Improving the Performance of Particle Swarm Optimization for Iris Recognition System Using Independent Component Analysis

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Abstract – Recently, iris recognition had been gained growing interest from researchers because of its high accuracy against other person identification techniques. This work presents an iris recognition system based on particle swarm optimization (PSO) and Independent Component Analysis (ICA) as feature extraction algorithm. Many experiments were conducted using different: swarm size (20, 40 and 80), PSO iterations (100 and 200) and ICA feature vector length (64, 128, 256 and 512). The results showed that: the best performance of the iris recognition system (high PSNR, high recognition rate and lower MSE) will be increased when increasing the ICA feature vector length to 512, increasing the swarm size to 80 and decreasing the number of iterations to 100. Best obtained value of recognition rate is 98%, best PSNR value is 38 and lower MSE value is 0.0011. The suggested iris recognition system has the ability to recognize untrained iris images but with lower performance.

Keywords: — Iris Recognition, Practical Swarm Optimization (PSO), Independent Component Analysis (ICA)

1 Introduction

Recently, biometric systems for person identification are becoming more important because of increasing the security requirements of organizations in private and public sectors in societies [1][2][3]. These systems provide persons’ identification based on their physical features such as iris, face, voice and fingerprints [4]. Traditional methods for personal identification include the token-based methods that use ID cards/keys for authentication and knowledge-based methods that use password for identification. These methods are not reliable. As a promising way of authentication, biometrics aims to recognize a person using physiological and/or behavioral characteristics such as fingerprints, face, voice, and so on [1][2]. Iris recognition can be regarded as the most reliable biometric identification system available that recognizes a person by iris pattern [5][6]. It can obtain high accuracy due to the rich texture of iris patterns. Therefore, biometric systems based on iris patterns play important role in network security and high level security systems [7] because iris has unique patterns and no two iris patterns are the same [8]. A biometric system consists of: sensor module to take biometric data; feature extraction; matching part to compare the feature vectors are with those in template; and decision making to establish the user’s identity [9].


Particle swarm optimization (PSO) is a heuristic, population-based, self-adaptive search optimization technique that is based on swarm intelligence to solve optimization problems in many applications. It comes from the research on the bird and fish flock movement behavior. The algorithm is widely used and rapidly developed for its easy implementation and few particles required to be tuned [16]. PSO was first introduced in 1995 by Kennedy and Eberhart [17] and has been growing rapidly. Many literature researches were focused on developing and enhancing the PSO [18..26]. Many literature researches were used PSO for solving recognizing problems such as: Object recognition [27]; Fingerprint [28]; Handwritten Characters Recognition [29]; Face recognition [30][31]; Palmprint recognition [32..35]; and Gait recognition [36..38]. Iris recognition analyses the iris pattern and these patterns are unique, stable and reliable with age in comparison with other biometric features such as face and fingerprint [8]. Many literature researches related to iris recognition systems were based on different algorithms and approaches. Few literature researches were based on PSO for iris recognition [39][40].
Independent component analysis (ICA) is a method for finding underlying components from multi-dimensional statistical data. ICA differs from other methods in that it looks for components that are statistically independent, and non-Gaussian. ICA was used for different applications such as: Medical and Finance data, Audio Processing, Array processing and Coding [41-44]. Many literature studies were used ICA for image recognition problems [45-49].

According to optimization features of PSO algorithm, this research is focused on building an iris recognition system based on PSO algorithm. To increase the performance of this suggested iris recognition system ICA will be used as a feature reduction and extraction algorithm. This paper is organized as follows: section 2 includes description of PSO. Section 3 includes description of ICA and section 4 includes research methodology and section 5 includes results. Finally section 6 concludes this work.

2 Practical Swarm Optimization

PSO algorithm can be implemented easily, converge rapidly, and can be applied on large number of samples. PSO is one of the swarm intelligence methods that explore global optimal solution and based on social behavior of birds flocking. It uses swarm of particles as the individuals in population for searching through solution space. Each solution in PSO is implemented as a particle that represents one individual of a population. A particle can be regarded as a point of N-dimension solution space and has a speed which is N-dimension vector. The swarm is population and it is a set of vectors. Each particle has a fitness function (value) associated with it. Each particle adjusts its position and evaluate their position and move closer to optimal point. Particles also compare themselves to their neighbors and imitate the best of that neighbor. Swarm of particles is flying through the parameter space and searching for optimum. The best value that particle in a local swarm reach it is called Lbest. Fig.1 shows the main steps of PSO [16-26]. The following equation is used to compute new velocity of each particle [16-26]:

$$v_{i}(t+1)=W \cdot v_{i}(t) + C_{1} \cdot \text{rand} \cdot (P_{best}(t)-X_{i}(t)) + C_{2} \cdot \text{rand} \cdot (G_{best}(t)-X_{i}(t))$$

(1)

Where,

- \(v_{i}[t]\): particle velocity,
- \(X_{i}\): ith particle of swarm
- \(W\): weight (random number between 0 and 1).
- \(C_{1}, C_{2}\): the speeding factors (with value 2).
- \(P_{best}\): represents the best value of the particle i.
- \(G_{best}\): the best value that one of the swarm particle reach it.

From Eq.1, the new velocity \(v_{i}(t+1)\) is affected by: \(P_{best}\), \(G_{best}\) and \(v_{i}(t)\): earlier velocity of ith particle X in time t.

The following equation is used to compute new fitness value of each particle in swarm:

$$X_{i}(t+1)=X_{i}(t) + v_{i}(t+1)$$

(2)

Particle will change its value according to its new velocity (vi(t+1)).

3 Independent Component Analysis

Many feature extraction algorithms used to extract the main feature of image for recognition process. [41][42][43]. Basic ICA assumed that the numeric multidimensional data series are available. Every individual data series is a mixture of a number of statistically independent source signals. ICA is used to solve the inverse problem of finding unknown sources without knowing the mixing conditions.

Let us assume that we observe the \(n\)-dimensional vector signal \(x(t)\), which is the result of an unknown mixing of \(m\) statistically independent source signals \(s(t)\) [50][51]:

$$x(r) = As(r) + n(r) = \sum_{i=1}^{m} s_{i}(r)a_{i}^T + n(r)$$

(3)

where \(a_{i}^T\) denotes the \(i\)-th row vector of an unknown mixing matrix \(A\). ICA can estimate \(m\) unknown sources and \(m \times n\)-dimensional separation matrix \(W(t)\). The m-dimensional vector should become (up to the scale and signal permutation) an estimate of original sources.

$$y(r) = W(r)x(r)$$

(4)

The source signals play the role of base vectors of expected image representation subspace, whereas the rows of matrix \(A\) represent the feature vectors. The ICA can estimate the sources based solely on the measurement data. The ICA-based texture description scheme is applied over conventional space to adjust the base functions to given images. The base functions are of general nature set in a heuristic way in conventional approaches. In ICA, the search in samples space for a non-orthogonal basis of a subspace that: retains structure of learning data, the base vectors correspond to interesting directions of sample structure; and also after individual rotations of sub-space vectors both an orthogonal basis and statistical independence of border distributions are achieved [50][51].

4 Research Methodology

An iris recognition system based on PSO and ICA for feature extraction is suggested in this work. The main steps of PSO for training/testing iris recognition system were implemented using MatLab2013. This section describes in details the database, training and testing steps of iris recognition system. Fig.2 shows 10 samples of two persons each with 5 images.
Fig. 1: PSO Algorithm

4.1 Iris Recognition Training Process

The training part of the suggested iris recognition system includes the following steps:
1. Read 100 images (each with 64x64 pixels) for 10 persons.
2. Each image is converted from two-dimension array (64x64) to one vector dimension 4096.
3. Add one byte to each image array (4096) of each person to be with size (4097). This byte is used to identify the person with ID and contains the same value for the 10 images of each person. As an example this byte includes the value 1 for the 10 images for person 1. The total size of the array containing the overall 100 images is 4097x100.
4. The person properties will be extracted by applying ICA algorithm for feature extraction. The ICA is computed for each image (with dimension 4097) to produce feature vector with size 64. Many experiments were conducted with different ICA feature vector length (128, 256, 512). At the same time one byte (ID) is added to each feature vector (65, 129, 257, 513) for person identification.
5. The classification PSO algorithm is used for each one of the 100 feature vectors (generated using ICA) to produce a classified PSO vector with length equal to swarm size plus one (for person ID) as follows:

   Step 1: initialize parameters of PSO algorithm as follows:
   - set swarm size (N) equal 80, 40, 20 separately for each experiments,
   - c1 equal 2, c2 equal 2, weight equal 0.7, number of Iterations equal to 100 and 200 for different experiments. Finally set ICA feature vector length equal to 64, 128, 256, 512 separately for each experiments.

   Step 2: initialize position and velocity (speed) of each sample. Initialize lbest and gbest.

   Step 3: Calculate fitness function of each sample.

   Step 4: Calculate optimal value of particle swarm (pbest) and optimum value of group (gbest) according to comparison between the current value of particle and the pbest and gbest.

   Step 5: Calculate the new speed of practical according to Eq. 1.

   Step 6: Compute the new position of particle according to Eq. 2.

   Step 7: repeat steps 3 to 6 while there are more iterations to be executed.

   Step 8: store the features sub set which are represented by vector with 40 values (according to population size) in sub features database: gaitdbf.

4.2 Iris Recognition Testing Process

The testing part of the suggested system is described by the following steps:
1. Read one image with 64x64 pixels for any person.
2. Convert this image from two-dimension array (64x64) to one vector dimension 4096.
3. Apply ICA for this image vector (4096) for feature extraction to produce feature vector with size either 64, 128, 256 or 512.
4. Apply PSO algorithm to this feature vector to produce a PSO vector with length equal to swarm size (20, 40, 80).
5. Compare this classified PSO vector with database containing 100 classified PSO feature vectors to determine which vector is most similar to the input vector.
6. Return the ID of the matched PSO vector.
5 Experimental Results

The implementation of PSO and ICA algorithms of the suggested iris recognition system was implemented using MATLAB 2013. Mean Square Error (MSE), peak signal to noise ratio (PSNR) and recognition rate (RR) were used to evaluate the performance of PSO based ICA model for iris recognition system. Many experiments were conducted for the suggested iris recognition based on the selected 100 images of 10 persons (each with 10 images).

In the first four experiments, the feature extraction process is achieved using ICA with feature vector length equal to 64, 128, 256 and 512 respectively. And PSO is executed with swarm size equal 80 and number of iterations equal 100. Table (1) shows the recognition rate, MSE and PSNR of these four experiments.

Table (1): PSO/ICA results
(Swarm size=80 and no. of iteration=100)

<table>
<thead>
<tr>
<th>ICA feature size</th>
<th>Reco.rate</th>
<th>MSE</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>90%</td>
<td>0.0122</td>
<td>30</td>
</tr>
<tr>
<td>128</td>
<td>94%</td>
<td>0.0098</td>
<td>32</td>
</tr>
<tr>
<td>256</td>
<td>96%</td>
<td>0.0055</td>
<td>34</td>
</tr>
<tr>
<td>512</td>
<td>98%</td>
<td>0.0011</td>
<td>38</td>
</tr>
</tbody>
</table>

We can note from Table (1) that best results including high recognition rate, high PSNR and low MSE were obtained when selecting ICA feature vector length equal 512.

Another 4 experiments were conducted for PSO with ICA. The ICA feature extraction process is achieved using different feature vector lengths equal to 64, 128, 256 and 512 respectively. Then PSO is executed with swarm size equal 80 and number of iterations equal 200. Table (2) shows the recognition rate, MSE and PSNR of these four experiments.

Table (2): PSO/ICA results
(Swarm size=80 no. of iterations=200)

<table>
<thead>
<tr>
<th>ICA feature size</th>
<th>Reco.rate</th>
<th>MSE</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>89%</td>
<td>0.0132</td>
<td>29</td>
</tr>
<tr>
<td>128</td>
<td>93%</td>
<td>0.0105</td>
<td>31</td>
</tr>
<tr>
<td>256</td>
<td>95%</td>
<td>0.0064</td>
<td>33</td>
</tr>
<tr>
<td>512</td>
<td>97%</td>
<td>0.0025</td>
<td>37</td>
</tr>
</tbody>
</table>

We can note from Table (2) that best results were obtained when selecting ICA feature vector length equal 512. We can note from Table (1) and Table (2) that increasing number of PSO iterations from 100 to 200 will reduce the performance of iris recognition system (lower recognition rate and lower PSNR).

Another 4 experiments were conducted for PSO with different ICA feature vectors length equal to 64, 128, 256 and 512 respectively. Then PSO is executed with swarm size equal 40 and 200 iterations. Table (3) shows the recognition rate, MSE and PSNR of these four experiments with swarm size equal 40 and 100 iterations.

Table (3): PSO/ICA results
(Swarm size=40 no. of iterations=100)

<table>
<thead>
<tr>
<th>ICA feature size</th>
<th>Reco.rate</th>
<th>MSE</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>88%</td>
<td>0.0154</td>
<td>29</td>
</tr>
<tr>
<td>128</td>
<td>92%</td>
<td>0.0123</td>
<td>30</td>
</tr>
<tr>
<td>256</td>
<td>93%</td>
<td>0.0087</td>
<td>32</td>
</tr>
<tr>
<td>512</td>
<td>95%</td>
<td>0.0034</td>
<td>36</td>
</tr>
</tbody>
</table>

We can note from Table (3) that best results were obtained when selecting ICA feature vector length equal 512. Another 4 experiments were conducted for PSO with different ICA feature vectors length equal to 64, 128, 256 and 512 respectively. Then PSO is executed with swarm size equal 40 and 200 iterations. Table (4) shows the recognition rate, MSE and PSNR of these four experiments with swarm size equal 40 and 200 iterations.

Table (4): PSO/ICA results
(Swarm size=40 no. of iterations=200)

<table>
<thead>
<tr>
<th>ICA feature size</th>
<th>Reco.rate</th>
<th>MSE</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>89%</td>
<td>0.0132</td>
<td>29</td>
</tr>
<tr>
<td>128</td>
<td>93%</td>
<td>0.0105</td>
<td>31</td>
</tr>
<tr>
<td>256</td>
<td>95%</td>
<td>0.0064</td>
<td>33</td>
</tr>
<tr>
<td>512</td>
<td>97%</td>
<td>0.0025</td>
<td>37</td>
</tr>
</tbody>
</table>

We can note from Table (4) that best results were obtained when selecting ICA feature vector length equal 512. We can note from Table (1) and Table (2) that increasing number of PSO iterations from 100 to 200 will reduce the performance of iris recognition system (lower recognition rate and lower PSNR).
Table (4): PSO/ICA results  
(Swarm size=40 no. of iterations=200)

<table>
<thead>
<tr>
<th>ICA feature size</th>
<th>Reco.rate</th>
<th>MSE</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>87%</td>
<td>0.0165</td>
<td>28</td>
</tr>
<tr>
<td>128</td>
<td>91%</td>
<td>0.0123</td>
<td>30</td>
</tr>
<tr>
<td>256</td>
<td>92%</td>
<td>0.0089</td>
<td>31</td>
</tr>
<tr>
<td>512</td>
<td>94%</td>
<td>0.0064</td>
<td>34</td>
</tr>
</tbody>
</table>

From Table (4), best results were obtained when selecting ICA feature vector length equal 512. Another 4 experiments were conducted for PSO with different ICA feature vectors length equal to 64, 128, 256 and 512 respectively. Then PSO is executed with swarm size equal 20 and 100 iterations. Table (5) shows recognition rate, MSE and PSNR of these four experiments.

Table (5): PSO/ICA results  
(Swarm size=20 no. of iterations=100)

<table>
<thead>
<tr>
<th>ICA feature size</th>
<th>Reco.rate</th>
<th>MSE</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>88%</td>
<td>0.0177</td>
<td>28</td>
</tr>
<tr>
<td>128</td>
<td>91%</td>
<td>0.0131</td>
<td>30</td>
</tr>
<tr>
<td>256</td>
<td>91%</td>
<td>0.0096</td>
<td>31</td>
</tr>
<tr>
<td>512</td>
<td>92%</td>
<td>0.0051</td>
<td>35</td>
</tr>
</tbody>
</table>

From Table (5), best results were obtained when selecting ICA feature vector length equal 512. Another 4 experiments were conducted for PSO with different ICA feature vectors length equal to 64, 128, 256 and 512 respectively. Then PSO is executed with swarm size equal 20 and 200 iterations. Table (6) shows the recognition rate, MSE and PSNR of these four experiments.

Table (6): PSO/ICA results  
(Swarm size=20 no. of iterations=200)

<table>
<thead>
<tr>
<th>ICA feature size</th>
<th>Reco.rate</th>
<th>MSE</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>87%</td>
<td>0.0171</td>
<td>27</td>
</tr>
<tr>
<td>128</td>
<td>90%</td>
<td>0.0132</td>
<td>30</td>
</tr>
<tr>
<td>256</td>
<td>91%</td>
<td>0.0093</td>
<td>30</td>
</tr>
<tr>
<td>512</td>
<td>92%</td>
<td>0.0078</td>
<td>32</td>
</tr>
</tbody>
</table>

From Table (6), best results were obtained when selecting ICA feature vector length equal 512.

5.1 Effect of Swarm Size on PSNR

We can note from Table (1), Table (3) and Table (5) that, the effect of swarm size (80, 40 and 20) on PSNR can be determined by using constant value of number of iterations (100) and constant value of ICA feature vector length (512) in the three experiments. Fig.3 shows that increasing swarm size will increase the PSNR of the reconstructed image.

5.2 Effect of Swarm Size on Recognition Rate

We can note from Table (1), Table (3) and Table (5) that, the effect of swarm size (80, 40 and 20) on recognition rate can be determined by using constant value of number of iterations (100) and constant value of ICA feature vector length (512) in the three experiments. Fig.4 shows that increasing swarm size will increase the recognition rate.

5.3 Effect of Swarm Size on MSE

We can note from Table (1), Table (3) and Table (5) that, the effect of swarm size (80, 40 and 20) on MSE can be determined by using constant number of iterations (100) and constant ICA feature vector length (512) in the three experiments. Fig.5 shows that increasing swarm size will decrease the MSE of the reconstructed image.
5.3 Recognizing un Trained Images

In additional experiments, the performance of the suggested iris recognition system is evaluated also using un trained iris images (i.e. images were not used in training process). The feature extraction process is achieved using ICA with feature vector length equal to 64, 128, 256 and 512 respectively. And PSO is executed with swarm size equal 80 and number of iterations equal 100. Table (7) shows the recognition rate, MSE and PSNR of these experiments.

Table (7): PSO/ICA results /untrained (swarm size=80 and no. of iteration=100)

<table>
<thead>
<tr>
<th>ICA feature size</th>
<th>Reco.rate</th>
<th>MSE</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>47%</td>
<td>0.6725</td>
<td>13</td>
</tr>
<tr>
<td>128</td>
<td>48%</td>
<td>0.6235</td>
<td>15</td>
</tr>
<tr>
<td>256</td>
<td>51%</td>
<td>0.5874</td>
<td>17</td>
</tr>
<tr>
<td>512</td>
<td>53%</td>
<td>0.5673</td>
<td>19</td>
</tr>
</tbody>
</table>

We can note from Table (7) that the best results of recognizing untrained images (highest recognition rate, highest PSNR and lowest MSE) are achieved when using ICA feature size = 512.

6 Conclusions

Iris recognition system is suggested in this work depend on PSO algorithm. ICA algorithm is used as a feature reduction and extraction algorithm. To improve the performance of PSO. This system training and testing programs of the PSO and ICA algorithms were implemented using MATHLAB 2013. The training and testing samples of the suggested iris recognition system was taken from web site. Many experiments were conducted using different: swarm size (20, 40 and 80), number of iterations (100 and 200) and ICA feature vector length (64, 128, 256 and 512).

The results shows that the iris recognition performance (high PSNR, high recognition rate and lower MSE) will be increased when increasing the ICA feature vector length to 512 and also increasing the swarm size to 80 with decreasing the number of iterations to 100. Best obtained recognition rate is 98%, best PSNR is 38 and lower MSE is 0.0011, this is taken when selection 100 PSO iterations, ICA feature size to 512 and swarm size equal 80. The suggested iris recognition system has the ability to recognize un trained iris images but with performance lower than the performance of it when using trained iris images.

As a future work, other feature reduction and extraction algorithms may be used such as Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT) and Linear Discriminative Analysis (LDA). These algorithms will be used separately with the PSO algorithm. Comparisons between the results of each algorithm.

7 References

[6] Libor Masek, Recognition of Human Iris Patterns for Biometric Identification, Bachelor of Eng. degree, School of Computer Science and SW Eng., University of Western Australia, 2003.


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