HYBRIDIZATION AND MODIFICATION OF THE PSO ALGORITHM AND ITS USE IN PERSONAL RECOGNITION BY OPG X-RAY

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Abstract

This research presents a new method in recognition based on panoramic dental radiography (OPG) image processing using one of the pattern recognition methods and artificial intelligence algorithm by which one can recognize the radiograph of upper teeth, lower teeth, and jaws so that allowing recognition of the unknown person. This artificial intelligence algorithm is called Particle swarm algorithm (PSO) and is applied after multi-staged image processing including the use of morphological methods. Because the jaw bones and teeth are considered strong and resistant parts of the body that can withstand the environmental factors usually without deformation, we can obtain clear informative radiographs each time the radiograph is taken. This algorithm worked well in dental and personal recognitions when used to recognize 150 patient radiographs. Also, it worked well in identifying teeth in cases of teeth extractions, fillings, or dental implant (25 patients included here). In addition, the algorithm succeeded in using the teeth as one of biometric methods in pattern recognition (% 98 success rates within only 30 seconds for every search using MATLABR 2016a).

Keywords: AHE, AI, Methods, Morphological, OPG, Pre-processing, PSO, Unsharp mask
1. Introduction
The personal recognition systems became very important in the last decades especially with the dramatic increase in the number of the victims of wars, natural disasters, and criminal and terrorist attacks. In the past, the recognition process was done through the visual personal method depending on the experience of the forensic doctor or dentist. There is a wide variety of person recognition systems that have been used in government institutions in addition to investigation bureaus and crime detection aids [1]. Our personal recognition system depends on the biometric records obtained from dental radiograph images and it is ideal in dead or alive personal recognition.

The biometric recognition refers to the automatic personal recognition using physiologic or behavioural features. It is possible by using the biometrics to identify personal identity on the basis of (who he is?) Instead of (what he has?). In the old ages they used the body features like the face and sound tone for recognition purposes .while fingerprints used in the late 19th century by making a data base from the collected criminals’ fingerprints so it can be compared to the fingerprints of the suspect persons . Also, the different biometric measurements have been used in many fields like security, identity determination and forensic medicine [2].

The personal recognition was considered as a difficult mission, so the experts used many technologies and a lot of algorithms for this purpose. It has been found that the biometric methods are the best by using the physiologic of behavioural features like fingerprints and signatures. These methods are very useful in facilitating access to the institutions, their computer systems and the mathematical and financial information related to these institutions .also they can be used in trading and social communications on internet. In fact, the use of personal recognition system gives the best chance for checking the personal identity and security of the work in general.

Choosing certain personal recognition method over other methods depends on the level of security hazards and importance of the thing we want to protect or the purpose from the recognition process itself. X-Rays use radiation to take pictures of bones and other parts inside the body [1].

An OPG (panoramic dental radiography) is a panoramic X-ray of the upper and lower jaws, including the teeth as shown in Fig. 1. The OPG unit machine is specifically designed to rotate around the patient’s head during the scan. An OPG will take approximately 20 seconds [3]. On the other hand, this paper, when compared to other studies in [4-7], used one of the artificial intelligence algorithms utilizing a meta-heuristic algorithm technology under the name of Particle swarm algorithm (PSO). The first step was the pre-processing of the OPG images then the PSO applied to the pre-processed OPG to obtain an excellent recognition ratio in a short time.

The rest of this paper is outlined as follows: Section 2 contains related works, Section 3 is medical background, Section 4 presents the proposed algorithm and system description, Section 5 presents the performance evaluation methods, the results and discussion are given in Section 6, conclusions are given in Section 7, and finally, the acknowledgement.
2. Related Works

Nomir and Abdel-Mottaleb [4] proposed a system of human recognition using the dental X-ray of type bite-wing image. The method divides the bite-wing image into individual teeth and extracts the contour of each tooth for retrieval then matching depends on the distance between the signature vector of the ante-mortem (AM) and the post-mortem (PM) teeth record. Fares and Feghali [5] proposed a method for individual recognition based on dental features. The authors used X-ray panoramic image with high resolution to ease the segmentation and features extraction process. Their method presents an efficient system for forensic human recognition based on the dental features in terms of accuracy and finding time. Khudhur and Croock [6] presented a biometric system for forensic human recognition based on dental X-ray image of type bite-wing by building a database which contains ante-mortem dental X-ray features (AM) and used for matching with the post-mortem dental X-ray features (pm). Tuan et al. [7] presented a method based solely on the dentist’s own experience. Dental diagnosis from X-ray images is proposed to support the dentists in their decision making. This paper presents an application of consultant system for dental diagnosis from X-ray images based on fuzzy rule.

3. Medical Background

3.1. An OPG can be used to look for [3, 8]:
- Fractures
- Dislocated jaw
- Infection
- Dentition (teeth)
- It can also be used for surgical planning.
- Screening for diseases in the face and mouth
- Dental decay, abscess, and gingival diseases.
- Screening for osteoporosis.

3.2. An OPG can be used to look for [3, 8]:
- Painless
- No radiation is left in your body after the OPG is finished.
- Evaluation of the upper and lower jaws in one film.
- Faster that intraoral periodical screening.
• Used in patient education and revealing diseases in the jaw bones and teeth.
• Less radiation than traditional full mouth intraoral radiography.
• Simple to perform [3, 8].

3.3. Disadvantages

• Image quality like magnification, geometric distortion, and poor definition.
• Teeth overlapping.
• Distortion of image that sometimes resulting in seeing structures in a larger than the actual size [2].

There are many kinds of biometric measurements that have been used for personal recognition like those utilizing HD cameras in detecting fingerprints, eye prints, faces, etc. But these methods have many limitations like the need for more than one camera or many views to obtain the necessary information. Also, it is necessary for the camera to be of high degree of definition and precision even with the bad environmental conditions that may be present in the area. In addition, it needs sufficient personal information or photos because the person to be identified can be standing in an inappropriate position or away from the camera [2].

The ordinary biometric systems also may suffer from some limitations like [2]:
• Noise: like rain sound regarding sound recognition systems.
• The personal data for each person in the database may differ from the data obtained in the recognition process thus affecting the negative recognition results, e.g., differences in the recording machines or change in the personal manipulation of these machines.
• There may be a high degree of similarity in the biometric features between different persons.
• Some persons may lose parts of their biometric features like fading fingerprints in persons dealing with some cleaning solutions, elderly persons or those who suffer from skin diseases.
• The biometric personal recognition machine also is subjected to the attacks of hackers or to the addition of fake data like artificial fingerprints.

In spite of the complicated nature of determining the biometric features of teeth in comparison with other features (because dental features change continuously via losing teeth or changing their appearance as a result of filling, disease or accident which decrease the reliability and credibility of this type of recognition) [9] but using OPG examination steadily aids us in identifying any change that can happen between examinations [6].

4. System Description

In the personal recognition systems, the image of the subject is compared with a group of images that belongs to persons whose information are stored in the database, these images in the database are collected by passing through the stage of recording information and taking the CBCT radiograph. Here the recognition system makes an improved search till it reaches the same image then it reveals the stored personal information of the identified person according to the user’s command. The mode of action of this system can be summarized in Fig. 2.

Each step can be explained as follows:
**4.1. OPG Pre-processing**

Many steps are included in the OPG images processing of both the database (The database contains information for a number of people, such as name, age, gender, address and their OPG X-rays) and the person needed to be identified as in Table 1.

<table>
<thead>
<tr>
<th>Name</th>
<th>Age</th>
<th>Sex</th>
<th>Country</th>
<th>OPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMER</td>
<td>33</td>
<td>Male</td>
<td>Iraq</td>
<td><img src="image1.jpg" alt="OPG Image" /></td>
</tr>
<tr>
<td>NOFAL</td>
<td>25</td>
<td>Male</td>
<td>Iraq</td>
<td><img src="image2.jpg" alt="OPG Image" /></td>
</tr>
<tr>
<td>BASIM</td>
<td>22</td>
<td>Male</td>
<td>Iraq</td>
<td><img src="image3.jpg" alt="OPG Image" /></td>
</tr>
<tr>
<td>NADA</td>
<td>40</td>
<td>Female</td>
<td>Iraq</td>
<td><img src="image4.jpg" alt="OPG Image" /></td>
</tr>
<tr>
<td>SUHA</td>
<td>20</td>
<td>Female</td>
<td>Iraq</td>
<td><img src="image5.jpg" alt="OPG Image" /></td>
</tr>
</tbody>
</table>

These important steps aid in improving the quality of the radiographs and make the recognition process easier. The details of these steps can be explained in the following points:

- **Data collection:** where OPG radiographs for a group of persons (125 images) were taken, collected and saved as jpg images. Also taking another OPGs for the same persons (25 images) after making certain changes on their teeth like fillings, implant and dental extractions, etc. as shown in Table 2.

- **The stored images are converted to grey images in order to decrease its size.**

- **The variation in the image is then improved by using AHE (Adaptive Histogram Equalization) image processing technology for re-distributing colours and lighting values in the image. This method is used to improve the internal colour variation, borders recognition and clarity in every part of the image [10]. This is because of the use of the traditional histogram algorithm that causes a lot of data losses. The AHE algorithm is very simple where every light pixel is classified according to its light intensity level as compared to the adjacent pixel (intensity values), then the new value of this light pixel is determined according to the...
feasible light intensity in a determined space that corresponds to its rank according to the following algorithm [11]:

1. For (X,Y) in OPG image:
2. { Rank=0;  
3. For each (i,j) in the region of pixel (x,y) do  
4. { OPG image (x,y)>image(I,j) then:  
5. Rank= Rank+1;  
6. Output (x, y) = (Rank * max - intensity) / (number of pixels in the region)
7. }}.

Table 2. The panoramic X-rays after and before the changes of dental treatment.

<table>
<thead>
<tr>
<th>Dental treatment</th>
<th>The panoramic X-rays before the changes of dental treatment</th>
<th>The panoramic X-rays after the changes of dental treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implant</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td>Filling</td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td>Extraction</td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>Filling</td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
</tr>
<tr>
<td>Filling</td>
<td><img src="image9" alt="Image" /></td>
<td><img src="image10" alt="Image" /></td>
</tr>
</tbody>
</table>

- Using one of the morphological features in the radiography image processing (Erosion feature) [12]:

\[ A \ominus B = A - b = \{z: (B+z) \subseteq A\} \]

where: \( \Theta \): Erosion is morphological method, and it means that small objects are eliminated so that only significant objects remain, thus the resulting pixel value is the lowest value of all pixels in the area. \( A \): any grey scale shape, \( B \): symmetric structuring element, \( z \): a vector, the equation refers to the erosion of \( A \) by \( B \) is the set of all points \( b \) such that \( B \), translated by \( b \), is contain \( A \).

- Improving the image by using image reconstruction which is one of the morphological algorithms where image re-building is done, and colour variation is improved. The variation is calculated from the source image and converted to mask or observer and generally the details of the variation is changed for the benefit of needed features e.g., focusing on certain areas and magnifying it with neglecting the unimportant features [13].

- In the next step we change the size of the input images by resizing all images to [200*300] pixels to obtain the largest possible amount of the image’s data.
Then we get rid of the unimportant parts of the jaw and face bones by cutting them with preserving the useful parts.

In the next stage the image is improved by sharpening its borders. This method aims at focusing light on the fine details and removing the darkness from the digital image with improving border lightning [14] and this is done by many methods like using unsharp mask to allow high frequency signals.

The image size is then affixed to the size of [100*100] pixels.

The image is converted from 2-dimensional array to 1-dimensional array [1*10000] pixels.

After finishing all these steps, we start with the recognition process of the pre-processed images, note Fig. 3:

**Fig. 3. Pre-processed image for the patient A’s X-ray.**

These steps can be summarized as shown in Fig. 4:

**Fig. 4. OPG pre-processing.**
4.2. PSO Algorithm

It is an AI technology used for scanning the search space of certain problems and simulating swarm intelligence at their habits that has a positive effect on their life like particle swarms or fish swarms. This method has been modified in 1995 by Eberhart and Kennedy and used by many applications for solving different problems. In the animal communities that does not rely on the presence of a leader and live in the nature as a swarm they usually find their food randomly and they every time follow the member who has the best opportunity to search the food. this is accomplished by the reactions and the communication through performing certain movements or dancing or even certain voices and creating odours. These methods all tell the swarm about the chance for getting food, so all members move toward it. this process is done repeatedly until they reach the best circumstances or find the food [15]. The traditional algorithm is summarized as follows [16]:

1. \( V_{max} \), which is the maximum velocity, restricts \( V_i(t) \) within the interval \([-V_{max}, V_{max}]\).
2. \( \alpha \) inertial weight factor is denoted as: \( \epsilon \).
3. Two uniformly distributed random numbers: \( \alpha_1, \alpha_2 \) which respectively determine influence of \( p(t) \) and \( g(t) \) on the velocity update formula.
4. Two constant multiplier terms self-confidence: \( S_1 \) and swarm confidence: \( S_2 \).

\[
V_{id}(t+1) = \epsilon \cdot V_{id}(t) + S_1 \cdot \alpha_1 \cdot (p_{id}(t) - x_{id}(t)) + S_2 \cdot \alpha_2 \cdot (g_{id}(t) - x_{id}(t)) \tag{1}
\]

\[
x_{id}(t+1) = x_{id}(t) + V_{id}(t+1) \tag{2}
\]

where: \( \epsilon \): inertia factor, \( S_1 \): self-confidence, \( S_2 \): swarm confidence, \( \alpha_1, \alpha_2 \): uniformly distributed random number in \([0,1]\) interval . The algorithm will be as following code [17]:

The input: - initialized position randomly of the practices: \( P_i(0) \) and velocity \( V_i(0) \).

The output: - the position of the global optima \( x^* \).

\( F(x_i) \) \( = \) fitness.

Begin

Repeat while max iteration is not reached do

Begin

For \( i = 1 \) to number of particles

IF \( F(x_i) < F(x_{new}) \) then

\( x_i = x_{new} \);

Update \( V_i \): using Eqs. (1) and (2);

Update \( P_i \) and \( g \).

i++;

End

End

End.

4.3. Hybrid modified PSO algorithm (HMPSO)

The traditional algorithm has been hybridized by using template matching method of the fitness value for every member of the swarm as set in the underling scheme Fig. 5 using Eq. (3) [17]:

\[
fitness = \frac{\sum_n \sum_m (W_{nm} - \overline{W})(B_{nm} - \overline{B})}{\sqrt{\sum_n \sum_m (W_{nm} - \overline{W})^2 \sum_n \sum_m (B_{nm} - \overline{B})^2}} \tag{3}
\]
where: \( W \) represents the weight matrix of a bat whose size is \( nxm \), \( B \): represents the weight matrix of the target function whose size is also \( nxm \), and \( \bar{W} = mean2(A) \), and \( \bar{B} = mean2(B) \) [17].

The work of the algorithm begins by entering the dental X-rays that make up the system database, where we begin to create the primary community of particles, depending on the stages of the mentioned primary treatment. The fitness value is then calculated for each member of the society, after that the values of the X-ray image to be distinguished and find sufficient information about it within the database are entered, so that the fitness value of this X-ray has been calculated in the same way. Then the Template matching method is used for comparison and search to find the best solution for the current society. Then begins a set of repeated steps until the best solution is found within a set of specific iterations according to a set of experiments for the algorithm.

The steps include finding new community members after each iteration, Update particle velocity according to the above-mentioned Eq. (1), With the hybridization of the original algorithm, by implementing the templates matching algorithm and calculates the best new solution and replace the best new solution with the old one, then refresh the velocities and change the locations of the particles in each cycle.

Fig. 5. HMPSO algorithm.
5. Performance Evaluation Methods

The following equations can be calculated to find the results [16, 17] note Table 3; where HMPSO represents the Hybrid Modified PSO Algorithm. MFPIS represents the meta firefly personal recognition system [16]. Where TN (true negative) represents the number of negative OPG X-rays and classified as negative, FP (false positive) represents the number of negative OPG X-rays and classified as positive, TP (true positive) represents the number of positive OPG X-rays and classified as positive, FN (false negative) represents the number of positive OPG X-rays and classified as negative, Sensitivity (SEN): measurement of the ability of proposed system to find the negative OPG X-rays and Specificity (SPE): measurement of the ability of proposed system to find the positive OPG X-rays.

1) DR= (No. of right Images discrimination )/(Total number of images)*100.
2) SEN=TP/(TP+FN)*100.
3) SPE=TN/(TN+FP)=1*100.
4) FN=FN/(TP+FN).
5) FP=FP/(FP+TN).
6) PP=TP/(TP+FP).
7) NP=TN/(TN+FN).

| Table 3. Results table for sample images. |
|-----------------|-----------------|-----------------|----------|----------|--------|
| Results         | DR              | SEN             | SPE      | FN       | FP     | NP     |
| HMPSO           | 98.13%          | 98.14%          | 100%     | 1.86%    | 0%     | 100%   | 80%    |
| MFPIS [16]      | 97.7%           | 96.6%           | 92.1     | 3.3%     | 7.7%   | 92.6%  | 94.2%  |
| Biometric system [6] | 70% | - | - | - | - | - |

6. Results and Discussion

The results are listed in Table 3, which represents the comparison between the suggested (HMPSO) algorithm, (MFPIS) algorithm used by research [16] and the Biometric system used by research [6]. The results show the efficiency of the suggested algorithm in detecting the person’s identity to whom the OPG radiograph belongs.

The results show high DR and PP percentages in the suggested algorithm represented by 98% and 100% respectively. This means better and more precise radiograph recognition and personal recognition as well than in the other algorithm.

In addition, the values of SPE and SEN were excellent which mean that the suggested system has very good ability for precise recognition and comparison with the other radiographs present in the database of the system. Also, the results clarify the system’ sensitivity to any change in the image like adding dental filling, tooth extraction, dental implant or any change that can happen on the teeth with time (Table 2).

On comparison of the results, between the suggested (HMPSO) and the (MFPIS) algorithm Fig. 6, one can notice the improved results obtained by using the hybrid PSO in personal recognition which means better reliability for the use of this system in various applications of recognition of unknown persons.

The value of NP was low. This is because of the number of strange and modified images used to check the NP parameter were low in comparison to the total number.
of images in the system’s database. Despite this, the algorithm attained good results in the rate of recognition especially for the modified and strange images.

On observing the results of comparison shown in Fig. 7, one can notice better values of FP and FN which gives the suggested system a great advantage in its ability to identify the modified images that have been subjected to some changes like teeth fillings or extraction also in it is ability to reject the strange images that are not present already in the system database. The FP and FN values were (0) and (1.9) respectively on the contrary of MPFIS where these values were higher indicating less efficient modified and strange images recognition.

![Fig. 6. DR, SEN, PP, NP results comparison.](image)

![Fig. 7. FN, FP results comparison.](image)

7. Conclusions
A new method of personal identification has been proposed by processing of dental panoramic radiographs using HMPSO algorithm, thereby allowing efficient, reliable, and fast identification process. This method can be used in varying aspects where there is a need for identifying unknown persons like crime scenes and disaster victims. The main conclusions of this research can be summarized as follows:

- The dental panoramic X-ray is dependable for use in human recognition due to the fact that the teeth are resistant to degradation.

```
HMPSO algorithm shows more efficient and reliable results in comparison with MFPIS one as shown in Table 3.

The pre-processing of the data base and unidentified person’s OPG is very important step to improve the quality of the radiographs and facilitate the process. Especially Images enhancement by using (AHE), Morphological Erosion and unsharp mask.

HMPSO algorithm shows 98% recognition accuracy and 100% for Positive Predictability and Specificity which mean the high ability of the algorithm to find the correct radiograph of the person.

The algorithm has proved its ability to detect the foreign radiograph at a high degree and this is observed in the ratio FP.

If our proposed system is used in real time and on the Internet, the system works with the same formula, with a difference that it will need the extra time to search for the required person information within a larger database and it also needs to have the internet available quickly and continuously. This is in addition to the need to schedule and coordinate the work if several people are working on it together.

Acknowledgements

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<table>
<thead>
<tr>
<th>Nomenclatures</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Any grey scale shape</td>
</tr>
<tr>
<td>B</td>
<td>Symmetric structuring element</td>
</tr>
<tr>
<td>n</td>
<td>inertial weight factor</td>
</tr>
<tr>
<td>$S_1$</td>
<td>self-confidence</td>
</tr>
<tr>
<td>$S_2$</td>
<td>swarm confidence</td>
</tr>
<tr>
<td>$V_{max}$</td>
<td>Maximum velocity</td>
</tr>
<tr>
<td>W</td>
<td>represents the weight matrix of a bat whose size is n * m</td>
</tr>
<tr>
<td>z</td>
<td>Vector</td>
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</table>

<table>
<thead>
<tr>
<th>Greek Symbols</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$\alpha_1, \alpha_2$</td>
<td>Uniformly distributed random number in [0,1] interval</td>
</tr>
<tr>
<td>$\Theta$</td>
<td>Erosion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abbreviations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHE</td>
<td>Adaptive Histogram Equalization</td>
</tr>
<tr>
<td>DR</td>
<td>Detection Rate</td>
</tr>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>FP</td>
<td>False Positive</td>
</tr>
<tr>
<td>FN</td>
<td>False Negative</td>
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<tr>
<td>NP</td>
<td>Negative Predictive</td>
</tr>
<tr>
<td>OPG</td>
<td>Orthopantomography</td>
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<td>PSO</td>
<td>Particle Swarm Algorithm</td>
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PP Positive Predictive
SEN Sensitivity
SPE Specificity

References

