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Comparison between PSO and Firefly Algorithms in Fingerprint Authentication

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Abstract*— One of the biggest challenges facing society is confirming the true identity of a person. Fingerprint identification may be preferred over traditional methods (e.g. passwords, smart-cards) because its information is virtually impossible to steal. Recently, a new trend has been opened by using swarm intelligence techniques in biometric field. Therefore, two swarm intelligence techniques (PSO and Firefly) are used in this paper in order to build fingerprints authentication system. The performance of the proposed system has been successfully tested, and a comparison between PSO and firefly swarm techniques is done. PSO is found to be better in extracting features from fingerprints.

***Index Terms*—Authentication system, Swarm Intelligence, PSO, Firefly Algorithm.**

I. INTRODUCTION

Due to the growing importance of the information technology and the necessity of the protection and access restriction, reliable personal identification is necessary. A biometrics system is a pattern recognition system that establishes the authenticity of a specific physiological or behavioral characteristic possessed by a user [1].There are several identification verification schemes that exist today but the most accurate identification schemes are in the area of biometrics. Some examples of identifying biometric characteristics are fingerprints, hand geometry, retina and iris patterns, facial geometry, and signature and voice recognition [1]. Sir Francis Galton [1], a British anthropologist scientifically proved in the late 19th century that no two fingerprints are exactly alike. According to his calculations, the odds of two individual fingerprints being the same are 1 in 64 billion. No identical twins will have the same fingerprints. Recently biologists and computer scientists in the field of "artificial life" have studied how to model biological swarms to understand how such "social animals" interact, achieve goals, and evolve [2]. Swarm Intelligence (SI) is part of artificial intelligence. In practice, the main aim of A.I during the last four decades has been to develop "Intelligent machine" with the capabapilities for solving complex task similar to human beings. It based on the study of collective behavior in decentralized and self-organized systems. The idea of SI comes from systems found in nature, including ant colonies, bird flocking and animal herding that can be effectively applied to computationally intelligent system. SI systems are typically made up of a population of agents interacting locally with one another and with their environment and local interactions between such nodes often lead to the emergence of a global behavior[3],[4].

II. PARTICLE SWARM OPTIMIZATION (PSO)

The basic PSO model consists of a swarm of particles, which are initialized with a population of random candidate solutions. They move iteratively through the d-dimension problem space to search for the new solutions, where the fitness, f, can be calculated as the certain qualities measure[5]. Each particle has a position represented by a position-vector xi (i is the index of the particle), and a velocity represented by a velocity-vector vi. Each particle remembers its own best position so far in a vector i-th, and its d-dimensional value is pbest(pid)[5]. The best position-vector among the swarm so far is then stored in the vector i-th, and its d-th dimensional value is gbest(pgd). During the iteration time t, the update of the velocity (vid) from the previous velocity to the new velocity is determined by Eq. (1) [5]. The new position (xid) is then determined by the sum of the previous position and the new velocity by Eq.(2) [5].

$$V(id+1) = w * vid + c1 * r1 * (pgd - xid) + c2 * r2 * (pid - xid) \quad (1)$$

$$X(id+1) = xid + v(id+1) \quad (2)$$

where i =1,2,…..,N; w is the inertia weight, r1 and r2 are the random numbers, which are used to maintain the diversity of the population, and are uniformly distributed in the interval [0,1] for the d-th dimension of the i-th particle. C1 is a positive constant, called coefficient of the self recognition component; c2 is a positive constant, called coefficient of the social component. From Eq. (1), a particle decides where to move next, considering its own experience, which is the memory of its best past position, and the experience of its most successful particle in the swarm. In order to guide the particles effectively in the search space, the maximum moving distance during one iteration must be clamped in between the maximum velocity [−vmax,vmax] [5]. The general basic algorithm for the Particle Swarm Optimization can be described in algorithm (1) [5]:

Algorithm (1) PSO Algorithm after [5]

Input: Initialize the algorithm parameters (c1, c2, w, vmax, Swarm_Size, Max_Iter,r1,r2).
Output: The optimization having the highest fitness as found by PSO.
Step 1: Randomly generate the initial particles and velocities to form a swarm

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Step 2: Calculate the fitness function of each of the particles.

Step 3: If the current position of the particle is better than the previous history, update the particles to indicate this fact.

Step 4: Find the best particle of the swarm. Update the positions of the particles by using equations (1) and (2).

Step 5: If the maximum number of iterations has exceeded or high fitness is found, then go to step 6 or else go to step 2.

Step 6: Copy the best value and exit.

PSO has a set of parameters, which is to be defined by the user. These parameters may be varied as the complexity of the problem [6].

III. FIREFLY (FF) ALGORITHM

The Firefly algorithm was developed by Xin-She Yang and it is based on idealized behavior of the flashing characteristics of fireflies. For simplicity, flashing characteristics can be summarized as the following three rules [7]: All fireflies are unisex, so that one firefly is attracted to other fireflies regardless of their sex. Attractiveness is proportional to their brightness, thus for any two flashing fireflies, the less bright one will move towards the brighter one. The attractiveness is proportional to the brightness and they both decrease as their distance increases. If no one is brighter than a particular firefly, it will move randomly. The brightness of a firefly is affected or determined by the landscape of the objective function to be optimized [8]. Based on these three rules, the basic steps of the firefly algorithm (FA) can be summarized as the pseudo code shown in Fig. 1 [9].

Begin
Initialize algorithm parameters:
Max Gen: the maximal number of generations
γ: the light absorption coefficient
r: the particular distance from the light source
d: the domain space
Define the objective function of f(**x**), where
x=(x1,.......,xd)^T
Generate the initial population of fireflies
or **xi** (i=1, 2 ,..., n)
Determine the light intensity of Ii at **xi** via f(**xi**)
While (t < Max Gen)
For i = 1 to n (all n fireflies)
For j=1 to n (n fireflies)
if (Ij > Ii), move firefly i towards j; **end if**
Attractiveness varies with distance r via Exp [$-\gamma\ r^2$]
Evaluate new solutions and update light intensity;
End for j
End for i
Rank the fireflies and find the current best;
End while
Post process results and Visualization
End

Fig. (1) Pseudo code of the Firefly Algorithm after [9]

In the firefly algorithm, the brightness I of a firefly at a particular location x can be chosen at I(x) α f(x). However, the attractiveness of β is relative, it should be seen in the eyes of other fireflies. Thus, it will vary with the distance r_{ij} between firefly i and firefly j. In addition, light intensity decreases with the distance from its source, and light is also absorbed in the media, so we should allow the attractiveness to vary with the degree of absorption [8]. As a firefly's attractiveness is proportional to the light intensity seen by adjacent fireflies, we define the attractiveness β of a firefly by Eq. (3) [8]:

$$\beta = \beta_0 e^{-\gamma r^2} \qquad (3)$$

Where r or r_{ij} is the distance between the ith and jth of two fireflies. β0 is the attractiveness at r = 0 and γ is a fixed light absorption coefficient. The distance between any two fireflies i and j at xi and xj is the Cartesian distance as in Eq.(4) [8].

$$r_{ij} = \left| x_i - x_j \right| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \qquad (4)$$

The movement of firefly i is attracted to another more attractive (brighter) firefly j is determined by Eq.(5) [8].

$$x_i = x_i + \beta_0 e^{-\gamma r_{ij}^2} (x_j - x_i) + \alpha\,(\text{rand} - 1/2) \qquad (5)$$

Where the second term is due to the attraction while the third term is the randomization with α being the randomization parameter. Rand is a random number generator uniformly distributed in the range of [0, 1]. For most cases in the implementation, β0 = 1 and α Є [0, 1] [8].

IV. THE PROPOSED SYSTEM

The block diagram of the proposed system is shown in Fig. 2.

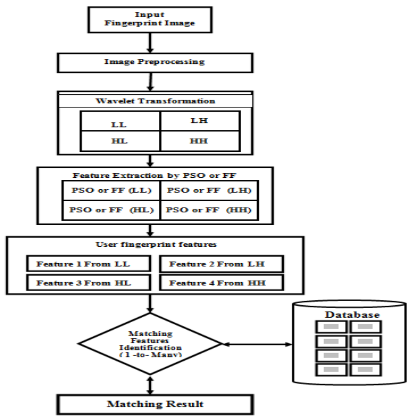

Fig. 2 Block Diagram of the Proposed System

A. *Input Fingerprint Image*

This is the first step, in which fingerprint image is taken from user by using the sensor of M2SYS device [10].

B. *Image Preprocessing*

The preprocessing of the fingerprint image consists of: (Object finder of fingerprint image, convert to gray level image, image smoothing, and image sharpening) [10].

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C. Wavelet Transform

In this step wavelet transform is used to get an efficient image representation that characterizes the significant image features in compact form. In this step the haar transform of an array of n samples (the array length should be a power of two) is used as [11]:

1- Find the average of each pair of samples. (n/2 averages).
2- Find the difference between each average and the samples it was calculated from: (n/2 differences).
3- Fill the first half of the array with averages.
4- Fill the second half of the array with differences.
5- Repeat the process on the first half of the array.

Two-dimensional discrete wavelet transform (2-D DWT) decomposes a gray-level fingerprint image into one average component sub-band and three detail component sub-bands. The first sub-band is LL and contains average components , second sub-band is LH and contains vertical edges, third sub-band is HL and contains horizontal edges and HH sub-band and contains diagonal edges.

D. Feature Extraction using PSO

In this step, PSO technique is used for extracting features from the fingerprint image depending on algorithm (1). PSO algorithm is applied to the four sub bands of the transformed image. The fitness function is evaluated for each location in the image and calculated by using statistical calculations. These calculations are X-position, Y-position, Mean, and Variance. X-position and Y-position refer to the two dimensional locations of the coefficient in the subband image.

The bird (particle) has the following information:

1- f(x) : fitness of the current position of the bird.
2- f(gbest) : best fitness of the position in the search space.
3- f(xbest) : best fitness of the neighbors f(x).
4- Lx means current position of the fitness bird.
5- Lgbest : position of the best fitness in the search space.
6- Lxbest : position of the best fitness of the neighbor f(x).
7- α , β : Acceleration parameters (are cognitive and social parameters that are bounded between 0 and 2).
8- rand1& rand2 are the random numbers distributed uniformly in [0,1].
9- D: maximum number of iteration.

Four features (values) are extracted by PSO algorithm according to four sub bands (LL, LH, HL, HH). The applied PSO is described in block diagram of Fig. 3. During an iteration of the algorithm, the best local position and the global best position are updated if better solution is found. The process is repeated till the specified number of iterations are exhausted. The no. of iteration that are used in the main proposed system is 500 iterations. In order to find one feature, then (500) features are averaged. This is the first feature extracted from LL subband. This process is applied on three other sub bands (LH, HL,HH), therefore four features are extracted from fingerprint image.

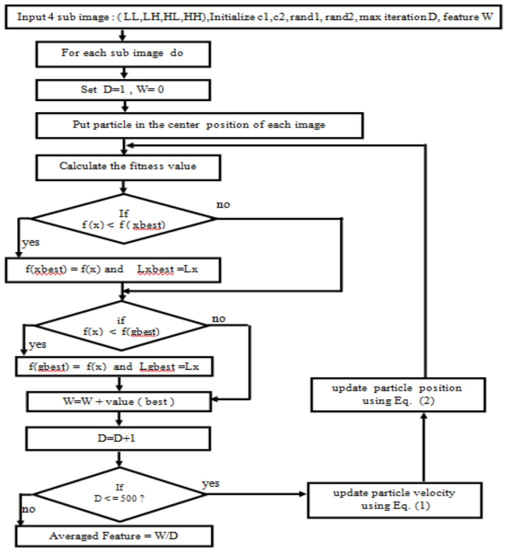

Fig. 3 Block Diagram of Applied PSO Algorithm

E. Feature Extraction using Firefly Algorithm

In this step, firefly algorithm is used for extracting features from the fingerprint image depending on pseudo code of Fig. 1. Firefly algorithm is applied to the four sub bands of the transformed image. The fitness function is calculated for each location using statistical calculations. These calculations are X-position, Y-position, Mean, and Variance. X-position and Y-position refer to the two dimensional locations of the coefficient in the subband image. Four features (values) are extracted by firefly algorithm according to four sub bands (LL, LH, HL, HH), i.e. firefly is applied four times. The applied firefly algorithm is described in block diagram of figure (4).

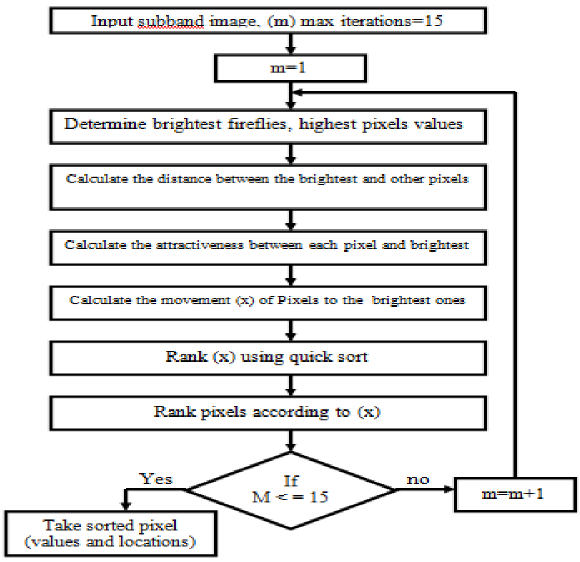

Fig (4) Block diagram of Applied Firefly Algorithm

F. Creation of Database

Database has been created before using the proposed system. (300) samples are taken from different students at the Institute of computer Science at sulaimaniya city using M2sys device. Four features with identification number for each sample are saved in database depending on the block diagram

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of Fig. 5.

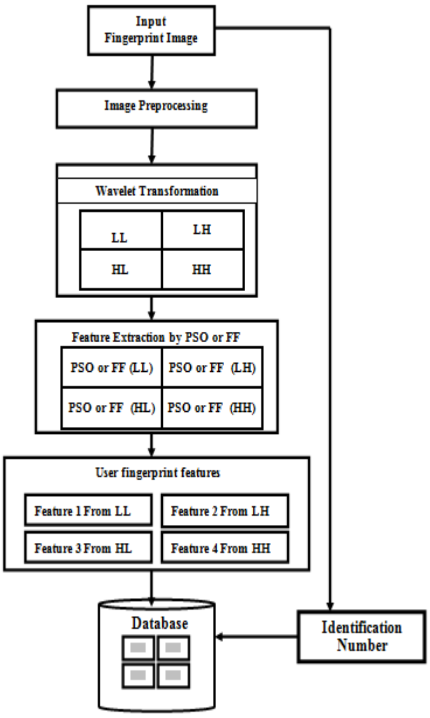


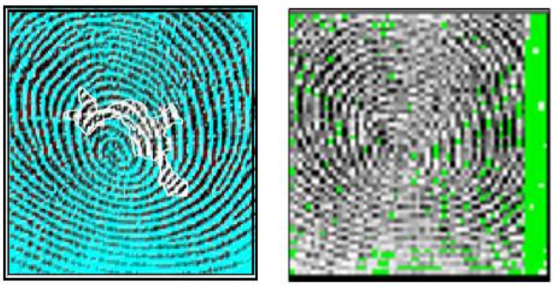
Fig. 5 Block Diagram of Creation Database for Proposed System

G. Matching

The proposed system relays on the matching operation for granting the authentication operation. The "one to many" matching is to match the person with all persons that enroll in the database. If the matching ratio between (database LL feature and temporary LL feature) is lower than 98% the person is unauthorized and if it is equal or greater than 98% then another comparison between (databases LH, HL, HH features and temporary LH, HL, HH features) is done. If the result of second comparison is equal or greater than 90% then the person is authorized otherwise the person is unauthorized.

V. RESULTS

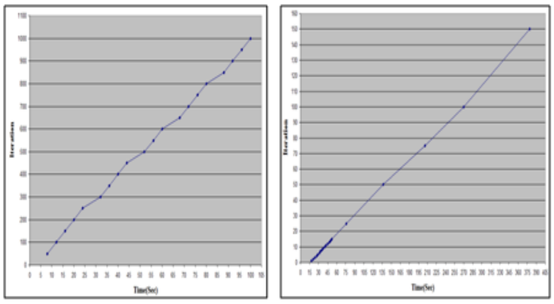
The best locations were located by PSO and firefly algorithms are shown in Fig. 6.



(a) (b)

Fig. 6 Best locations Visited by (a) PSO Algorithm (b) Firefly Algorithm.

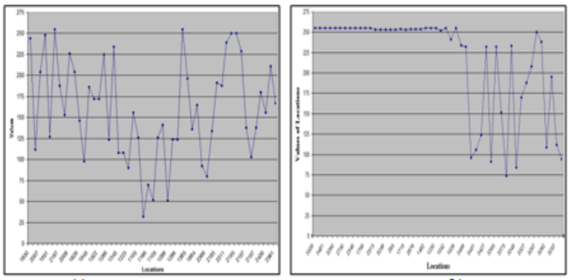
Fig. 7 shows the time required for implementation PSO and firefly algorithms with respect to the number of iterations.



(a) (b)

Fig (7) Relation between Time and No. of iteration for (a) PSO Algorithm (b) Firefly Algorithm

Fig. 8 shows the relation between values and locations that are selected by PSO and firefly algorithms for 50 locations for LL subband.



(a) (b)

Fig. 8 Relations between Values and Locations Selected by (a)PSO Algorithm (b) Firefly Algorithm for LL subband

VI. CONCLUSION

Conclusions that can be inferred from this work are specified below:

1. Fig. 6 shows that PSO algorithm is better than firefly algorithm in fingerprint features extraction because the selected locations by PSO are concentrated around the center of the fingerprint, while the selected locations by firefly are scattered around the fingerprint.
2. An evaluation of the proposed system using PSO or firefly is shown in Table (1), depending on [12].

Table (1): An Evaluation of Matching Ratio for the Proposed System

System	Subband	Matching Ratio%
Proposed System using PSO	LL	99
	LL,LH, HL,HH	100
Proposed System using Firefly	LL	98
	LL,LH, HL,HH	100
Published PSO System Results [12]	LL,LH, HL,HH	99.992 - 99.995
Published Genetic Algorithm Results[12]	LL,LH, HL,HH	80-95

3. Table (2) shows that the performance of the proposed system is quite good depending on decision error rate (“false accept rate (FAR)” , “false reject rate (FRR)” , and “correct verification rate (CAR)”) , where FAR, FRR, and CAR are defined in Eq.s 8,9, and 10 [13]:

FAR= number of false acceptation / total number of test sample (8)

FRR= number of false rejection / total number of test sample (9)

CVR=(1-FAR-FRR) *100 % (10)

Table (2) Performance of the Proposed System

Error Rate		Performance Value
Proposed System using firefly	FAR	0.00
	FRR	0.02
	CVR%	98
Proposed System using PSO	FAR	0.00
	FRR	0.01
	CVR%	99

VII. ACKNOWLEDGMENT

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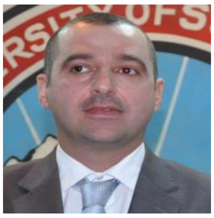

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