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Dental X-Ray Based Human Identification System for Forensic

Abstract-*Forensic dentistry is an important branch of the forensic science. It is based on the dental characteristic. This method uses the dental features as a biometric tool to identify persons, who their bodies have been affected badly. In the other meaning, the dental biometrics are considered at the absence of tools, such as, DNA, fingerprint, iris etc. for different reasons. This paper presented a biometric system for forensic human identification based on dental X-ray. The aim of this system is to build a database, which contain ante-mortem dental radiograph features (AM), used later for matching with the post-mortem dental radiograph features (PM). These features are Standard Deviation (STD), Euler number and Area extracted from X-ray image of type bite-wing. The investigated X-Ray image goes through three stages algorithm which are: image segmentation, classification and features extraction. The obtained features represents the records of the system database for each tooth individually in distinct person. The proposed system utilizes the Graphical User Interface (GUI) provided from the Visual Studio with the usage of MATLAB software for feature extraction and the SQL Server 2012 environment for database building. The Achieved results show the outperformance of the proposed system in terms of matching and searching accuracy as well as the finding time. In addition the editing and insertion processes are performed in high accuracy and efficiency.*

Keywords-*Database, Dental biometric, Forensic dentistry, Human identification, MATLAB, SQL Server 2012.*

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1. Introduction

A biometric system uses the reliable technologies to provide an assertive decision about identification or verification purpose. Forensic Odontology (forensic dentistry) uses the dental biometric to identify individuals when other biometric technologies are not practical. Dental biometric is a valuable method that uses the dental radiography to distinguish the victims of a mass disasters and fire accident because the tooth enamel is a stiffer material in the human body. Moreover, the teeth are really opposition to the physical factor. The anatomical location of the teeth makes them more resistant to the septic and combustion factors for a long time (with the exception of the front teeth) which may reach to the 500 degrees Celsius [1]. The dental radiograph composes a distinctive features to each individual which can be considered as a fingerprint that makes the possibility of matching two fingerprint for two individuals is impossible potential [2]. Attention to the forensic dental medicine has begun in America since 1986, when a forensic dentist was appointed by US military at a special center in Hawaii to identify the victims of the army in the war.

2. Related works

In [2], the authors proposed a new system with semi-automatic method for human identification and verification using the dental X-ray which based on dental work information (i.e. crown, filing and bridge). Their method depends on computing the distance and angle between dental works in each record in their database to produce a dental code which is used as a distinctive imprint to each individual .

In 2005, the authors of [3] proposed a system that is based on human identification using the dental bite-wing image. The introduced method segments the dental X-ray into individual tooth and extract the contour of each tooth for retrieval. Additionally, the matching depends on the distance between the signature vector of the PM and AM teeth record. This method cannot correctly pinpoint the segment lines for the poor quality image. Several year later, in 2008 the same authors presented a new technique based on matching teeth contours by using the Hierarchical Chamfer Matching. Based on this technique, they reduced the searching space and increased the robustness of their system [4 .[

In 2008, a framework for forensic human identification based on dental X-ray was presented. This method needs human intervention to select region of interest (ROI). Moreover, the proposed system is incorporated with traditional system with the text-based method (i.e. WinID). This is to use

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one method for pre-filter the database and the other one for refine the result [5].

In [6], 2013, the authors proposed a method for individual identification based on dental features i.e. dental work, dental screw, missing teeth. They used panoramic image with high resolution to ease the segmentation and features extraction process.

This paper presents an efficient system for forensic human identification based on the dental features in terms of accuracy and finding time. The dental radiographs (X-Ray) processed utilizing MATLAB software in a three steps algorithm: image enhancement, image segmentation and features extraction. The obtained features are stored in a database for each tooth of individuals. The average value of each tooth has been considered as a first finding filter to reduce the searching time efficiently. A Graphical User Interface (GUI) has been introduced to ease the use of the system by users. This GUI is built using visual studio C# to connect the database built in SQL server and MATLAB. The results show the efficiency of the proposed system in terms of image processing and database management. This includes the processing on the database information such as, insertion, searching, matching and editing.

3. Dental X-Ray

Dental X-ray is one of the most important diagnostic tools in dentistry which are classified, as shown in Figure (1), into three main types. Firstly**,** Orthopantomogram **(**OPG) provides a panoramic image in which all the teeth appear. Moreover, it was showed the bones of the upper and lower jaws and bones of the nose and sinuses as well as the surrounding bone, such as the bones of the bottom of the eye. This type is not practical for the purposes of forensic cases as it need a special device and a special position. Secondly, Periapical shows the whole tooth from root to the crown only in one jaw (upper or lower jaw). Lastly, the Bite-wing X-rays shows a limited number of teeth from each jaw in one image. Although the Periapical and Bite-wing X-ray need multi image to provide a whole information about all teeth, the resolution it more suitable in forensic cases than an OPG. Moreover, the required machine is possible in forensic use cause it doesn't want a special position from the individual [6,7].

The proposed system automates the process of forensic dentistry by utilizing the bite-wing image to provide a distinctive features to each individual in a database built by SQL server. Microsoft Visual Studio (MSVS) was utilized to design a GUI that allow an ordinary user to deal with the system in a high degree of flexibility.

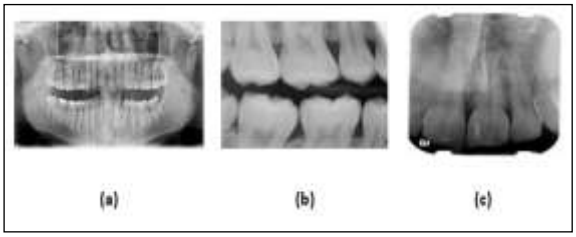


Figure 1: Dental X-Ray type: (a) OPG (Orthopantomogram), (b) Bite-wing X-Ray (c) Periapical X-Ray

4. Proposed System

The presented system deals mainly with the dental X-ray to identify human based on the extracted features. The extracted X-ray image features are saved in a database to retrieval these for matching with the PM dental features. The system includes a set of Bite-wing images from both side of the jaw, which is considered as (AM) image. These AM images are processed using MATLAB in three stages algorithm to allow the designed database receiving them for reusing in matching state. This algorithm can provide the database either dental profile file with full features of each image or the user can enter them manually .

At the other hand, the processing of the data for human identifications in terms of image feature extraction and database management can be summarized in a flowchart as shown in Figure (2).

For the clear explanation, the working steps of the proposed system can be divided into two main parts.

I. Image Processing

At this process, a MATLAB three stages algorithm is considered. These stages are: *Image Enhancement*, *Image Segmentation and Feature Extraction*. Image Enhancement is the first stage, which is an important part of image processing. The output result of this stage is a more suitable image for the applications than the original image. In this stage, the Histogram Equalization is used to equalize the brightness level of the image. In addition, the two step thresholding is employed to convert the gray scale image to binary image. At the beginning, we utilize the Contrast-limited adaptive histogram equalization (CLAHE) and then we used Global image threshold (Otsu's method) so that the output image is a binary image as shown in Figure (3). Moreover, the morphological operation was utilized in this stage.

The second stage of image processing is Image Segmentation. The goal of this stage is to separate the teeth from the background and other tissue. At

this stage horizontal and vertical projection are computed to detect the valley between jaws and teeth that ease the segmentation process. Edge detection was done by using canny algorithm. Canny edge detection provide an excellent result than another algorithm in our system. Canny algorithm works in five separate steps, which are *Smoothing, Finding gradients, Non-maximum suppression, double thresholding* and *Edge tracking by hysteresis*. To detect each teeth in the resulted image, the connected edges are detected by using the 8-connectivity so that each teeth considered as an object which is ready for extract features. Figure (4) shows the segmented teeth.

In the last stage, three traits are extracted from four teeth for each side (eight teeth for each individual as a result) which are: fifth Upper Left, sixth Upper Left, fifth Lower Left, sixth Lower Left, fifth Upper Right, sixth Upper Right, fifth Lower Right and sixth Lower Right. The tooth is numbering by Palmer Notation Method as shown in Figure (5) [8]. The extracted traits are: STD, Euler number and Area of the selected teeth. The STD can be computed by the following equation:

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

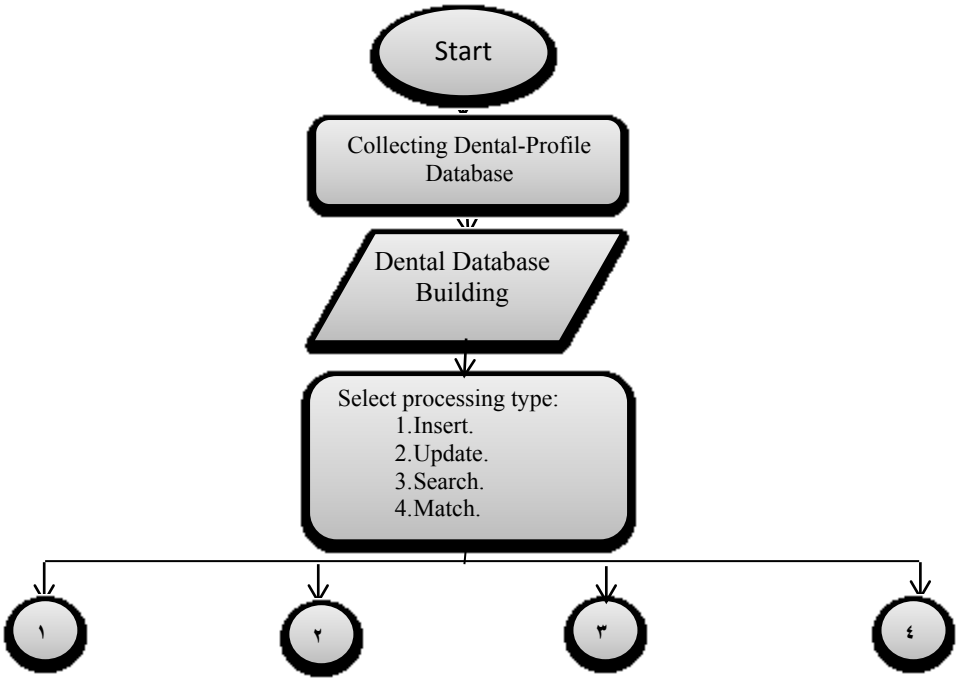
Where the STD = Standard Deviation, I_{rc} = Pixels of object matrix, (r, c) = Denoted to the raw and column, N, M= Dimension of object matrices and m = the arithmetic mean of the data.

While the Euler number is a scalar whose value is the number of objects in the binary image minus the total number of holes in those objects.

$$A_i = N \times \quad (2)$$

Where A_i = the area of the object, i = the object, N, M= Dimension of object matrices.

Now a table of features is ready to be stored in the database.



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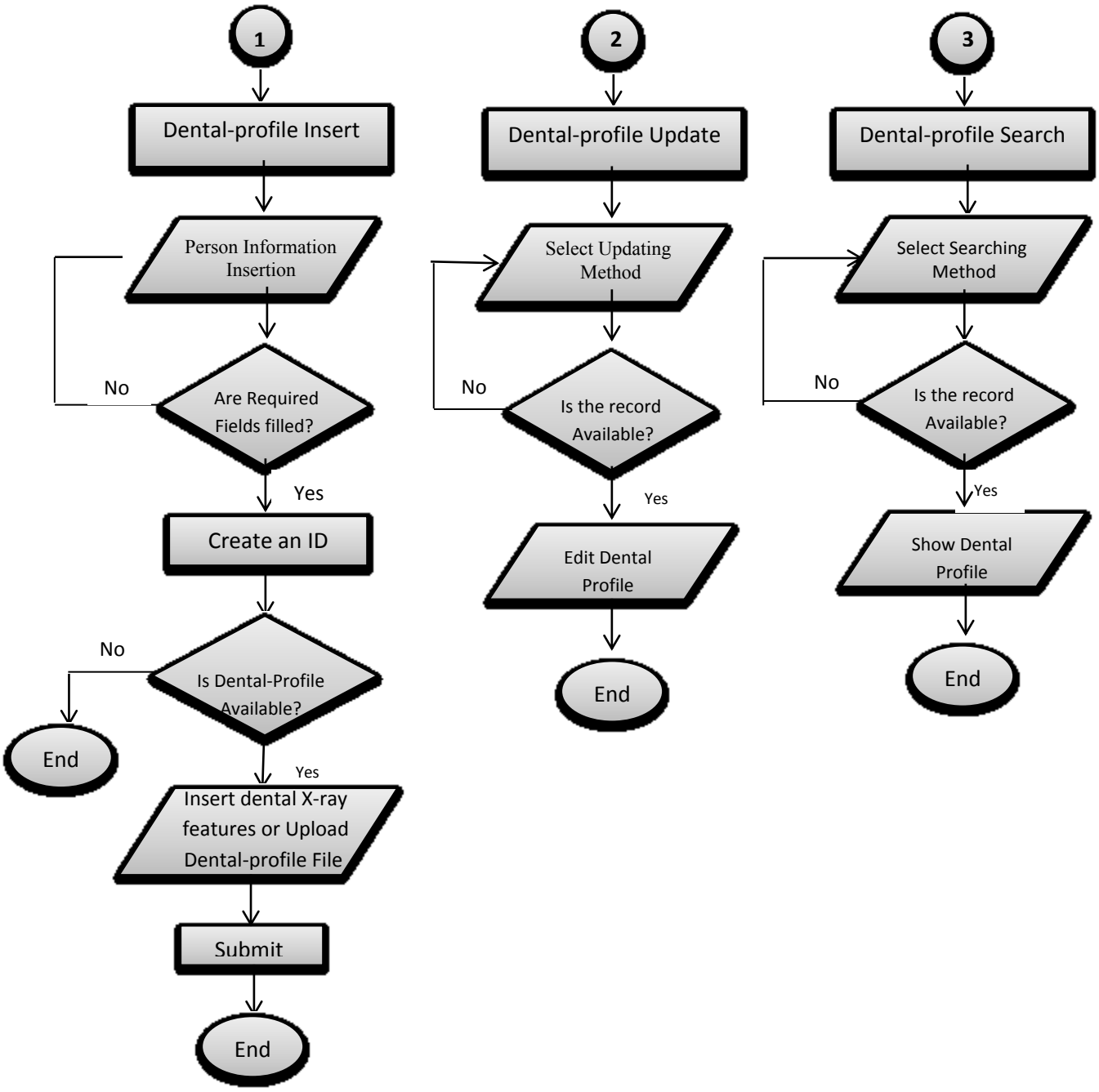

1
Dental-profile Insert
Person Information Insertion
No
Are Required Fields filled?
Yes
Create an ID
No
Is Dental-Profile Available?
End
Yes
Insert dental X-ray features or Upload Dental-profile File
Submit
End
2
Dental-profile Update
Select Updating Method
No
Is the record Available?
Yes
Edit Dental Profile
End
3
Dental-profile Search
Select Searching Method
No
Is the record Available?
Yes
Show Dental Profile
End

(Continued)

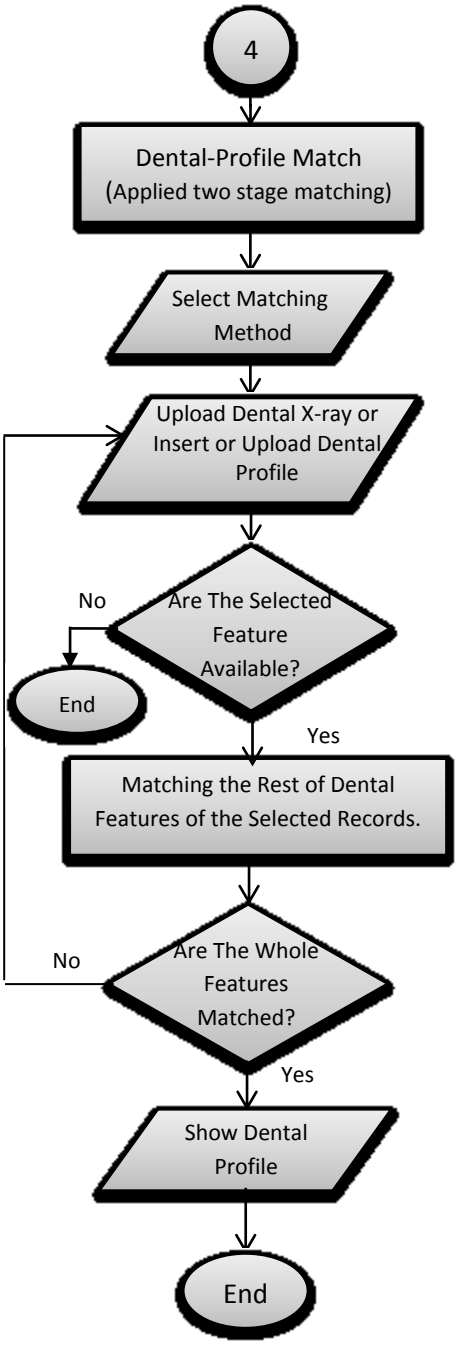


Figure 2: The algorithm of the proposed system

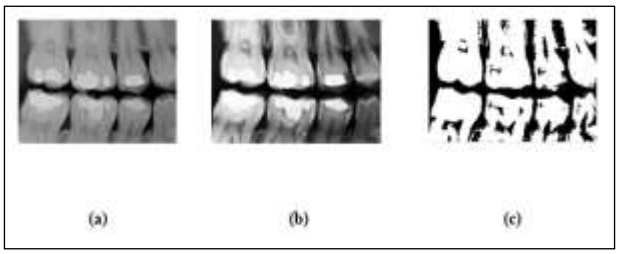


Figure 3: Dental X-ray type: (a) Original Image; (b) Equalized Image; (c) Binary Image.

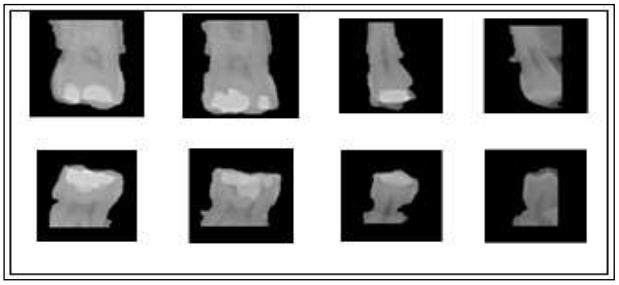


Figure 4: Segmented Teeth

II. Human Identification Process

After the features are extracted from the selective teeth, they are stored in the database. As mentioned above, the database was built using a SQL Server Management Studio (SSMS). SSMS supply the server with an integrated environment for managing all SQL Server components in a practical and ease manner [9,10,11]. The database involves two tables. The first one composes the personal information and is called "IndividualInfo". The second table composes the dental profile (i.e. dental features) and is called "indivDENTALprofile".

The "IndividualInfo" table allows the investigator to hold more information about the individual such as full name, mother name, education degree, career, work place, address as well as a profile picture as shown in the Figure (6). Whereas the "indivDENTALprofile" table includes 32 columns; the dental features for the selective teeth for the each side of jaw as shown in Figure (7). Each row is dedicated to one person**.** It is important to note that the Figure (5 and 6) show a sample of the whole table due to the limit size of the screen. There is a shared column between these tables which is ID column. The ID column composes an identity and unique number to each individual in the database.

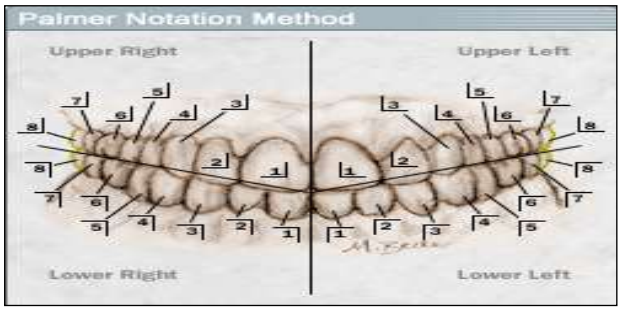
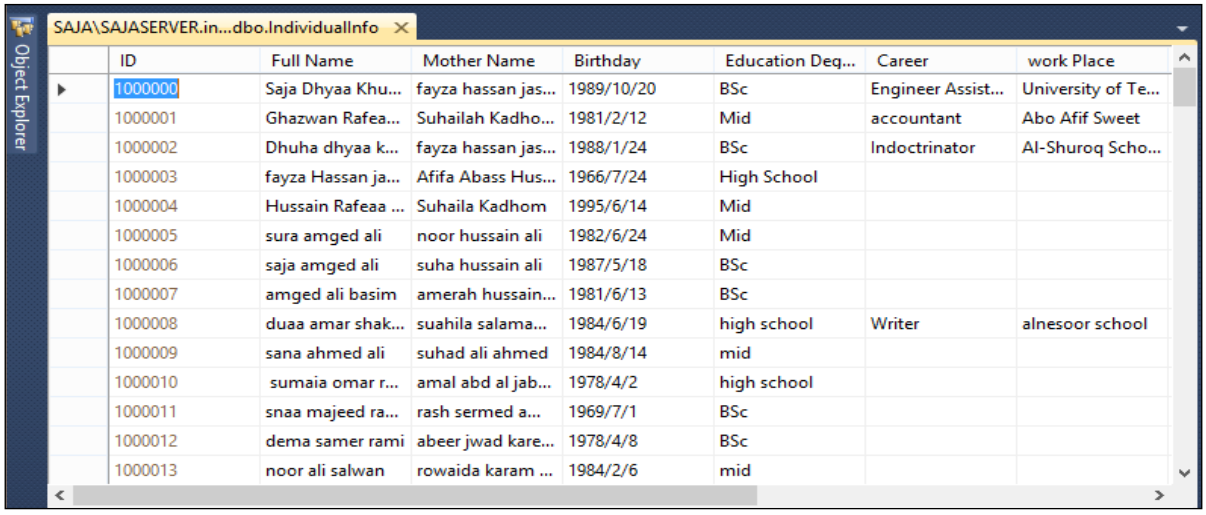


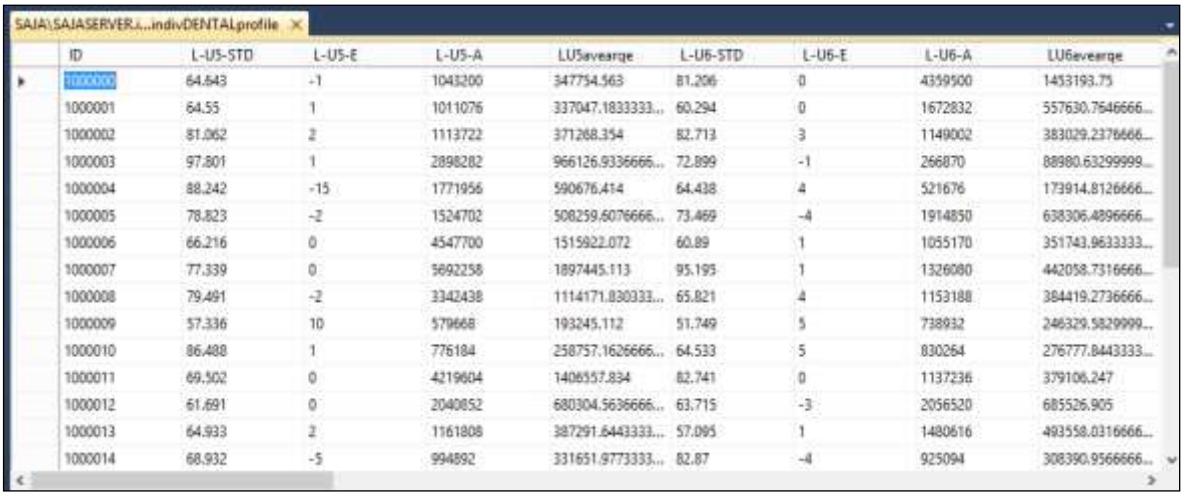
Figure 5: Palmer Notation numbering system [8]



SAJA\SAJASERVER.in...dbo.IndividualInfo

ID	Full Name	Mother Name	Birthday	Education Deg...	Career	work Place
1000000	Saja Dhyaa Khu...	fayza hassan jas...	1989/10/20	BSc	Engineer Assist...	University of Te...
1000001	Ghazwan Rafea...	Suhailah Kadho...	1981/2/12	Mid	accountant	Abo Afif Sweet
1000002	Dhuha dhyaa k...	fayza hassan jas...	1988/1/24	BSc	Indoctrinator	Al-Shuroq Scho...
1000003	fayza Hassan ja...	Afifa Abass Hus...	1966/7/24	High School		
1000004	Hussain Rafeaa ...	Suhaila Kadhom	1995/6/14	Mid		
1000005	sura amged ali	noor hussain ali	1982/6/24	Mid		
1000006	saja amged ali	suha hussain ali	1987/5/18	BSc		
1000007	amged ali basim	amerah hussain...	1981/6/13	BSc		
1000008	duaa amar shak...	suahila salama...	1984/6/19	high school	Writer	alnesoor school
1000009	sana ahmed ali	suhad ali ahmed	1984/8/14	mid		
1000010	sumaia omar r...	amal abd al jab...	1978/4/2	high school		
1000011	snaa majeed ra...	rash sermed a...	1969/7/1	BSc		
1000012	dema samer rami	abeer jwad kare...	1978/4/8	BSc		
1000013	noor ali salwan	rowaida karam ...	1984/2/6	mid		

Figure 6: Individual Info table



SAJA\SAJASERVER.i...indivDENTALprofile

ID	L-U5-STD	L-U5-E	L-U5-A	LU5avearge	L-U6-STD	L-U6-E	L-U6-A	LU6avearge
1000000	64.643	-1	1043200	347754.563	81.206	0	4359500	1453193.75
1000001	64.55	1	1011076	337047.1833333...	60.294	0	1672832	557630.7646666...
1000002	81.062	2	1113722	371268.354	82.713	3	1149002	383029.2376666...
1000003	97.801	1	2898282	966126.9336666...	72.899	-1	266870	88980.63299999...
1000004	88.242	-15	1771956	590676.414	64.438	4	521676	173914.8126666...
1000005	78.823	-2	1524702	508259.6076666...	73.469	-4	1914850	638306.4896666...
1000006	66.216	0	4547700	1515922.072	60.89	1	1055170	351743.9633333...
1000007	77.339	0	5692258	1897445.113	95.195	1	1326080	442058.7316666...
1000008	79.491	-2	3342438	1114171.830333...	65.821	4	1153188	384419.2736666...
1000009	57.336	10	579668	193245.112	51.749	5	738932	246329.5829999...
1000010	86.488	1	776184	258757.1626666...	64.533	5	830264	276777.8443333...
1000011	69.502	0	4219604	1406557.834	82.741	0	1137236	379106.247
1000012	61.691	0	2040852	680304.5636666...	63.715	-3	2056520	685526.905
1000013	64.933	2	1161808	387291.6443333...	57.095	1	1480616	493558.0316666...
1000014	68.932	-5	994892	331651.9773333...	82.87	-4	925094	308390.9566666...

Figure 7: indiv DENTAL profile table

In the database process, four main operation are utilized to ease the using of the proposed system for ordinary users. These operation are:

a) Inserting: At this operation, a new record for a new individual is added to the Individual Info table. An individual ID number is generated for the inserted record. This ID is used to allocate a dental profile to the related information in the indiv DENTAL profile table, which contains the dental features for that individual. All fields with (*) mark must be filled.

b) Update: The updating of the existing record is performed here. The finding of the required record is achieved by using the ID, Full Name or Mother Name searching. The rewriting of any field in the desired record is carried out with ease manner.

c) Searching: The searching of a desired profile is done here. As the updating operation the following fields which are ID, Full Name or Mother Name can be used.

d) Matching: The most important operation in the proposed system can be achieved here. At this operation the dental features for the unknown person is inserted to get the records which has a matching rate equal or greater than the matching proportion that dedicated by the entry user. The matching process has two stage which are: Filtering and Finding. At the first stage all records that has a similarity proportion with the average of features (the average of all the features mentioned previously of each tooth) of all the selective teeth are filtered to be used in the next stage. As a result of this stage, the system resources are utilized in an efficient manner with the decreases of the time consuming. Now the filtered records are entered to the Finding stage. At this stage, the record that have a similarity percentage that required by the entry user is the one who nominates.

5. GUI Design

The system interfaces are accomplished utilizing the VS environment which provides an attractive and flexible interfaces. This allows the ordinary users to deal easily with the proposed system and without need to a prior knowledge. The home page of the system comprises four main buttons as shown in the Figure (8) which are clearly explained bellow.

I. Dental profile Insert

This is the insertion operation (mentioned early). By clicking on this button all fields about the personal information will appear as shown in Figure (9).

As mentioned previously in the insertion operation, at least all fields with (*) must fill to activate the "Create an ID" button, which in turn generate a unique ID to the Individual. These information filled will be considered as a new record in the Individual Info table.

Later the dental features can fill the corresponding fields by one of several ways. These are inserting a dental features manually, uploading a dental features and uploading a dental X-ray that is then forwarded to the MATLAP program to extract features from it. Finally, the user must click on the "Submit" button to add the dental profile to the indiv DENTAL profile table and as the result, the whole profile of the individual is completed.

Figure 8: Dental Profile Database Form

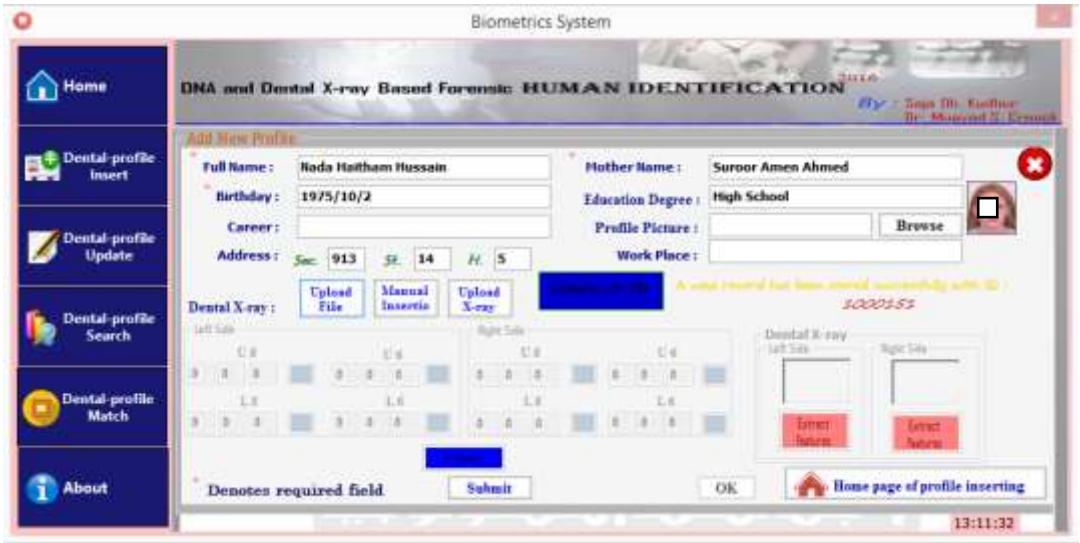


Figure 9: New Record Insertion

II. Dental Profile Update

This is for the updating operation which is mentioned above. When the user click on it, Dental profile Update form will appear as shown in Figure (10). Now user can utilize the ID number, Full Name or Mother Name of the desired profile to update any field in it with ease.

III. Dental Profile Search

The searching operation is done as the same manner as the updating operation when clicking on this button as shown in Figure (11). Print the profile, save profile as a PDF file and get a screen capture of it is the outcome of this operation**.**

IV. Dental Profile Match

Here, the matching process is performed. This process starts with the first stage as mentioned previously in the proposed algorithm section, which is filtering stage. In this stage all records are searched in order to select the similar ones. Then all the candidate profiles are forwarded to the next stage that inspects for the profile that have a similarity percentage asymptotic to the matching rate dedicated by the user. As a result, the time consuming and system resources are minimized with a probability of error equal to 5.2%. Figure (12) shows the matching process to the query dental X-ray for unknown person with matching rate equal to 70%.

Moreover, another buttons in the home page which are: "Home" and "About" buttons. This is to return back the user to the home page of the system and the other to provide the user a highlighted information about the system, sequentially.

Figure 10: Dental-Profile Update.

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Figure 11: Dental-Profile Search

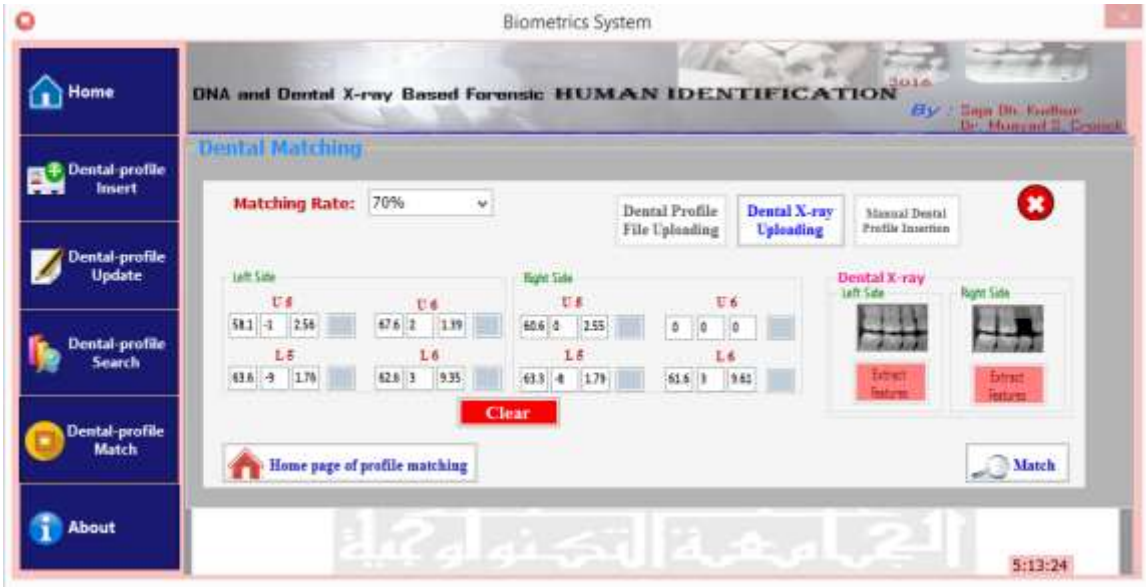


Figure 12: Dental-Profile Match

6. Results

The performance of the proposed system was evaluated for Image processing and human identification process. At the Image processing stage the proposed algorithm applied to the 80 bite-wing images some of them have a missing tooth. It always correctly enhancing the image, segmenting teeth from other and background, extracting features from the selective teeth and detecting the missing tooth. Table (1) shows a sample of features which are extracted from four AM dental image for four teeth in both left and right sides. These features are saved in the database to be used for the human identification propose.

It is important to note that the process explained in section 3 and Figures (3 and 4) has been adopted in feature extraction of the inserted dental X-ray images. After segmentation, the features of *STD, Euler number and Area* have been inserted to the database for each tooth individually. Then, the features of whole teeth for the same person are collected.

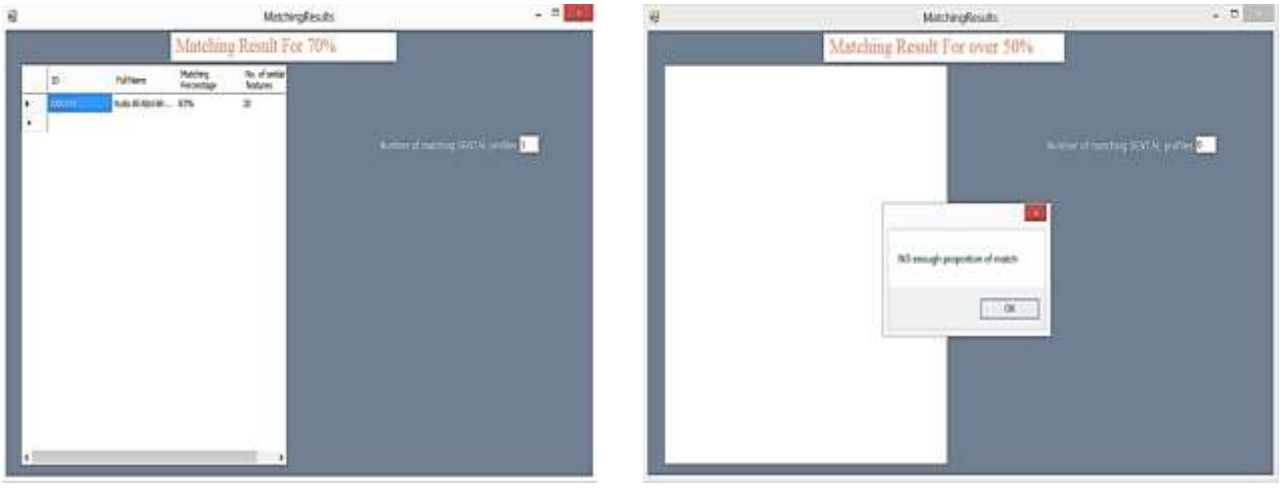
On the other hand, the extracted features are exported from MATLAB in different file types, such as Microsoft Excel and data.

Table 1: Bite-wing Features

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

	66.19956912	-2	649200	94.51665713	-2	4103976

At the human identification process, the matching algorithm of the system are tested on a set of bite-wing dental X-ray images. Some of these images with their features are saved in the database and other are not saved. The matching process starts with entering the dental X-ray of the investigated individual as shown in Figure (12). Figure (13,a) shows the output of the matching process when the features of the query PM image are found for an individual existed in the database. On the other hand, Figure (13,b) shows the results of the matching algorithm when the results come out with no matching. Moreover, the inserting, updating and searching processes are tested and the outcomes of these processes shows high accuracy and searching efficiency. Figure (14) and (15) shows the results of the updating and searching processes sequentially.



(a) **(b)**

Figure 13: Output of matching process (a) When the features for an existence individual; (b) When the features for non-existence individual

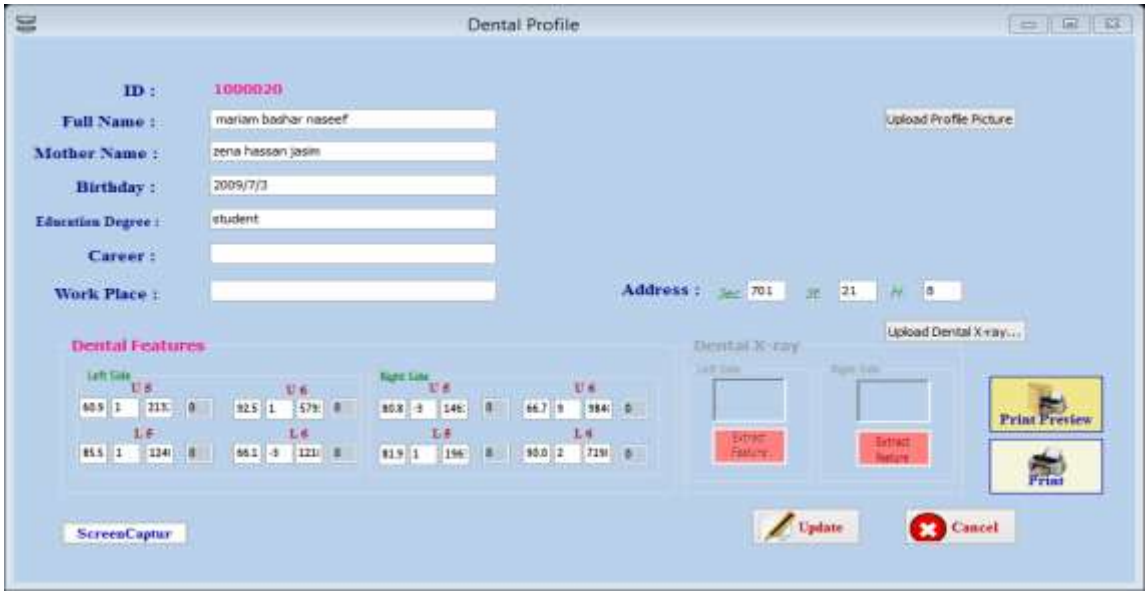


Figure 14: Output of Update process

Figure 15: Output of Searching process

7. Conclusions

In this paper we proposed a system that automated the human identification based on dental X-ray. It included a features extraction method for separation teeth and a complete database system with full actions, such as matching, searching, editing and insertion. In addition, bite-wing dental X-ray image was utilized due to high resolution in comparison with other types. The obtained features have been saved in the database built by the SQL Server platform. The query PM features are compared with the AM features by calculating the differences between them. The minimum difference is selected to be the best match. The performance of the system was evaluated in terms of capacity, accuracy and time complexity using different dental X-ray image samples. The outcome shows the outperformance and efficiency of the proposed system in the human identification. The GUI of the system was built by the Visual Studio environment that allow the ordinary user to deal with the whole system with ease and without needing any knowledge about the mechanism. At the end, the dental biometrics is the reliable technology in forensic cases because the teeth have a distinctive features that make them as imprint to each individual.

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