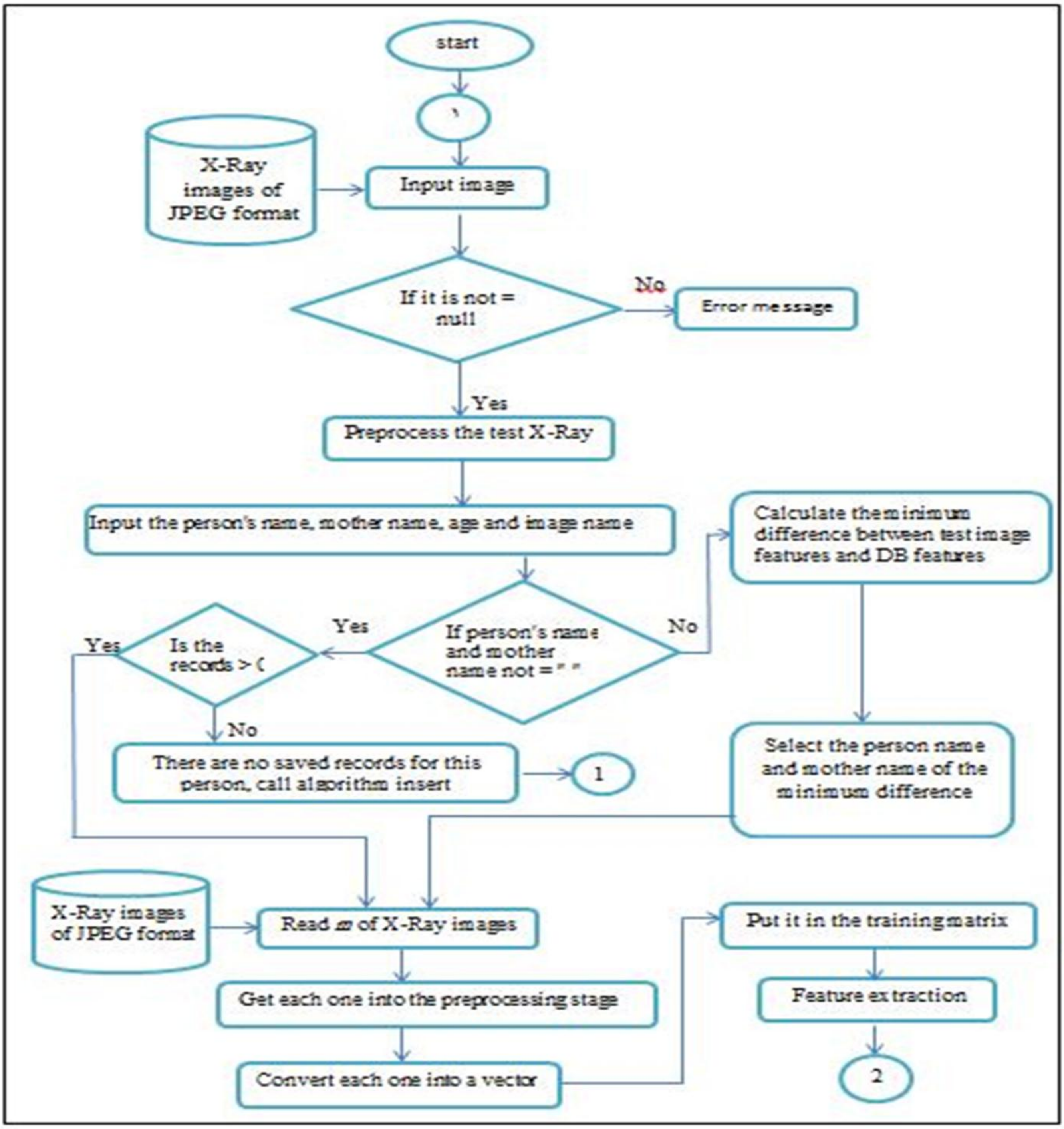
Algorithm (1): Mean, Variance, STD, Distance Features of the Test X-Ray

Input: Read the test X-Ray image from the preprocessing stage
Output: mean, STD, variance, distance

Begin:
Step one: Read X-Ray image from the preprocessing stage
1.1 Read row and column of the image
1.2 Calculate mean value from the equation
Mean = $\sum_{r=0}^{row}\sum_{c=0}^{col} image_{(r,c)} / (row * col)$
Step two: Calculate variance, STD from equations
Var= $\sqrt{\frac{(\sum_{r=0}^{row}\sum_{c=0}^{col} image_{(r,c)} - Mean)^2}{(row * col)}}$
STD= $\sqrt{Var}$
Step three: Detect boundary for each object in the image
3.1 Read each pixel point (x,y) in each boundary
3.2 Calculate the distance (dis) between each point in the disjoint boundary objects (obj1, obj2) from the equation
distance= $\sqrt{(obj_{1x} - obj_{2x})^2 + (obj_{1y} - obj_{2y})^2}$

Select the minimum distance (dis)
Step Four: return Mean, STD, variance, distance
End

After inserting the dental features into the DFT, now continue to the identification stage. Firstly, the system input a test X-Ray image from the X-Ray images database that is containing all the dental X-Ray images of all the persons with all of its cases (original, darken, lighten, noisy and rotated one). And pass through all the stages (preprocessing, features extraction) where the system asked for the person's name and mother's name. Then, reading five X-Rays, preprocessed to get them into the training matrix. checking if there are five records for this person's X-Ray in the DFT, if so, it will bring all the features that belong to that person as average which is bringing all the five rows of the pca value to calculate the average pca value and all the other features of the test image and the training matrix to calculate the minimum distance between the average features of test X-Ray five records and the features of the training matrix. Algorithm (2) displays the dental identification rate calculation, Identification process structure illustrated in fig (7).


start
X-Ray images of JPEG format
Input image
If it is not = null
No
Error message
Yes
Preprocess the test X-Ray
Input the person's name, mother name, age and image name
Calculate the minimum difference between test image features and DB features
Yes
If person's name and mother name not = " "
No
Yes
Is the records > 0
No
There are no saved records for this person, call algorithm insert
1
Select the person name and mother name of the minimum difference
X-Ray images of JPEG format
Read m of X-Ray images
Put it in the training matrix
Get each one into the preprocessing stage
Feature extraction
Convert each one into a vector
2

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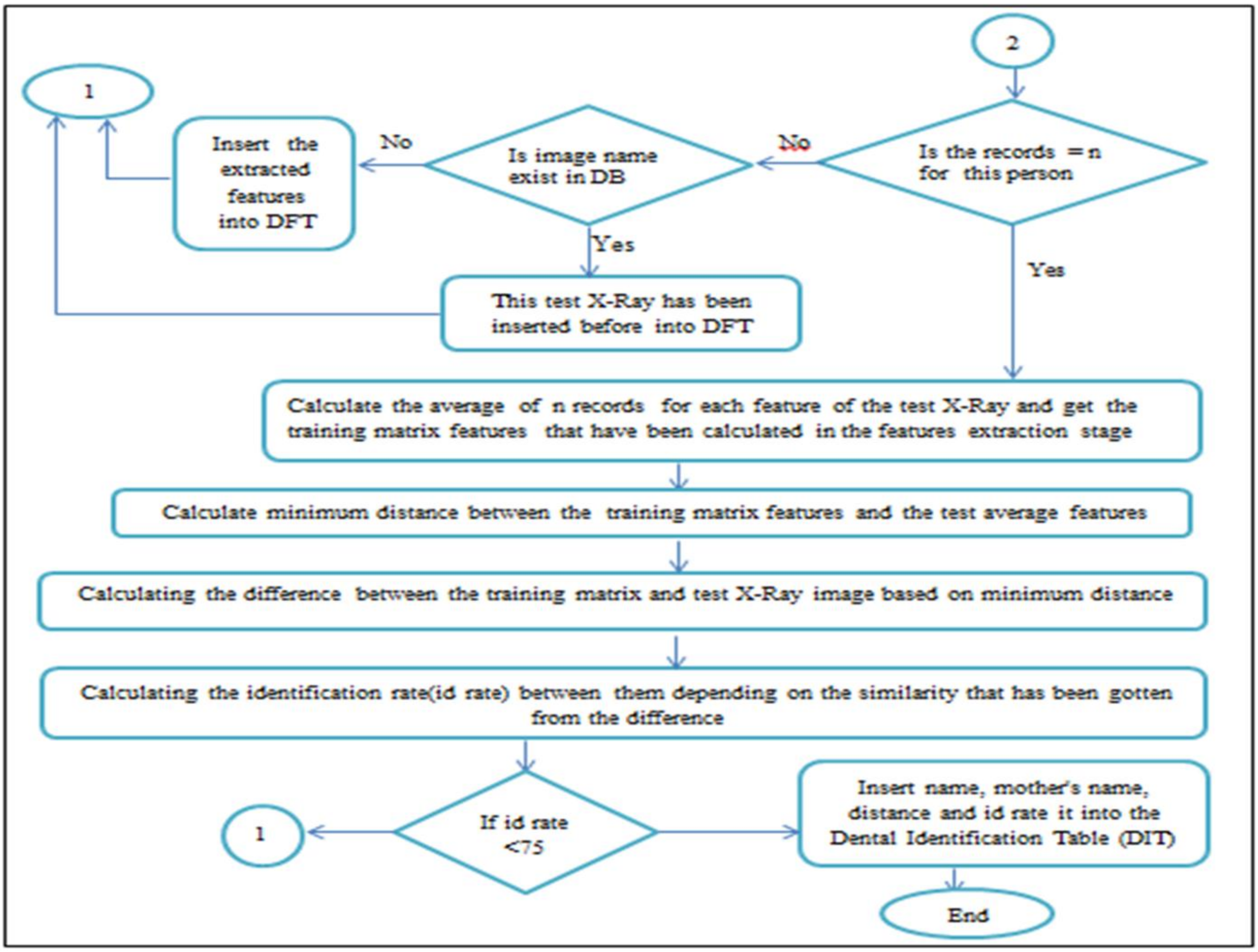

Figure (7): Structure of the Identification Process

Algorithm (2): Dental Identification Rate Calculation

Input: Read test X-Ray image and input person name (name), mother name (mname), age and image name (imgn)

Output: Identification rate

Begin:

Step One: Get the test image into preprocessing stage

Step Two:

2.1 if name and mname not = " "

2.2 calculate the difference (minimum distance) between the test features and each row of the DFT features

For each row (i) do:

$$D=\sqrt{(PCA_i - PCA_{test})^2 + (Mean_i - Mean_{test})^2 + (STD_i - STD_{test})^2 + (var_i - var_{test})^2 + (dis_i - dis_{test})^2}$$

If D < min

Min= D

ii=i

End if

End for

Select person name and mother name of the Min (ii) and go to step 3.2

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Step Three:

3.1 if records > 0

3.2 read m of X-Ray images and get into preprocessing stage

Convert each image into a vector (1D) and put it in the training matrix

Get the training matrix into features extraction stage

3.3 if records = n for the query person

3.3.1 Calculate average of n records for each feature of the test image as Equations:

avgPCAtest= $\sum_{i=1}^{n} pca_i$ / n

avgMeantest= $\sum_{i=1}^{n} mean_i$ / n

avgSTDtest= $\sum_{i=1}^{n} STD_i$ / n

avgvartest= $\sum_{i=1}^{n} var_i$ / n

avgdistest= $\sum_{i=1}^{n} dis_i$ / n

Calculate the training matrix features as equations:

PCAtr= $\sum_{i=1}^{n} pca_i$ / n

Meantr= $\sum_{i=1}^{n} mean_i$ / n

STDtr= $\sum_{i=1}^{n} STD_i$ / n

vartr= $\sum_{i=1}^{n} var_i$ / n

distr= $\sum_{i=1}^{n} dis_i$ / n

Calculate the minimum distance between test and training features As equation:

$$\text{Dis}=\sqrt{(PCA_{tr-}avgPCA_{test})^2+(Mean_{tr}-avgMean_{test})^2+(STD_{tr-}\,avgSTD_{test})^2+(var_{tr-}\,avgvar_{test})^2+(dis_{tr-}\,avgdis_{test})^2}$$

Calculate the length of the integer number in Dis select Num from the formula:

Num = 10, 100, 1000, 10000, 100000

Calculate the difference (Diff) from equation: Diff= Dis / Num

Calculate identification rate (id rate) from equation:

3.3.2 Id rate= 100 – Diff, check if it is less than 75, don't insert it into DIT otherwise insert it into DIT with personal information.

Else if the imgn exist in the DFT, then show a message that it has been previously inserted the features into DFT.

Else show a message that there are no saved records in DFT for this person Insert records by pressing button "insert"

Step Four: return Id rate

End

Discussion of the Results

The preprocessing stage can be considered as a useful tool for enhancing the image because it is taken from radiograph and that may have poor quality therefore it needs to be adjusted in case of image contrast, brightness, removing noise and threshold to show the unclear important features. While, Features extraction is used to extract all the important distinguishable features that make each one unique than the other one. In this paper, the features that have been extracted from the image are mean (ḡ), Principal Component Analysis (PCA), variance, distance and Standard Derivation (STD). Training phase take five images for each person to be processed and extract their features and inserted into the dental features table. Then testing phase compare the extracted feature of the test image with the training phase to give the decision (matched or rejected). There are some measurements that are calculated to evaluate the quality of the image, compare and evaluate the performance of the system. Such measurements are Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). MSE is calculated to give the average of the squared intensity of the original image and the output image pixels as illustrated in eq(6). PSNR is a quality measure that calculated from the difference pixels between two images (original image pixels and the reconstructed image pixels) which is depending on MSE to give the result of PSNR as illustrated in eq (7). Table (1) displays the differences of the MSE and PSNR on different images sizes.

$$\textbf{MSE} = \frac{\sum_{M,N}[I1(m,n)-I2(m,n)]^2}{MXN} \quad \text{.......(6)}$$

$$\textbf{PSNR} = 10\log_{10}\frac{1}{\text{MSE}} \quad \text{........(7)}$$

Table (1): MSE and PSNR on Different Images Sizes

	Original	Processed
Image Size	286 KB	164 KB
Mean	0.7736	0.5187
MSE	0.0650	
PSNR	27.3323	
Image Size	435 KB	164 KB
Mean	0.6652	0.5144
MSE	0.0227	
PSNR	37.8363	
Image Size	269 KB	164 KB
Mean	0.8605	0.5215
MSE	0.1149	
PSNR	21.6362	

These measurements would let us being sure that the preprocessing stage enhances the image or not. The dental model training dataset includes 75 images belong to 15 persons (five for each one of them). The best result displays 89% as an identification rate.

4. Conclusions

The usage biometric measures to identify unknown person would achieve flexibility to the system which means that an identifying him/her from the dental record. The usage of PCA algorithm increased the accuracy of the system because it extracted the most important trait (unique) that is existed in the dental image to distinguish between them. Besides the other extracted feature that helps to accurate the result. It can resist the changes that may be found in the image, so it enhances the image (remove the damage and show the important features) to identify the person even though the image is damaged. The maximum identification rate in dental model is 89%.

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ISSN (Print): 2074 – 0204 ISSN (Online): 2521 – 3504

تحديد الهوية بالاعتماد على صور الاسنان

شيماء حميد شاكر هاجر نجاح عبد الصاحب
الجامعة التكنولوجيا ، قسم علوم الحاسوب

المستخلص :

نظام تحديد الهوية (مطابقة) هو نموذج للتمييز والتصنيف يساعد في تحديد الهوية اعتمادًا على صورة الأسنان السينية الخاصة به / بها. يعرض هذا العمل طريقة جديدة للتعرف على شخص من صور الأشعة السينية التي تستخدم على نطاق واسع في الطب الشرعي ، وتنظيم الحدود ، واختيار الأبوة والأمومة والتحقيقات. الهدف من هذه الورقة هو تصميم نموذج تحديد فعال يعتمد على صورة الهويات السينية للأسنان والتي يمكن أن تكون مفيدة في التعرف على الأفراد المجهولين الذين ماتوا. التقنيات المستخدمة هي معالجة الصور وتتميز بتقنيات الاستخراج التي تمت إضافتها لتحسين الهدف. كانت أفضل نتيجة تم الحصول عليها من نموذج الاشعة السينية للأسنان ٨٩٪ كمعدل لتحديد الهوية.