Fingerprint Feature Extraction Using Convolution and Particle Swarm Optimization Algorithms

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Abstract

Most of the existing fingerprint extraction systems are based on the global features and detailed characteristics of fingerprints, which have a weak performance in cases of poor quality fingerprint images, such as the fingerprint image is incomplete. In order to improve recognition accuracy, reliability and quickness to identify the fingerprints a new trend has been opened by using swarm intelligence techniques in biometric field. Therefore, particle swarm optimization techniques (PSO) are used in this paper to build fingerprints authentication system. A fast fingerprint identification method based on the convolution transformation and Particle Swarm Optimization algorithms proposed. The convolution algorithm was used to extract the convolved feature and then found the optimal solution from this feature by using Particle Swarm Optimization algorithm. Experimental results show that, the proposed method has a high efficiency in extracting features from fingerprints, strong strength, and good accuracy for recognition.

Keywords: Biometrics, Fingerprint, Histogram Equalization, Binarization, Convolution, Particle Swarm Optimization.

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استخراج ميزة بصمة الأصبع باستخدام خوارزمية الالتفاف وأسراب الطيور

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الخلاصة

تستند معظم أنظمة استخراج ميزات الإصبع الموجودة على السمات ألعامه والخصائص التفصيلية لبصمه الإصبع والتي لديها ضعف أداء في حالة كون الصورة ذات تفاصيل قليلة.من أجل الحصول على الموثوقية والدقة والسرعة في التعرف على بصمة الأشخاص تم فتح اتجاه جديد لاستخدام تقنيات ذكاء الأسراب في مجال التحقق من الأشخاص. في هذا البحث تم استخدام تقنيه أسراب الطيور لبناء نظام التحقق من هوية الأشخاص قائمه على أساس تطبيق خوارزميه الالتواء مع تقنية أسراب الطيور.خوارزميه الالتواء تستخدم لاستخراج خاصية الالتواء وبعد ذلك تطبيق تقنية ذكاء الطيور لاستخراج أفضل خاصية لبصمة الإصبع .وقد أظهرت النتائج أن الطريقة المقترحة لديها كفاءة عالية في استخراج ميزات قويه من بصمات ألأصابع ودقة جيدة لتعرف على الأشخاص.

الكلمات ألمفتاحية : القياسات الحيوية ، بصمة الإصبع ، المخطط التكراري، التحويل الثنائي، الالتفاف ، أسراب الطيور

Introduction

With the increased use of computer technology for data processing and access to sensitive or personal data also becomes more important. The use of PIN (personal identification number) is not more reliable to secure these types of data; therefore, the use of biometrics is the perfect solution. Biometric technologies can block unauthorized access or misuse of any system (computer networks, cellular phones, ATMs, PCs, Smart cards, etc.). Personal identification numbers and passwords can be forgotten, and determine identification symbolism can be stolen. Therefore, identification of biometric systems has more interest [1].

Matching fingerprints is a standout amongst the most huge and reliable approaches to identify the person. There are two major applications on a comparison of fingerprints: fingerprint identification and verification of fingerprints. While the motivation behind the fingerprint identification is to determine a person's identity, the objective of the fingerprint verification is to install the identity of the person. As a rule, fingerprintercognition includes comparing the select fingerprint with a huge number of fingerprints put away in a database. And that takes a tall time. To minimize the search time and low computational intricacy, and is often used rating of fingerprints to divide the database into smaller subsets [2]. Yager [3] a recent review of the methods of rating of fingerprints. Usually, it is classified fingerprints into five noteworthy classes, known as "Henry classes", specifically Arch, Tented Arch, Whorl, Left Loop and Right Loop. Maltoni [4] Non-direct bends coming from skin flexibility, sensor clutter and Low quality of fingerprint image make the problem of fingerprint rating very difficult so that a many frameworks have been proposed to manage this problem. The primary element that characterizes the "Henry classes" is the ridge flow pattern design, which on a basic level can be described by the number and sorts of singularities in the direction field (i.e., ridge direction field). Kawagoe and Tojo [5] delta and Core focuses are the fundamental elements utilized as a part of guideline based methodologies. However, these systems are subject to failure when his characters do not show or cannot be extracted. Wang [6] has presented one of these ways to take advantage of the orientation information. Chong [7] for the same purpose ridges represented by splined curves were employed. Cappelli [8] an auxiliary methodology utilizing apportioning of the orientation field into homogeneous areas.Zhi-Hui Zhan [9] an adaptive particle swarm optimization (APSO) presented an algorithm which has the best optimal efficiency in search of classical particle swarm optimization (PSO). Gabriel [10] two improvement procedures are assessed for this assignment: genetic algorithms (GA) and particle swarm optimization (PSO) utilizing standard GA and make a distinction PSO. In this paper we present a proposed mechanism for fingerprint feature extraction using a new way where research include two parts: The first part is the use of convolution transformation and in the second part we used the way of Particle Swarm Optimization algorithm to extract the best feature from fingerprint image.

Convolution

The mathematical concepts of convolution and the kernel matrix are used to apply filters to images, to perform functions such as extracting edges, lines, corners and reducing unwanted noise. Convolution filtering is used to modify the spatial frequency characteristics of an image.

Convolution of an input with one mask (kernel) produces one output feature, and with H masks independently produces H features. Starting from top-left corner of the input image, each mask is moved from left to right, one element at a time. Once the top-right corner is reached, the mask is moved one element in a downward direction, and again the mask is moved from left to right, one element at a time. This process is repeated until the mask reaches the bottom-right corner. For the case when N = 5 and k = 3 , there are 3 unique positions from left to right and 3 unique positions from top to bottom that the mask can take. Corresponding to these positions, each feature in the output will contain 3x3 (i.e., (N-k+1) x (N-k+1)) elements. The convolved value obtained by summing the similar elements between the mask and the input image [11].

Particle Swarm Optimization

Interest was growing in researches of particle swarm optimization (PSO) which is proposed by theEberhart and Kennedy in 1995[12]. In comparison the PSO with many other optimization algorithms, PSO has an advantages of strong global search, faster convergence rate, few adjustable parameters, simplicity of the algorithm, and ease of implementation [13]. Due to its many advantages, the particle swarm optimization algorithm can be used widely in the fields such as function optimization, the model classification, machine study, neural network training, the signal processing, vague system control, and automatic adaptation control [14].

PSO is a population based search procedure in which the individuals, called particles, adjust their position to search through the search space. Each particle Pi has a position vector $Vi = (X_{i1}, X_{i2}, \dots X_{ik})$ and a velocity vector $Vi = (V_{i1}, V_{i2} \dots V_{ik})$. For each iteration the particles learn from its own previous best position P_{best} and the best position of all the other particles l_{best} in the swarm, and updates it's' velocity and position. The update equation at $(k + 1)$ -k_h iteration can be written as follows:

$$\vec{v}_i(k+1) = \vec{v}_i(k) + c_1 * r_1 * \left(x_{p_{best,i}} - x_i(t)\right) + c_2 * r_2 * \left(x_{L_{best,i}} - x_i(t)\right) \dots (1)$$

$$\vec{x}_i(k+1) = \vec{x}_i(k-1) + \vec{v}_i(k+1) \dots\dots (2)$$

Where *c1* and *c2* are the cognitive and social scaling parameters respectively, and *r1* and *r2* are random numbers in the range of [0, 1].

As there are few parameters to adjust for the Particle Swarm Optimization (PSO) and its updating procedure has only simple arithmetic operations, it is a good choice for fast optimization. The Particle Swarm Optimization (PSO) algorithm provides a better control of the adaptation process. It allows the user to control the number of particles, particles' maximum velocity, and ranges of each coefficients, tolerance level, and stability[15].

The Proposed System

The block diagram of the proposed system is shown in Figure (1)

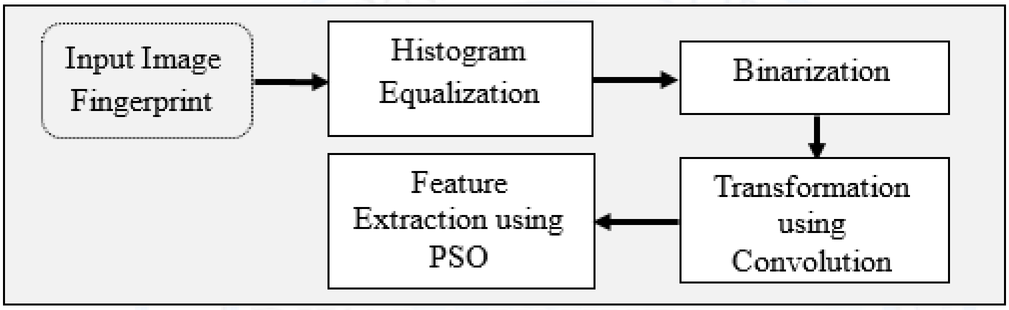

Figure 1: The block diagram of applied fingerprint feature extraction algorithm

1. Input Fingerprint Image

This is the initial phase, in which unique fingerprint impression image is taken from user by utilizing the sensor of M2SYS gadget.

2. Image Pre-Processing

The preprocessing of the fingerprint image consists of: (Object finder of fingerprint image, convert to gray level image, image smoothing, and image sharpening) there may be artifacts in the image of a fingerprint, which should be corrected before the measurement and analysis. The various candidates for the correction as follow:

• **Corrections sensor**: These include dead pixel correction, lens geometric distortion, andvignette. Lighting corrections. Lighting can enter the deep shadows that obscure local texture and structure; also, in varying lighting scene may skew the results. The methods include correct candidate rank filter, graph equation, and redraw the map of terminals.

• **The noise:** This comes in many forms, and may need special image pre- processing.

• **Color corrections**: It can be useful for the redistribution of color saturation or the antiques lighting in the channel density.

A. Histogram Equalization

Is a method for image processing using the contrast adjustment by using the graph of the image, this method often increases the global variation of many images, through the distribution better on the histogram. Histogram equation is work based on the propagation and effectively spreading the most intensity values. The main advantage of this method is completely clear technique and invertible operator, since the histogram has equal function, so it can restore the original graph [16].

B. Image Binarization

Binarization can be defined is that a process of digitizing the images by converting a gray level image to a binary image. Therefore, binarization converts the image from a 256-level image to a 2-level image that gives us the same information. Normally, the value '1' is given to an object pixel, while a background pixel is given a value of '0'. At the end, a binary image is created by coloring each pixel white or black, depending on a pixel's label (black for 0, white for 1)[17].

C. Transformation using Convolution

Fingerprint as the natural images have property stationary, meaning that the statistics of one part of the image are the same as any other part. This suggests that the features that we learn at one part of the image can also be applied to other parts of the image, and use the same features at all locations, take the learned features and convolve them with the larger image, thus obtaining a different feature activation value at each location in the image. As in the algorithm 1.

Algorithm 1: Feature Extraction using Convolution	
Input	Input the Binarization of fingerprint
output	output transformation image finger print using Convolution
Step1	Set FirstScal←2, SecondScal←1, f1 ← 1 For all I,J do {where 2 to Wid-1,2 to Hig-1} Step 3 For all Fi,Fj do {where -FirstScal + I to FirstScal + I, -FirstScal + j to FirstScal + j } AMask(im, jm) ←ValueRed (Fi, Fj) End For

```
   For all In,Jn do {where 1 to 3,1 to 3}
AFeature(ni, nj) ← 0
   End For
   For all Im,Jm do {where 1 to 3,1 to 3}
       Set fcount← 0 ,ni← 0
       For all Fi,Fj do{where -SecondScal + Im to SecondScal + Im, -SecondScal + Jm to
SecondScal + Jm }
          If AMask(Fi,Fj) = FeMask(Fi,Fj) Then
fcount←fcount + 1
          End If
       End For
CFeMask(Im, Jm) = fcount
       Set ni←1
       For all Fi do{where -SecondScal + Im to SecondScal + Im, }
           Set nj←1
           For all Fj do{where -SecondScal + Jm to SecondScal + Jm }
              If Im = ni And Jm = nj Then
AFeature(Fi, Fj) = CFeMask(ni, nj)
              End If
              Set nj←nj +1
       End For
       Set ni←ni+1
   End for
End For
```

D. Feature Extraction using PSO

The feature is extracted from the image of a fingerprint using particle swarm algorithm (PSO) which is a mathematical way to improve the problems that in the pictures by trying to replicate a solution to improve the candidate with respect to certain the masterminding of quality . And called the name of the particles as they move around the space of the image to find the best neighbor based on a simple calculation formulas are affected quickly and the position of the particle. It is expected that the squadron is moving toward a better solution, thereby feature extracting of a fingerprint. The goal of this algorithm is to get the optimal solution and the result is better - across simulate the behavior of birds in search of better food and so any system that relies on this algorithm will be formed at the beginning of the random grouping of random solutions.After recording information , fingerprints capture and the features extract of the fingerprint using an PSO algorithm ,feature exraction using PSO explains in algorithm 2.

Algorithm 2: Feature Extraction using PSO	
Input	Pso[n].value Pso[n].row, //structure of Pso Pso[n].Col Rows Cols
output	output tabel_pso // the best value from pso

Step1	Read data image
	ImagePixels(0 to Wid-1, 0 to Hig-1)
	For all X,Y do {where 0 to Wid-1,0 to Hig-1}
	Set ValueRed(X.Y) ←getValuePiexl(X,Y) // Red component of Image
	Set ValueGreen(X.Y) ←getValuePiexl(X,Y) // Green component of Image
	Set ValueBlue(X.Y) ←getValuePiexl(X,Y) // Blue component of Image
	End For
	Read x_mid
	Read y_mid
	Set Sum = 0
	For all I do{0 to Rows *Cols}
	Sum ←Sum + pso(i).value
	End For
	Mean← (Sum / (Rows *Cols))
	For all ifteness do{0 to Rows *Cols}
	pso(ifteness). fteness←(pso(ifteness).value - Mean) ^ 2 / (Rows *Cols)
	End For
	set ←best = find_value(x_mid, y_mid) // call function to return value from pso where location x_mid, y_mid
	FunPso←0
	tabel_pso(FunPso) ← best
	pbest←pso(best). fteness
	xlbest← best
	fxit←pso(best). fteness
	xit ,xi ,T_xlbest←best
	For all lopp do{0 to 100}
	If fxit<= pbest Then
	Pbest←fxit
	best ←xit
	End If
	xnegber← 1
	Temp = find_xxbest(xnegber, pso(T_xlbest).value, pso(T_xlbest).row, pso(T_xlbest).Col, xlbest)
	xxmean←(pso(xlbest).value - mean) ^ 2 / (Rows *Cols)
	lbest←xxmean
	If fxit>= lbest Then lbest←fxit
	v =←pso(xit).value + RAN * (best - xit) + RAN * (xlbest - xit)
	X = (Int((xit + v) * -1)) * -1
	shi = X Mod (Rows *Cols)
	shift_arrr (pso [].value. ,shi)
	T_xlbest←xlbest
	fxit←(pso(xlbest).value - mean * 0.001) ^ 2 / (Rows *Cols)
	xit←xlbest
	End For

Experimental Results

In this section will display the results that were obtained from the experiments after the implementation of the convolution transformation and PSO algorithm on a number of fingerprints images.

1. Different Mask Effect

The feature extraction is the important step in proposed method, these feature should be unique for each voter. transformation using convolution is method used here and it depend on mask such: 3*3 convolute in widow such 5*5, these will produce 10 different cases these will count its histogram and get max one as shown in table1. The first mask is [1 1 1 ; 0 0 0 ; 1 1 1].

Table 1: Unity feature test (transformation using convolution mask 1)

Mask 1=[1 1 1;0 0 0;1 1 1]					
#	image 1	image 2	image 3	image 4	image 5
0	4	1	0	0	5
1	37	21	22	3	34
2	829	186	330	19	331
3	6657	4240	1320	219	7181
4	2916	4334	1562	598	2245
5	2996	5181	2227	1061	2416
6	17903	17829	26108	30153	19683
7	1017	529	800	308	447
8	39	75	30	37	53
9	2	4	1	2	5

As explain in previous table 1 in spite of the case number 6 is it in most image but the value of histogram are differ as shown figure 2.

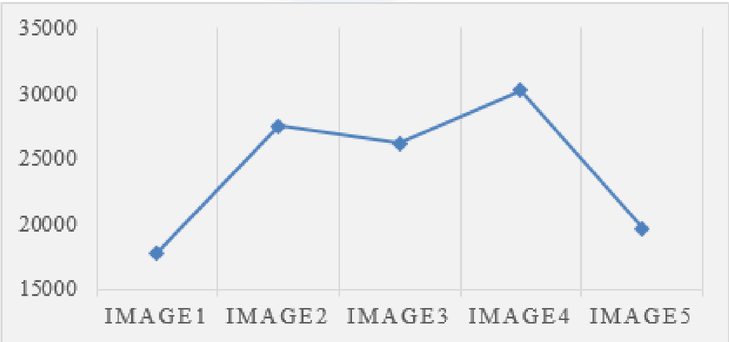

Figure 2: Max histogram values for mask 1

The second mask used is [1 1 1 ; 1 0 0 ; 0 1 0] used and represent the other 10 cases of features explain in table 2.

Table 2: Unity feature test (transformation using convolution mask 2)

Mask 2=[1 1 1;1 0 0;0 1 0]					
#	image 1	image 2	image 3	image 4	image 5
0	3	0	1	0	4
1	80	3	93	9	50
2	538	88	545	76	289
3	1989	981	1147	311	1281
4	8049	948	2195	877	8403
5	19034	1155	26172	30367	20668
6	2014	4700	1502	619	1332
7	586	163	611	120	316
8	105	23	127	21	55
9	2	3	7	0	2

The previous table 2 show the majority max histogram is in case number 5also different value as shown in figure 3.

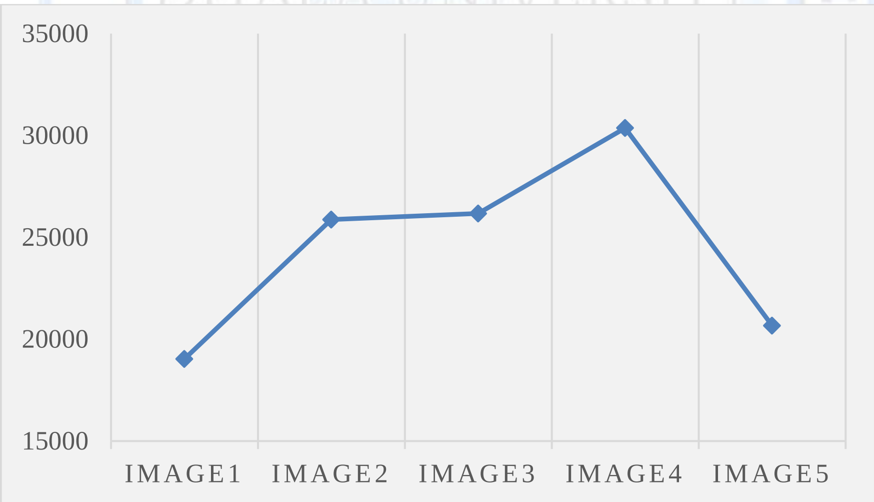

Figure 3: Max histogram values for mask 2

The third mask used is [1 0 0;0 1 0;0 0 1] used and represent the other 10 cases of features explain in table 3.

Table 3: Unity feature test (transformation using convolution mask 3)

Mask 3=[1 0 0;0 1 0;0 0 1]					
#	image 1	image 2	image 3	image 4	image 5
0	2	2	1	2	5
1	39	58	30	37	53
2	1017	1664	800	308	447
3	17903	18077	26108	30153	19683
4	2996	3761	2227	1061	2416
5	2916	3119	1562	598	2245
6	6657	4501	1320	219	7181
7	829	1166	330	19	331
8	37	47	22	3	34
9	4	5	0	0	5

The previous table 3 shows the max histogram is in case number 3 also different values as shown in figure 4.

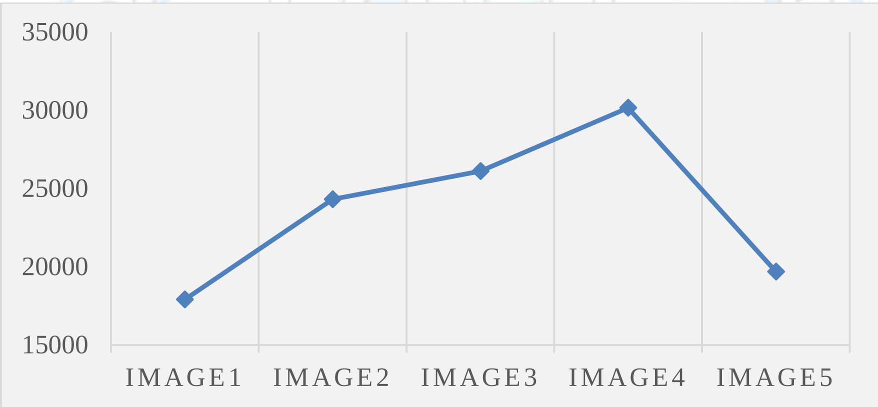

Figure 4: Max histogram values for mask 3

2. Feature Optimization

The PSO used for optimization the feature extracted from fingerprint by mean or standard deviation on the location of features used in previous (transformation using convolution). The feature should be unique for every person in the election as shown in table 4.

Table 4: PSO Feature Optimization (Mean)

Fingerprint Images	PSO Iteration (Mean) [010101010]				
	100	150	200	250	300
Image 1	4.673267327	4.529801325	4.587064677	4.326693227	4.375415282
Image 2	4.366336634	4.205298013	4.258706468	4.729083665	4.262458472
Image 3	4.089108911	4.132450332	4.432835821	4.350597609	4.122923588
Image 4	4.396039603	4.344370861	4.144278607	4.099601594	4.189368771
Image 5	4.643564357	4.675496689	4.636815920	4.685258964	4.833887043

In previous table 4 the feature value that optimized using PSO are didn't have intersection in any values. The other value such as standard deviation could be used in PSO optimization as shown in table 5.

Table 5: PSO Feature Optimization (Standard deviation)

Fingerprint Images	PSO Iteration (Standard Deviation)				
	100	150	200	250	300
Image 1	0.048724363	0.040617085	0.035434053	0.042763529	0.034618207
Image 2	0.065260629	0.040084426	0.040585327	0.048399028	0.032596388
Image 3	0.028348698	0.027585778	0.080735598	0.061611123	0.028666269
Image 4	0.048664566	0.038668191	0.063091153	0.061010829	0.022583050
Image 5	0.073539978	0.047340266	0.082725947	0.050100368	0.034155402

The previous table 5 also explain there are no intersection in any values in table so the unity of feature are satisfied.Table 6 show the results of fingerprint feature extraction by using bee's algorithm.

Table 6: Bee's Feature Optimization

Fingerprint images	Bees Iterations				
	100	150	200	250	300
Image1	5	4.899052	4.490244	4.716049	4.773267
Image2	4.90033	4.62981	4.5122	4.55556	4.49024
Image3	4.3889	4.4286	4.3171	4.6298	4.1485
Image4	4.09091	4.28572	4.490244	4.38272	4.37624
Image5	4.90033	4.66667	4.60976	4.59259	4.77595

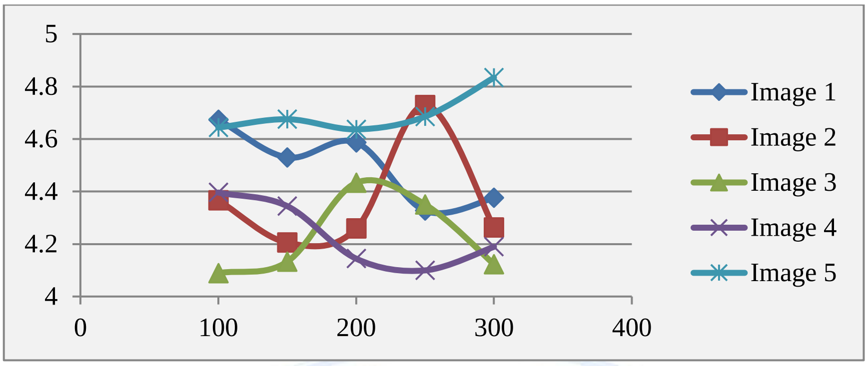

Figure 5: Features extraction using mean

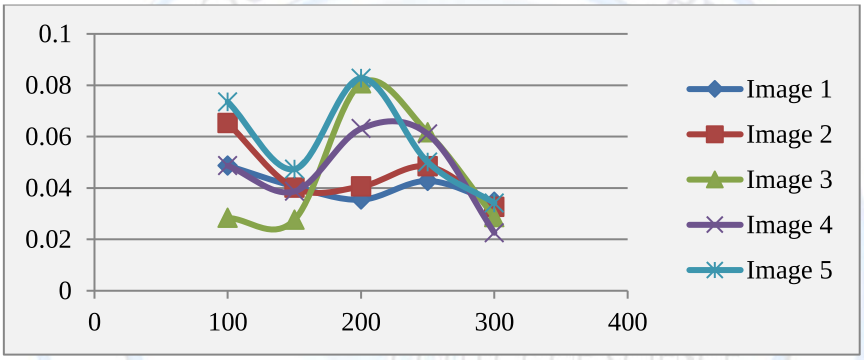

Figure 6: Features extraction using standard deviation

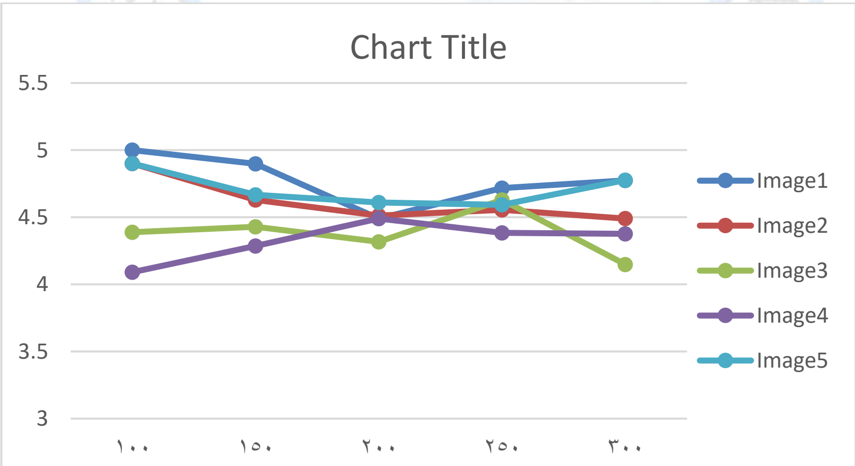

Figure 7: Features Extraction using Bee,s Algorithm

Figure 5 and 6 shows that the extracted features of the fingerprint images using the mean be spaced more than the Standard deviation and thus guarantee that the used of mean to extract a unique feature to each person.Figure 7 explain that the feature extracted from fingerprint image by using bee's algorithm not unique for each person since there is a similarity between the extracted features.

Conclusions

The proposed algorithms satisfy the following:

- A fingerprint feature extraction based on the convolution and Particle

Swarm Optimization algorithms is proposed.

- The Selection of Particle swarm Optimization (PSO) algorithm is tried to give unique features that are useful in recognizing the identity of person.
- The enhancement process is very important in order to get clear and pure fingerprint image for further operation.
- From the experimental result section, we may conclude that the convolution and Particle Swarm Optimization algorithms produced best results for the tasks of feature extraction.
- Particle Swarm Optimization for feature extraction give diverged with respect to bee's algorithm

In future work, we intend to explore further the use of PSO as a feature extraction algorithm,with the aim of better studying variation in the parameters and their influence on the results.

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