Face Recognition Using Harmony Search-Based Selected Features

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Abstract

Harmony search algorithm (HSA) is an evolutionary algorithm which is used to solve a wide class of problems. HSA is based on the idea of musician's behavior in searching for better harmonies. It tries to find the optimal solution according to an objective function. HSA has been applied to various optimization problems such as timetabling, text summarization, flood model calibration. In this paper we used HSA to select an optimal subset of features that gives a better accuracy results in solving the face recognition problem. The proposed approach is compared with the standard Principal Component Analysis (PCA). A set of images that each has a face adopted from the literature is used to evaluate the proposed algorithm. The obtained results show that using HSA to select the subset of features gives better accuracy in face recognition.

Keywords: *Face Recognition, Evolutionary Algorithms, Harmony Search, Principal Component Analysis.*

1. Introduction

Object recognition is the problem of matching shapes from a database with similar objects found in images. The importance of object detection and recognition comes from the wide range of applications that uses it in real life, such as biometric recognition, optical character recognition, and digit and document recognition.

Face recognition problem [30] is the problem of automatically identifying a human face from a database of images. The face recognition problem is challenging, due to the multiple possible variations of the appearance caused by the change in illumination, facial features, occlusions, etc. It has been studied extensively and used in security systems [25]. In addition, the biometric recognition system which is based on iris or fingerprint has become reliable technologies [26]. Other object recognition applications include: surveillance, industrial inspection, content-based image retrieval (CBIR), robotics, medical imaging, human computer interaction, and intelligent vehicle systems [1].

In general, face recognition systems involves three steps; face detection, feature extraction, and face recognition. As illustrated in Figure 1.

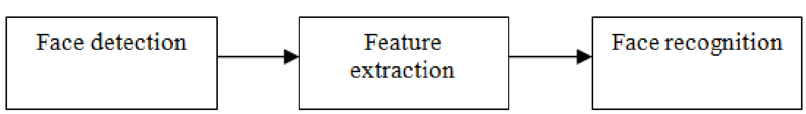

Figure 1. Steps in Face Recognition System

Face detection is the process of extracting and locating faces in an image. The feature extraction step extracts the most relevant facial features from the images dataset. These features could be certain face regions, or distances and angels between the parts of the face. In the recognition step, the system would return the matched image from the database. Many applications don't need face detection step, since normalized images are stored in the database, and the input image have a standard format.

Principal component analysis (PCA) [28] is a mathematical method that transforms a number of possibly correlated variables, into a smaller number of un-correlated variables called principal components. PCA is a popular technique which can be used to derive a set of features that is applied for face recognition. Any face can be economically represented along the Eigen pictures coordinate space, and approximately reconstructed using a small collection of Eigen pictures. This can be done by projecting a face image to several face templates called Eigen faces. These can be considered as a set of features that represent the variation between face images.

Once a set of Eigen faces is computed, a face image can be approximately re-constructed using a weighted combination of the Eigen faces. The projection weights form a feature vector that is used for face representation. When a new test image is given, the weights are computed by converting the image into the Eigen face vectors. The classification is then carried out by comparing the distances between the weight vectors of the test image, and the images from the database.

A face recognition technique based on PCA is not optimal, due to the fact that larger Eigen values does not necessary contains the most important aspects of the data in terms of classification [27]. The recognition based on PCA is called the standard PCA for face recognition.

Harmony search algorithm (HSA) is an evolutionary algorithms used to solve a wide class of problems. HSA is based on the idea of musician's behavior in searching for better harmonies. It tries to find the optimal solution according to an objective function. HSA has been applied to various optimization problems such as timetabling, text summarization, flood model calibration, and hearing aids [2].

In this paper, we use the HSA to select an optimal combination of Eigen vectors. The features obtained will have the best classification ability for a better face recognition accuracy. The proposed approach is compared with the standard PCA on a set of images that each has a face which is adopted from the literature.

2. Background

2.1. Face Detection and Recognition

Face recognition is a part of the object detection problem. It is a complex and challenging problem in the field of computer vision, because of the large number of variations caused by the changes in facial appearance, lighting, and expression [31]. There are many methods applied to solve the problem of face recognition [23]:

1. Knowledge-based method, which encode the human knowledge of what constitutes a typical face (usually, the relationships between facial features).
2. Feature invariant approaches; which aims to find the structural features of a face which exist even when the pose, view point, or lighting conditions varies.
3. Template matching methods, that use several standard patterns stored to describe the face as a whole or the facial features separately. It calculates the correlation between a test image and pre-selected facial templates.

4. Appearance-based methods, in which the models (or templates) are learned from a set of training images which captures the variability of facial appearance. This method adopts machine learning techniques to extract important features from a pre-labeled training set.

Many methods used to perform the recognition process, some methods involve face detection, while other needs to identify the class of the face. Etemad and Chellappa [31] proposed a new approach for human face recognition. In their system they used the Linear Discriminates Analysis (LDA) for feature extraction. LDA tries to obtain the differences between different classes of images. It requires that the data points from the same class to be close as much as possible. LDA extracts the most relevant features that carry the most relevant information for the classification. In a database with medium size, the system achieved excellent classification accuracy, with a small number of features.

Cheng et al. [32] proposed a novel method named Supervised Kernel Locality Preserving Projections (SKLPP) for face recognition. In this method, geometric relations are preserved according to the last class information. They used images with real faces that contains complex nonlinear variations.

Latha et al. [30] used the neural network to recognize faces. Their algorithm involves the following steps:

1. Pre-processing stage; in which the images are made zero-mean and unit-variance.
2. Use PCA to reduce the dimensionality of the image in order to improve the classification process.
3. The reduced vectors produced by the PCA are applied to train the neural network classifier to obtain the recognized image.

Their method has the ability to recognize non linear face images, and it has 90% acceptance ratio.

One of the most popular approaches that are based on machine learning is designed by Viola and Johns [3]. The approach was tested on complex images with variants in illumination, scale, and pose. The first stage of the technique converts the image into a new representation of called integral image. This representation allows the features to be computed very quickly. Using integral image, the location x, y is the sum of the pixels above, and to the left of x, y, as shown in Figure 2.

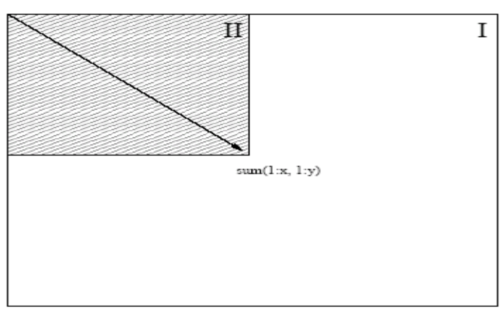

Figure 2. Integral Image Representation [3]

The second stage is the learning stage. The AdaBoost learning algorithm is used to boost the classification performance. The final stage is called cascade, which is used to reduce the part of the image where the classifier is applied (i.e., discarding background regions and spending more computation time on object-like features). In their approach they achieved good results, but a large time has been consumed in the learning stages. The AdaBoost has three operations:

1) Evaluate the features, and this requires between 6 and 9 arrays references per feature.
2) Compute the weak classifier for each feature, and this require one threshold operation per feature.
3) Combine the weak classifiers, and this require one multiply, one addition, and a threshold operation.

In order to reduce the computations complexity, Torralba et al. [4] introduced a new algorithm called joint boosting. In joint boosting algorithm for each possible subset of classes there is a feature which is used to distinguish the face from the background. The algorithm repeat choosing the best ones until a predefined number of features is reached, or until the error reduced on the weighted training set for all classes. This detection technique has a good performance because the classifiers are jointly trained, so they shared features as much as possible and make the number of features and training set as few as possible. Using this framework the parts can be used to detect the face.

Heisele et al. [5] presented a fast method for face detection using Support Vector Machines (SVMs) as a classifier. Their system includes two steps: first, the features are extracted using Principle Component Analysis (PCA). The features are ranked according to their scaling factors, and the optimal ones are selected using the criterion of the classification algorithm. Second, the hierarchical classifiers is used which consist of several levels. The bottom level is the stage where the background parts in the whole image are removed. The top level is the stage where more accurate detection is performed, because it uses the best classifier with a non linear SVM. In the top level if the face is not centered in the classier window, it will be classified as a non-face. Applying the feature reduction to all levels of hierarchical classifier may give better results, but it requires more computations.

Levi and Weiss [6] introduced an approach to detect faces which focused on using a small training database. It depends on selecting a good feature that is crucial to the system ability to learn from a small number of examples. The local Edge Orientation Histogram (EOH) is used to increase the recognition performance when compared with Viola-John's linear edges and average intensity features. The EOH is invariant to global illumination changes in the images, and it has the ability of capturing geometric properties of objects. Using only 250 examples, the system achieved excellent results.

Another work performed by Schneiderman and Kanade [7] in which they detect faces and cars at any size, location and pose by using multiple classifiers. Each classifier determines whether a face or a car resides at a specific position and pose. At the learning stage, an image and a series of resized copies of that image are scanned to increase the algorithm ability of detecting objects variations in size and location. The input variables are grouped into parts (sets). For example, eyes, nose and mouths are parts of a face. The variables within a part are statistically dependent, while the parts are statistically independent. The system can be used to detect cars and faces only.

There are other systems that are not feature-based, such as Neural Networks-based systems by Gracia and Delackis [15], and Sung and Paggio [16]. A convolutional Neural Network is used by Osadchy et al. [17] as the basic architecture of a face detector. Raw pixels are used to learn low-level features and high-level representation. One disadvantage of Neural Networks is that there is no semantic information that is available in the statistical classifiers [18].

2.2. Face Recognition using Evolutionary Algorithms

Evolutionary algorithms (EAs) are stochastic optimization techniques inspired by the natural evolution [33]. EAs such as genetic algorithm and particle swarm algorithm are used in to solve the problem of face recognition.

GA (Genetic Algorithm) and GP (Genetic Programming) are optimization procedures inspired by the biological mechanisms of reproduction. They have been used to solve different problems including face detection. Sun et al. [8] presented a simple general and powerful approach for face detection. The approach concentrate on the importance of finding optimal subset of features that is relevant to the problem of interest (see Figure 3).

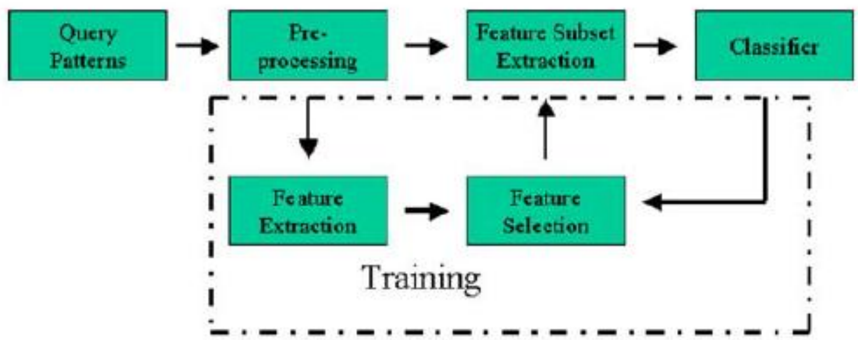

Figure 3. The Structure of the Object Detection System [8]

Principle Component Analysis (PCA) is used in the stage of feature extraction. It linearly serializes the image in a low dimensional space. Then the GA is used to select the optimal features according to their fitness function.

In the feature selection stage the initial population is generated randomly (sequence of 0s and 1s). Then using offspring to double the size of the population and selecting the best individuals from the combined old and new individuals. Support Vector Machines (SVMs) are used for classification. The experimental results showed that their method improves the face detection accuracy.

Ramadan and Abdel-kader [34] used the particle swarm optimization (PSO), which is based on the collaborative behavior of the birds flocking or fish schooling. PSO is used to reduce the number of features, remove irrelevant, noisy and redundant data to achieve more accuracy in face recognition. In feature extraction phase they used Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). Then, the PSO searches for the most representative feature subset through the feature space.

The Euclidean distance is a classification technique which is used to measure the similarity between the input vector and the reference vectors in the database. Euclidean distance represents the straight line distance between two points p and q. The PSO-based algorithm compared with GA-based algorithm and was found to yield comparable results with fewer numbers of features.

Anam et al. [35] proposed a face recognition system using genetic algorithm and back-propagation neural network. The system consists of three phases. The first phase, in which the input image is pre-processed, by removing the noise in the image using filtering techniques. Then the image is clipped to remove un-necessary parts such as backgrounds. After that, an edge detector is applied. The second phase extracts features from the image. The final phase is the recognition phase, that uses the extracted features in the genetic algorithm and back-propagation neural network. The maximum efficiency of face recognition using genetic algorithm is 82.61%, while it is 91.30% for face recognition using back-propagation neural network.

3. Harmony Search Algorithm

One of the proposed algorithms in the field of evolutionary algorithms is the harmony search algorithm (HSA). It is a meta-heuristic algorithm that is based on the improvisation of harmony in the music composition where musicians improve their instrument's pitch searching for a best state of harmony.

HSA developed recently by Geem in 2001 [2]. In HSA each decision variable initially assigned a value randomly within the allowed range. These values jointly make one solution vector. All these solution vectors are stored in the harmony memory. There is a correspondence between the improvisation process in music and the optimization process in HSA. The harmony corresponds to the optimization solution vector, the musicians correspond to decision variables, and musical instrument's pitch range analogous to decision variable's value range. Harmony at a certain time analogous the solution vector at a certain iteration, and audience's agreements corresponds to objective function.

When each variable selects one value in the HSA, it will follow one of three rules:

- Selecting a random value from the allowed range.
- Selecting a value from the harmony memory.
- Selecting an adjacent value of one of the values in the harmony memory.

These rules are similar to the musician's behavior which is used to produce a piece of music with perfect harmony:

- Composing new or random notes.
- Playing any famous tune exactly from his or her memory.
- Playing something similar to the aforementioned tune.

Any of the optimization problems that will be solved by HSA should have an objective function to be minimized or maximized and a number of constraints that shouldn't be violated. If any of the solution vectors violates any of the constraints, ignore the vector or add a certain amount of penalty to the objective function value.

Harmony Search algorithm has a set of parameters that should be set with certain values, these parameters are: Harmony Memory Size (HMS) which is the number of solution vectors in harmony memory. Harmony Memory Considering Rate (HMCR) $\in$ [0, 1], Pitch Adjustment Rate (PAR) $\in$ [0, 1], Maximum Improvisation (MI) and Fret Width (FW) [22].

The main steps of the algorithm are:

1. Initialize the optimization problem (problem formulation) and the parameters of the algorithm.
2. Initialize the Harmony Memory (HM).
3. Improvise a new harmony from the HM.
4. Update the HM.
5. Repeat steps 3 and 4 until the termination criterion be satisfied.

4. Methodology

In this paper we develop an approach which correctly recognizes an input face, and matches this face with the faces in the database based on harmony search algorithm. This is performed by selecting the optimal combination of features. Recognition performance has many measurement standards. The most important and popular formula is the recognition rate [38, 40]:

$$Recognition\ rate = \frac{the\ number\ of\ recognized\ images}{the\ number\ of\ testing\ images}$$

Finding a good fitness function that maximizes the recognition rate is a critical point to gain an efficient recognition system. The Harmony Search Algorithm (HSA) shows promising performance in different problems such as Document clustering [19], Solving Sudoku Puzzles [21], Design of water distribution network [20] and network decomposition in power systems [24]. We use the HSA to select the optimal subset of features that is needed to solve the problem of face recognition.

4.1. Principle Component Analysis (PCA)

Principle Component Analysis is a mathematical procedure used to extract the features from an input image. There are two types of features [36]:

1. Holistic features: where each feature is a characteristic of the whole face.
2. Partial features (hair, nose, mouth eyes, etc.), which make some measurements for many crucial points of the face.

PCA is a holistic feature technique, it reduce the dimensionality of the data space to a smaller dimensionality of feature space [36].

A face, which is an image, can be viewed as a vector. For an image with width M and height N, the vector has M * N components. Each pixel is coded by one vector component. The construction of this vector from an image is performed by a simple concatenation, such that the rows of the image are placed beside each other, as shown in Figure 4.

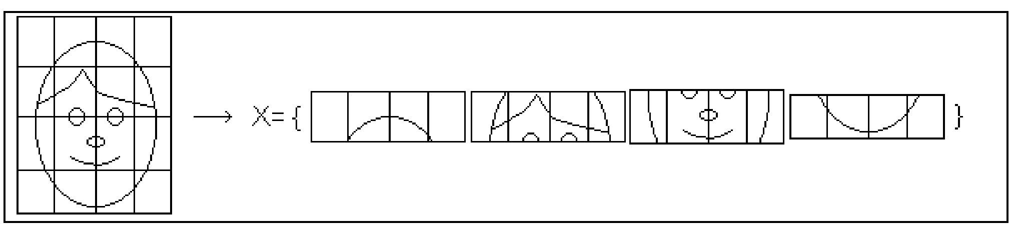

Figure 4. Face as Vector

If we define the image pixel values as $X_i = [p_1 \ldots p_n]^T$, $i= 1, \ldots, M$ [29], Where p_j is the pixel value. The mean image calculated according to the equation:

$$m = \frac{1}{M}\sum_{i=1}^{M} Xi$$

Then m which represents the mean image is subtracted from the image vector X_i, producing the mean centered image w_i according to the equation $w_i = x_i - m$. The goal of

PCA is to find a set of Eigen vectors *ei's* which have the largest possible projection onto each of the *wi's*.

$$\lambda_i = \frac{1}{M}\sum_{i=1}^{M}(e_i^T w_n)^2$$

Where λ_i is the eigenvalue. The e_i's and λ_i's are given by the Eigen vectors and Eigen values of the covariance matrix

$$C = WW^T$$

Where W is a matrix composed of the column vectors w_i placed side by side. The size of C is large. For example, an image of size 64 X 64 creates the covariance matrix of size 4096 X 4096, so the Eigen vectors and Eigen values of the covariance matrix $W^T W$ [29].

4.2. Harmony Based Face Recognition System

The harmony search algorithm is used to select the optimal combination of features that give an optimal matching. PCA recognition system uses limited number of features that have the highest weights, so using PCA to recognize faces is not efficient because it uses only those features that have the highest Eigen values. We increased the number of features used in the recognition process. This is illustrated in Figure 5.

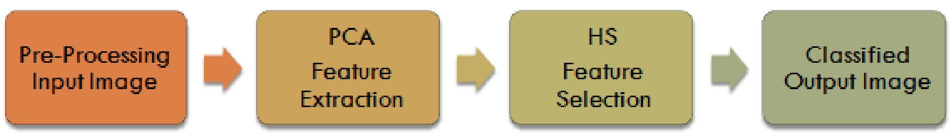

Figure 5. Block diagram of HS-based recognition system

The full image space is not an optimal space that describes the face. The task of PCA aims to build a face space which better describes the faces. The basis vectors of this face space are called the principal components.

The dimension of the image space is *number of rows* * *number of columns*. The pixels of a face image are related, and each pixel depends on its neighbors. So, the dimension of the face space is less than the dimension of the image space. The dimension of the face space cannot be determined, but it is sure that it is to be far less than that of the image space.

PCA aims to catch the total variation in the set of the training faces, and to explain this variation by a few variables. Reducing the dimension is important due to the fact that a few variables is easier to handle, and when many faces have to be processed the dimensionality reduction is an important point.

4.3. Harmony Representation

Each vector in the initial harmony memory is produced by random generation of 1s and 0s. In this representation, 1 means that the feature is selected, while 0 means it is not selected. The task of the harmony search algorithm is to select the optimal subset of features.

In each generation, each harmony is evaluated, and a value of goodness is returned by a fitness function. This evolution is driven by the fitness function that evaluates the quality of evolved harmonies in terms of their ability to maximize the class separation term indicated by the scatter index among the different classes [37].

Suppose w_1, w_2 ,..., w_L are the classes of images, and N_1, N_2 , ..., N_L are the number of images within each class. Then we calculate M_1, M_2 ..., M_L as the means of image classes and it is calculated as follows [37]:

$$M_i = \frac{1}{N_i}\sum_{j-1}^{N} W_j^{(i)} \ , i = 1, 2, \ldots, L$$

Where $W_j^{(i)}$, denotes the images in the class w_i.

In this case M_0 is the grand mean in the feature space, which calculated as follows [37]:

$$M_0 = \frac{1}{N}\sum_{i=1}^{L} N_i M_i$$

Where N is the total number of images in all classes. Thus the scatter measurement among classes is given by the equation [37] $F = \sqrt{\sum_{i=1}^{L}(M_i - M_0)^t (M_i - M_0)}$.

An overview of the proposed HS-based feature selection algorithm is shown in Figure 6.

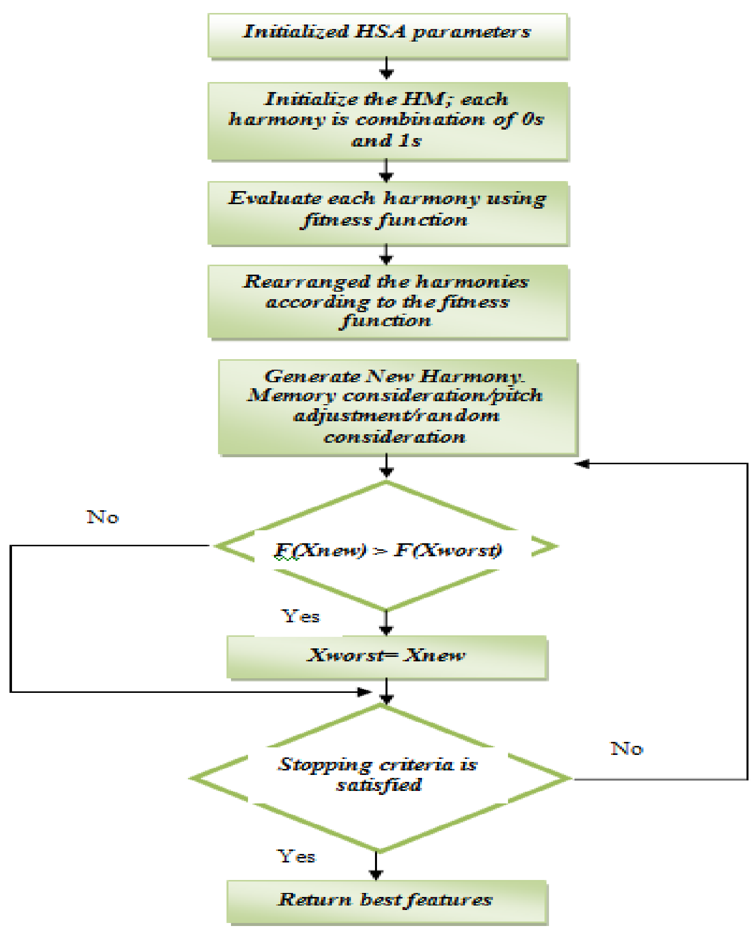

Figure 6. The HS-based Feature Selection Algorithm

4.4. Euclidean Distance

The well-known Euclidean distance is used to measure the similarity between the test vector and the reference vectors in the training set. Euclidean distance is defined as the straight-line distance between two points. For N-dimensional space, the Euclidean distance between two points p_i and q_i is given by [34]:

$D = \sqrt{\sum_{i=1}^{N}(p_i - q}$, Where p_i and q_i is the coordinates of p and q in dimension i.

4.5. Cosine Similarity

Another face matching distance classifier method commonly used is the cosine similarity. For any two given vectors x and y, the cosine similarity, θ, is represented using a dot product and magnitude as [41]:

$$\textit{Cosine Similarity}(x, y) = (x^T y / ||x||.||y||)$$

For face matching, the attribute vectors x and y are usually the term frequency vectors of the images. The cosine similarity can be seen as a method of normalizing image length during comparison. The resulting similarity ranges from −1 meaning exactly opposite, to 1 meaning exactly the same, with 0 usually indicating independence, and in-between values indicating intermediate similarity or dissimilarity.

5. Evaluation and Results

5.1. Introduction

The harmony Search Algorithm's parameters are set according to [39], where the value of HMCR = 0.9, their results showed that increasing the HMCR value improves the performance of the algorithm. PAR = 0.3, in their results there were no single choice that is superior to the others. The HS = 5, there is no affects of this choice over others, except that using a small HM size reduces the space requirements. NI = 50,000 evaluations of the objective function; increasing the number of improvisations increases the possibility to obtain the optimal subset of features. Since the elements of the harmony are 0s and 1s, the step of pitch adjustment involves flipping the value.

The performance of the proposed face recognition system is evaluated using the standard Cambridge ORL gray-scale face database. The ORL database of faces contains a set of face images taken between April 1992 and April 1994 at the AT&T Laboratories by the Oliver Research Laboratory in Cambridge, United Kingdom [34].The database is composed of 400 images corresponding to 40 distinct persons. The images are in PGM format. The original size of each image is 92x112 pixels, with 256 grey levels per pixel. Each subject has 10 different images taken in various sessions varying the lighting, facial expressions (open/ closed eyes, smiling/ not smiling) and facial details (glasses/ no glasses). All the images were taken against a dark homogeneous background with the subjects in an upright, frontal position. The first 20 image classes were used. Five images per person were used in the training set, and the remaining five images were used for testing. Figure 7 shows sample images from the ORL face database.

Figure 7. Sample Images of the Dataset

PCA is used to extract eigenvectors that can be thought of as a set of features that together characterize the variation between face images. It is possible to display these Eigen vectors as a sort of ghostly face image which is called an "eigen face". The average face of training images and Eigen faces of the face images are shown in Figure 8.

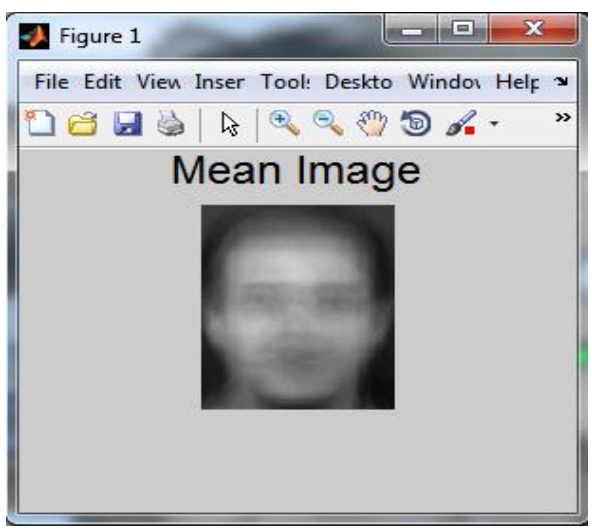

Figure 8. Average Face of the Sample Faces

Face recognition systems can be measured using different standards. We used the most common formula that measures the recognition rate which mentioned in section 4.

To evaluate the performance of the proposed face recognition system, a human judge inspects the results to decide if the recognized face is similar to the test face or not. The answer will be either true match or wrong match. In the evaluation we tested 200 images (faces) from 20 classes. First, the feature extraction and feature selection steps were performed, and then the target image to be recognized was selected. The system returned the matched image, which maybe correct match or not. The number of recognized images is divided on the number of testing images to gain recognition rate of the system.

5.2. Experimental Results

The experiment was performed using variant sizes of training samples. During the first test, 3 images were used as training samples and the recognition rate was computed using the system based on HSA for feature selection. In the next test, 5 images were used as training samples. The experimental result showed that each time the number of training images increased the recognition rate is increased. Figure 9 shows the face to be recognized and the result using our recognition system.

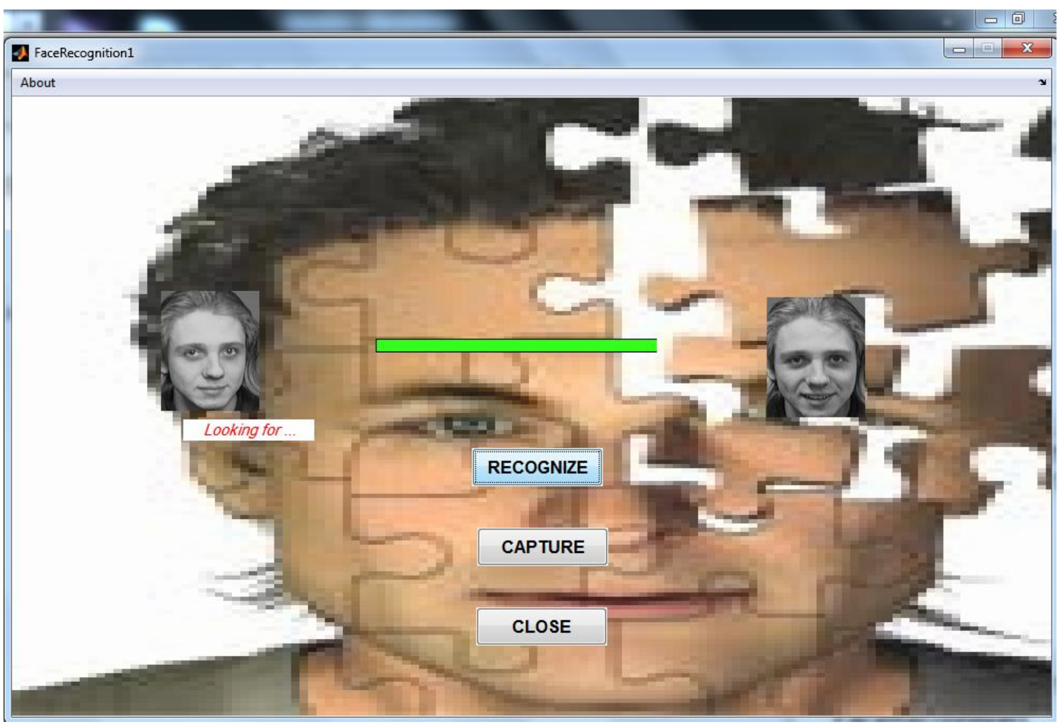

Figure 9. Recognized Image Using the Proposed System

Table 1 shows the recognition rate for the Harmony Search Algorithm for feature selection with different number of training samples.

Table 1. Recognition Rate with Different Number of Training Samples

Recognition Rate	Number of Training Images
75.2%	1
77.4%	2
85.8%	3
90%	4
94%	5

The performance of the proposed approach in terms of its recognition rate is compared with the standard PCA where only the Eigen faces with the highest Eigen values were selected. As shown in Table 2, the proposed approach based on HSA for feature selection achieved a recognition rate of 94% which is better than the recognition rate of the standard PCA that achieved 80.5%. The test conditions for standard PCA and the proposed method are the same, where five images from every class were used as training images while the rest five images used as test images.

Table 2. Comparison between Standard PCA and the Proposed Approach

Method	Recognition Rate	Test Condition
Standard PCA	80.5%	Five images per person were used in the training set and the remaining five images were used for testing.
PCA+HS for feature Selection	94%	Five images per person were used in the training set and the remaining five images were used for testing.

Now a comparison between the two classifiers that were used: the Euclidean distance and the Cosine similarity. The system evaluated twice, at first time the Euclidean distance used, while in the second the Cosine similarity is used. The comparison between the classifiers recognition rate is shown in Table 3. The results showed that the system performs the same for both Cosine similarity and Euclidean distance.

Table 3. Comparison between the Two Classifiers

Classifier	Recognition Rate
Euclidean Distance	94%
Cosine Similarity	93.5%

6. Conclusion and Future Work

In this paper, a novel HS-based feature selection algorithm for face recognition is proposed. The algorithm is applied to feature vectors extracted by a feature extraction technique called Principle Component Analysis (PCA). The algorithm is utilized to search the feature space for the optimal feature subset. Evolution is driven by a fitness function defined in terms of class separation.

The performance of the proposed approach evaluated using the ORL face database. The experimental results show the superiority of the HS-based feature selection algorithm in generating excellent recognition accuracy with a minimal set of selected features. The performance of the proposed algorithm is compared to the performance of the standard PCA that used the highest Eigen values in the classification. Our proposed algorithm yield a comparable recognition accuracy results with less number of selected features.

In the classification phase; two classifiers were used; Euclidean distance and Cosine similarity. The performance of the face recognition system is almost similar for both Euclidean distance and cosine similarity.

In the future, the performance of the proposed face recognition algorithm can be improved in terms of recognition rate, time and memory space by using improved Harmony Search Algorithm for feature selection. For example Global-best Harmony Search or Binary Harmony Search can be used and compared with the obtained results. In addition, another fitness function can be used to get the optimal subset of feature selected for classification.

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