Journal of Information Assurance and Security.
ISSN 1554-1010 Volume 11 (2016) pp. 385-394


# A New Scheme for Face Recognition System Using a New 2-Level Parallelized Hierarchical Multi Objective Particle Swarm Optimization algorithm

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*Abstract*: **Video surveillance and security are still studied in recent works due to its application in wide range of applications. Biometric provides a consistent solution to recognize identity of persons. The use of physiologic traits like Fingerprint, Iris, Face, Retina, etc. is more recommended. Face recognition problem is still an area of research where we can further widen the gap nil unless new approaches and techniques. The feature selection for face recognition domain is defined in this article and is treated by a new multi-objective optimization approach called pareto bi-directional Multi Objective Particle Swarm Optimization (pbMOPSO), known for its rapid convergence, its distributed hierarchical architecture. The sub-swarms are obtained from the dynamic population subdivision using Pareto fronts. The algorithm deals with a problem defined by two goals, characterized by contradictory aspect, ie, maximize the classification performance and minimize the number of features. Both objectives are addressed simultaneously constituting the objective function. To evaluate our effective representation of features, we compared our approach with other techniques like Genetic Algorithm (GA) and minimum Redundancy maximum Relevance (mRmR). This comprehensive experimental study was carried out on popular databases for face recognition ORL and Caltech faces. The experiments demonstrates that our new scheme for face recognition based on pbMOPSO highlights performance more than other bio-inspired features selection techniques such as Genetic algorithm.**

***Keywords***: Multi-Objective Problem, MOPSO, Features Selection, Classification

## I. Introduction

Biometric is method used to recognize human identity based on morphological, behavioral and organic characteristics like fingerprint, iris, face, retina, palm and hand geometry, etc. Face is very important research field due to its wide range of its application in many contexts such as access control, portable media, time attendance systems [1],[2], etc. In this paper, face modality is used due to its simplicity and intuitiveness. Face is used by the human brain to recognize people. Face can be acquired at distance without user implication in recognition process, contrary to the fingerprint which has shown great efficacy. The Multi-Objective Problem solving process is one of the system stages that help with the decision making (see figure 1). The decision makers is to choose between three types of criteria; the ones defined either before the optimization phase, at the end of the resolution, or throughout the optimization process.

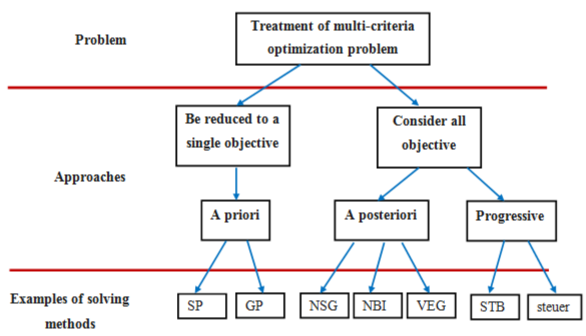


**Figure. 1**: Approaches to multi−objective optimization

The main difficulty of a Multi-Objective Problem is that there is no definition of the optimal solution. The decision maker may simply reflect the fact that a solution is better than another, but there is no better solution than all the others. To solve this problem, the scientific community has adopted two types of behavior. The first consists in bringing a Multi-Objective Problem to a single objective one in order to avoid any problem meaningless. The second is an attempt to provide answers to the problem while taking into account all the criteria. The main quality of a multi-purpose solver is to make the decisions easier and less subjective. Many applications can be solved by MOPSO [29] [30]. In this paper, as application of techniques of optimization, the security establishment is an important objective to accomplish. For this raison, we propose in this paper to develop a secure biometric system based multi-objective particle swarm optimization. The remainder of this paper is organized as follows: In section 2, a brief overview of the PSO and their application to the multi-objective face recognition domain are presented. In section 3, we describe the proposed solution for feature selection problem, the developed approach and the problem description. The experimental phase of the proposed approach is assessed in section 4. Finally, section 5 contains the concluding remarks.

## II. State of the art

### *A. Related work on face recognition*

Face recognition refers to techniques used for features extraction, features selection and features classification. Figure 2 gives the generic architecture of face recognition system.

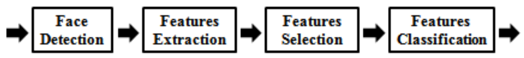


**Figure. 2**: Generic architecture of face recognition system

Face detection is categorized in three classes since recently scientific works. Face detection based on knowledge [3] which consists on definition of some rules like symmetry of eyes, Region of Interest of eyes are darken than mouth and nose areas, etc. Rules definition is the major drawbacks of these methods. Face detection based on Template Matching [4]. Templates used for similarity measure are based essentially on Sobel edge detection [3],[4] of each facial part like eyebrows, eyes, nose and mouth. These approaches are limited by accessories such as eyeglasses, beard and moustache. Face detection based on invariant features like the use of skin color segmentation [5]followed by some morphological operations to select right faces using width height ratio and area of the face. Viola and Jones proposed [6] a robust approach for face detection based on harr-like features and cascade Adaboost classifiers. Viola and Jones algorithm is used in this paper for face localization in images form ORL and Caltech Faces databases. Features extraction consists on new facial image representation with a set of characteristics computed by applying of different descriptors categorized in literature as shown in figure 3.

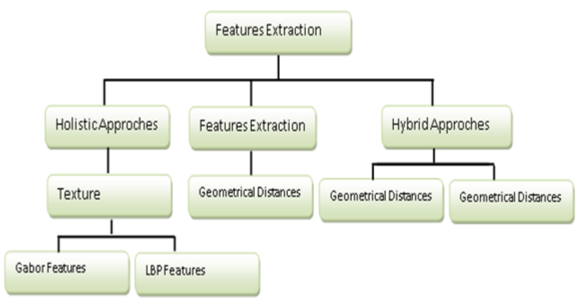


**Figure. 3**: Categorization of popular features extrcation descriptors

Features extraction approaches can be categorized in three families. Holistic approach based on application of textures descriptors (as example expanded in many scientific proposed face recognition systems) like Gabor filter [7], Local Binary Pattern (LBP) [8] operators, SIFT [9], Zernike Moments [10] and SURF features [11] on the whole face. Features based approaches which used geometrical distances [12] between facial parts. Many related works defined a set of distances measures and angles between eyes, nose, mouth and jaw. Hybrid approach consists on the application of descriptors used in holistic approach but not on the whole image. Facial parts localization is much recommended in hybrid approaches to apply descriptor in modular way like modular PCA [14], modular LDA, modular Gabor and modular LBP

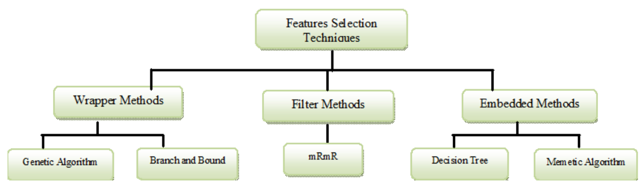


**Figure. 4**: Categorization of popular features selection techniques

Features Selection consists on choice of most relevant features which can differentiate human faces. The surveys comparison [13] of selection methods are multiple in literature. We note three families of features selections methods: Wrappers, Filters and Embedded techniques. Wrappers methods use training set as a block box and the selection will be conducted by a prediction power computing. Filters methods are based on cascade selections techniques to eliminate at each stage the worst features. Embedded methods are based on learning of each feature in training set. Features selection is an interesting component to succeed face recognition. Figure 4 illustrates categorization of some techniques used in literature for features selection performed in case of Pattern Recognition and Computer Vision fields. Features classification is the last step in face recognition process. Many methods are offered in literature to validate the identity of users. There are three approaches of face classification

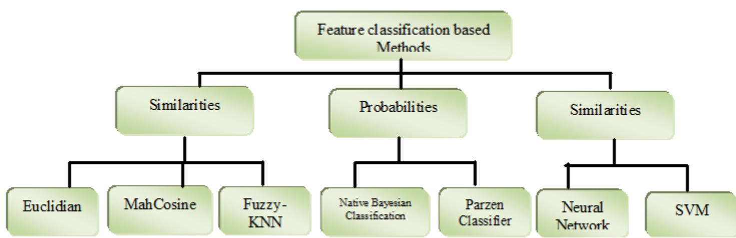


**Figure. 5**: Categorization of popular features Classification techniques

Classification based similarities. It is the simplest method for classification, which computes similarity between user to identify and users enrolled in database. It is based on measure similarity which can be based on many types of distances like Euclidian [9], Cosine, MahCosine [7], Hausdroff, etc. Classification based on Probabilities. We compute in this case the probability of the membership of object to such class. In literature, authors used nave Bayesian classifier [7]and Parzen classifiers. Classification based on Decision Boundary. Many types of classifiers are used in literature to classify object. We note as example Neural Network [7], Binary Decision Tree, RBF, and Support Vector Machines [8], etc.

### *B. Related work on Evolutionary Methods*

An important problem of pattern recognition is to extract or select feature set, which is included in the pre-processing stage. In order to extract feature set, principal component analysis has been usually used and SFS (sequential forward selection) and SBS (sequential backward selection) have been used as a feature selection method. Weston, et al. (2001) [15] introduced a method of feature selection for SVMs which is based upon finding those features which minimize bounds on the leaveone-out error. The method was shown to be superior to some standard feature selection algorithms on the data sets tested. Xing, Jordan and Karp (2001) [16] successfully applied feature selection methods (using a hybrid of filter and wrapper approaches) to a classification problem in molecular biology involving only 72 data points in a 7130 dimensional space. They also investigated regularization methods as an alternative to feature selection, and showed that feature selection methods were preferable in the problem they tackled. Forman (2003) [17] presented an empirical comparison of twelve feature selection methods. Results revealed the surprising performance of a new feature selection metric, Bi-Normal Separation (BNS). Guyon and Elisseeff (2003) [18] gave an introduction to variable and feature selection. They recommend using a linear predictor of your choice (e.g. a linear SVM) and select variables in two alternate ways: (1) with a variable ranking method using correlation coefficient or mutual information; (2) with a nested subset selection method performing forward or backward selection or with multiplicative updates. There are two big approaches for the problem of the selection of the features: filters and wrapper approaches. The method of filter selects informative characteristics independently of their performance of classification reality (the judgment of classifier). Most of the methods of filtering adopted selection of statistical function, which demands a minimal effort of calculation. It measures independently of the importance of every characteristic to choose a good subset. The method of filter can miss some useful information which can be obtained that from the mixture of two or several characteristics. The method of packaging selects a set of features according to its performances of classification on a certain group of classifiers [19] and thus considers the mutual dependence between the characteristics. He allows us to make simultaneously the selection of the features and the formation of classifier to produce the optimal mixture of features and classifiers [**?**] [20] for a problem of particular classification. The first second-hand way genetic algorithm (GA) is defined by Goldberg [21] and it operates successfully the method of wrapper for the problem of selection of feature with a function set of data moderated on a large scale. However, this method becomes too complex to operate with a big characteristic of level and can give unsatisfactory results. However, diverse research projects were led to surmount this limitation. For example, Hong and Cho [22] brought back a new variant of a GA to fight against enormous scales problems of selection of feature in a zone of the bio-computing [23], [24] . They used a large number of features obtained from the technology of micro-networks and proposed the technique of speciation, to improve the performance of the selection of feature by the obtaining of diverse solutions. The representation of chromosomes was modified to manage the enormous problem range. The technique of the speciation treats the capacity of the chromosome by using the Niching pressure to check the process of selection. Interesting results were obtained with data of DNA microarrays of cancer patients. Oh and al. [25]proposed a GA crosses with local operators of research embarked to refine the process of selection of feature. Their approach was tested with a variety of databases and was shown to improve their classifier ' performance. Besides, according to the analysis of their method seem to be more low complexity of calculation comparing with classic algorithms. It is due to the local operations of research towards solutions optimum local mobile. However, their research used a GA for the problem of selection of feature, where the desirable number of features is predetermined. A fixed number of selected functions limits the space of research, but loses the possibility of finding a better solution with another group of features cut. Ho-Canard Kim and al. [26] apply a genetic algorithm which is a popular method for problem of not linear optimization for the problem of the selection of the features. Thus, we call it the selection of feature of the genetic algorithm (GAFS) and this algorithm is compared with other methods in the aspect performance. Cheng-San Yang and al. [27], used the optimization by binary swarm of particles (BPSO) in the resolution of problem of selection of feature. The authors apply the chaotic cards to determine the weight of the slowness of the BPSO.

## III. Proposed Solution

### *A. Face Detection*

Viola and Jones Algorithm [28] is based on Harr-like features obtained by computing of difference between black and white rectangles. 32 stages are defined for features classification to eliminate worst candidate region of facial part. Adaboost is used in cascade way to obtain in the end of all stages the right face detected as given in figure below where we performed Viola and Jones algorithm on two samples of faces from ORL and Caltech Faces Databases. All faces detected will be cropped and resizing into 120*120 resolutions.

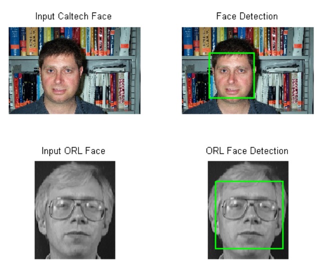


**Figure. 6**: Face Detected on two samples of images form ORL and Clatech Faces using Viola and Jones Algoirt

*Table 1*: 33 points annotated Designation

| Points | (X,Y) X | Y | Designation | Points Labels |
|---|---|---|---|---|
| 1 | | | Head Point | HP |
| 2 | | | Left End of Left EyeBrows | LELEB |
| 3 | | | High End of Left EyeBrows | HELEB |
| 4 | | | Right End of Left EyeBrows | RELEB |
| 5 | | | Lower End of Left EyeBrows | LoELEB |
| 6 | | | Center of Left EyeBrows | CLEB |
| 7 | | | Left End of Right EyeBrows | LEREB |
| 8 | | | High End of Right EyeBrows | HEREB |
| 9 | | | Right End of Right EyeBrows | REREB |
| 10 | | | Lower End of Right EyeBrows | LoEREB |
| 11 | | | Center End of Right EyeBrows | CREB |
| 12 | | | Left End of Left Eye | LELE |
| 13 | | | High End of Left Eye | HELE |
| 14 | | | Right End of Left Eye | RELE |
| 15 | | | Lower End of Left Eye | LoELE |
| 16 | | | Center End of Left Eye | CLE |
| 17 | | | Left End of Right Eye | LERE |
| 18 | | | High End of Right Eye | HERE |
| 19 | | | Right End of Right Eye | RERE |
| 20 | | | Lower End of Right Eye | LoERE |
| 21 | | | Center End of Right Eye | CRE |
| 22 | | | Left End of Nose | LEN |
| 23 | | | High End of Nose | HEN |
| 24 | | | Right End of Nose | REN |
| 25 | | | Lower End of Nose | LoEM |
| 26 | | | Left End of Mouth | LEM |
| 27 | | | High End of Nose | HEM |
| 28 | | | Right End of Nose | REM |
| 29 | | | Lower End of Nose | LoEM |
| 30 | | | Center of Mouth | CM |
| 31 | | | Left End of Jaw | LEJ |
| 32 | | | Right End of Jaw | REJ |
| 33 | | | Lower End of Jaw | LoEJ |

### B. Features Extraction

To prepare training dataset of geometrical distances of all images from the two facial databases ORL and Caltech Faces, we annotate all facial images using annotation process validated in [1] and [1] . Annotation process gives 33 points for each facial images detailed in table below (Table 1). To annotate ORL Faces database, we have imitate annotation rules used for AR Face Database.

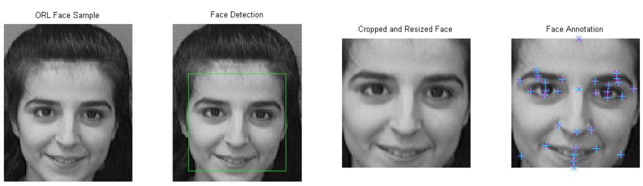


**Figure. 7**: Annotation Process

Training dataset of geometrical distances is constructed by Euclidian distances measures defined in Table 2.

### C. Features Selection Technique using a new pbMOPSO

#### 1) Description

The MOPSO, which was based on our study, is described in Figure 8. In each generation, for each sub swarm and each particle, a leader is selected from the archive external to which was applied a measure of quality (fitness) and the flight is conducted.

*Table 2*: 20 Geomrtric distances used as input for features slections techniques

| Distance | Description | Designation | Points used |
|---|---|---|---|
| D1 | Height of Face | HF | {1,33} |
| D2 | Distance between HP and CLEB | HP-CLEB | {1,6} |
| D3 | Distance between HP and CREB | HP-CREB | {1,11} |
| D4 | Distance between HP and HEM | HP-HEM | {1, 23} |
| D5 | Distance between HP and CRE | HP-CRE | {1,16} |
| D6 | Distance between HP and CLE | HP-CLE | {1,21} |
| D7 | Distance between HP and LoEM | HP-LoEM | {1,25} |
| D8 | Distance between HP and CM | HP-CM | {1,30} |
| D9 | Distance between HP and LEJ | HP-LEJ | {1,31} |
| D10 | Distance between HP and REJ | HP-REJ | {1,32} |
| D11 | Distance between HEN and LoEN | HEN-LoEN | {23,25} |
| D12 | Distance between CLE and LoEN | CLE-LoEN | {21,25} |
| D13 | Distance between CRE and LoEN | CRE-LoEN | {16,30} |
| D14 | Distance between CLE and CM | CLE-CM | {21,30} |
| D15 | Distance between CRE and CM | CRE-CM | {16,33} |
| D16 | Distance between CLE and LoEJ | CLE-LoEJ | {21,33} |
| D17 | Distance between CRE and LoEJ | CRE-LoEJ | {21,33} |
| D18 | Distance between LoEJ and LEJ | LoEJ-LEJ | {33,31} |
| D19 | Distance between LoEJ and REJ | LoEJ-REJ | {33,32} |
| D20 | Distance between CRE and CLE | CRE-CLE | {16,21} |

After a mutation operator is applied. Then the particle is evaluated and its pBest is updated. A new particle replaces its pBest particle when this particle is dominated,
or that all particles have been updated, the entire leadership is maintained. Finally, the measure of quality of all leaders is recalculated.

```
Begin
Initialise Swarm
Initialize leaders in an external Archive
Quality (leaders)
g = 0
While g < gmax
    For each Particle
        Select leader
        Update Position (Flight)
        Mutation
        Evaluation
        Update pbest
    EndFor
    Update leaders in the external Archive
    Quality (leaders)
    g++
EndWhile
Report results in the external Archive
End
```

**Figure. 8**: MOPSO

This process is repeated a number of iterations (usually fixed). Based on this model, we developed a new hierarchical architecture. It is based on two parts or levels of hierarchy. To ensure good convergence and diversity of non-dominated solutions, several operators are integrated into the basic process of multi-objective PSO.
Recall that in a MOPSO, the particles move in space goals through two equations (1) and (2) which ensure the convergence to the optimal.

### 2) *Used operators*

To describe the notion of optimality that interests us, we will implement these definitions:

- Given two vectors x and y Rk, we say that x y if xi yi for all i = 1, ..., k, and that x dominates y if x y and x y.
- Definition2: We say that a decision variables vector x X Rn is non-dominated with respect to X, if there is no other x ' X such that f (x') ¡f (x ).
- Dfinition3: We say that a vector of decision variables x* F Rn (F is the feasible region) is Pareto Optimal if it is non-dominated with respect to F.
- Definition4: The set Pareto Optimal P* is defined as: P = x * F — x is Pareto optimal
- Definition5: The Pareto Front PF* is defined by: PF * = f (x) Rk — x P*. Figure 9 shows an example of Pareto Front with two objective functions.

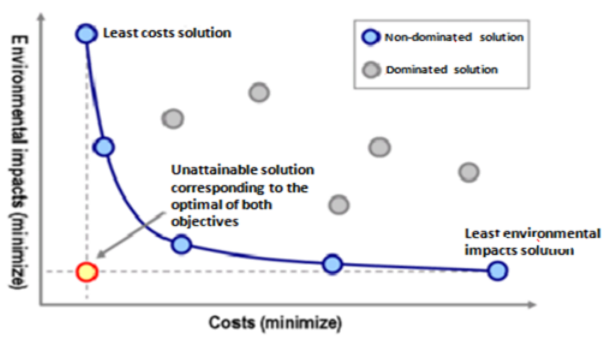


**Figure. 9**: Pareto Front with two objective functions

The operator used to subdivide the population, is based on the Ranking operator. It uses the operator of Pareto dominance. The result of this classification is a set of fronts: front 1 having rank 0, front 2 having rank 1, etc.,

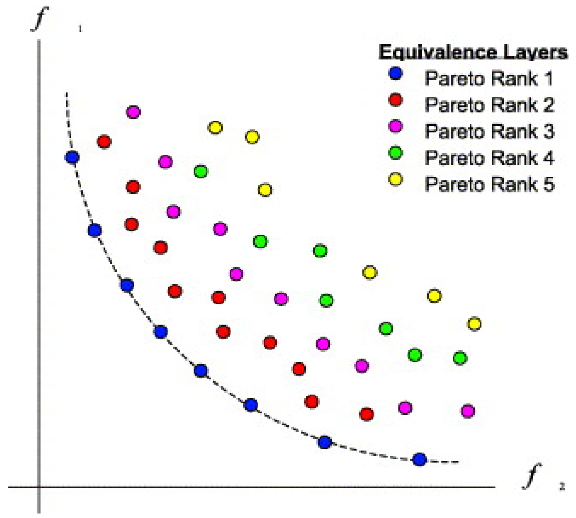


**Figure. 10**: the distribution of Pareto Fronts based Ranking Pareto operator

### 3) *Flochart of the pbMOPSO Algorithm*

In the context of Multi-Objective Particle Swarm Optimization, we use a MOPSO named pbMOPSO [31] (figure 10) to solve the feature selection problem [28]. This problem is one of many real problems we can solve using MOPSO [29] , [30] .

$$x_i(t) = x_i(t-1) + v_i(t) \quad (1)$$

$$v_i(t) = W\, v_i(t-1) + C_1 r_1(xpbest_i - x_i(t)) + C_2 r_2(xleader - x_i(t)) \quad (2)$$

- - Level 1 Knowing that the architecture of our approach is based on two bidirectional levels, it should be noted here state a criterion of transition from one level to another. In our case, a number of iterations equal to the total divided by 2 is the switch condition. So the first level, a MOPSO is run on the entire population. Once we reach the criterion, we strive at level 2 (figure 10).
- - Level 2 In the second level, we are asked to perform simultaneously in different nodes MOPSO. Those nodes do not share information but at the end of the iterations, they are required to give their results. Each MOPSO compares the optimal solutions, he found with those existing in the archive. If they are better, the old existing values in the archive are replaced by the new ones. The archive size is fixed (figure 10).

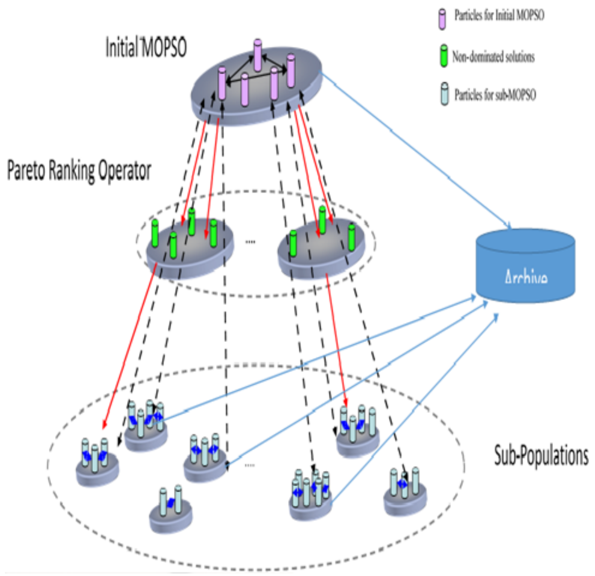


**Figure. 11**: Flowchart of the pbMOPSO algorithm

*4) Problem description*

To evaluate a solution candidate, we use the fitness function defined in (3) , where f(V) is the classification performance of a 1-NN classifier with a feature set V. where k1, k2 ∈ [0, 1] are the weights for f(V) and the feature set size, respectively.

$$Fit(V) = \begin{cases} \min k_1 f(V) \\ \min k_2 |V| / |U| \end{cases} \quad (3)$$

The parameters k1 and k2 are set, without loss of generality, to k1 = k2 = 1.We obtain Eq. (4):

$$fit(V) = \begin{cases} \min f(V) \\ \min |V| / |U| \end{cases} \quad (4)$$

Each particle is encoded on a chain constituting a possible solution.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 1 | 0 | 0 | ...... | 1 | 0 | 0.75 |

## D. Feature Classification

*1) Euclidian Distance*

Its a metric given by the Pythagorean formula. In the Euclidean plane, if A = (x1, y1) and B = (x2, y2) then the distance is given by:

$$d(\mathbf{p}, \mathbf{q}) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2}. \quad (5)$$

*2) MahCosine Distance*

The MahCosine Distance is a metric to evaluate the cosine of angle between two vectors after it transformation into Mahalabonis space. The MahCosine Distance between two points I and J with their projection a and b in the Mahalabonis space is given by:

$$MahCosine(i, j) = cos(\theta_{ij}) = \frac{|a||b|cos(\theta_{ij})}{|a||b|} \quad (6)$$

*Table 3*: Some Faces Databases used in literature

| Databases | Number of Persons | Databases Characteristics |
|---|---|---|
| ORL | 40<br>10 images per person | Gray level images<br>Resolution [112x92]<br>Pose Changes |
| Caltech | 26<br>10 images per person | RGB Color Image Resolution [592x896] Complex Background Changes illumination |

# IV. Experimental Results

*3) Databases*

To validate proposed approaches in scientific researches done on face recognition problems, many Face databases are used. There are many face databases in currently use. To make choice of database, comparison can be done based on some information like: Number of samples, Number of images per sample, changing illumination, changing pose, facial expression, eyeglasses, and aging. This table below presents popular face databases used in literature [13], [14].
It should be noticed that experimental process was made independently in the two databases with 10 tests. For each test, a randomly split of data was made. A set of performance measures is used to obtain reported results. We used in this paper, multiple performance measures. To analyze and study qualitatively the experimental results, we aim to compare between features selections techniques and features classification performed on ORL and Caltech Faces Database. The most robust approach will be compared later with face recognition approaches based on global features. All experiments performed are described in the two following tables.

**Figure. 12**: Samples of Faces from ORL Database

*Table 4*: Samples of Faces from Caltech Faces Database

| | GA | pbMOPSO |
|---|---|---|
| Population size | 200 | 200 |
| Number of Evaluations | 50000 | |
| Crossover | SBXCrossover | |
| Crossover_prob | 0.9 | |
| Mutation_prob | 1.0/nb_var | |
| Archive size | 100 | 100 |
| R1 R2 | | RANDOM |
| C1 C2 | | [1.5, 2.0] |
| W | | [0.1, 0.5] |
| Max Iteration | | 500 |
| Sub-swarm size | | 20 |

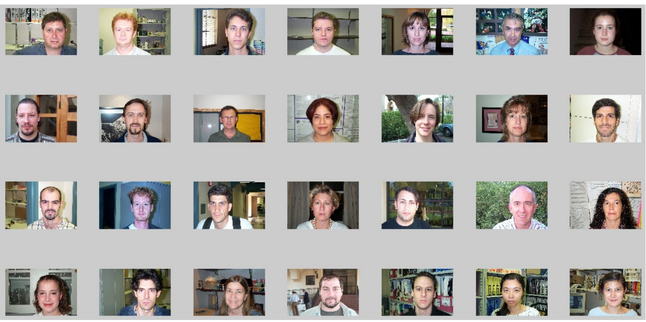

**Figure. 13**: Samples of Faces from Caltech Faces Database

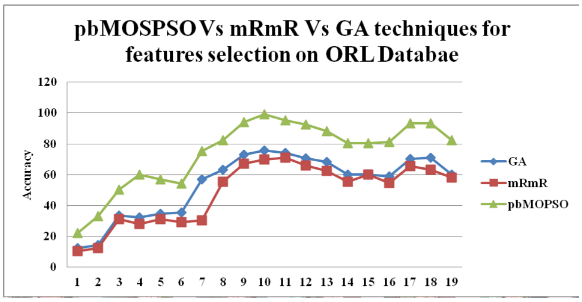


**Figure. 14**: Fronts Pareto generated by pbMOPSO Vs mRmR Vs GA techniques for features selection on ORL Databae

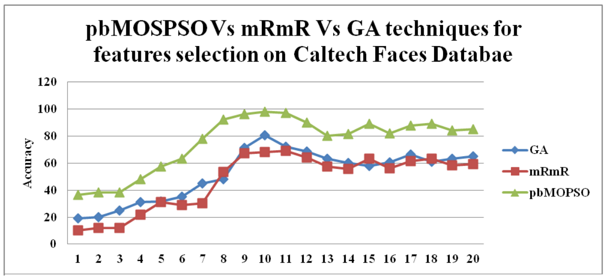


**Figure. 15**: Fronts Pareto generated by pbMOPSO Vs mRmR Vs GA techniques for features selection on Caltech Faces Databae

#### 4) *Databases*

We planned to conduct tests based on two databases as ORL Database and Caltech Database. They are used to prove the efficacy of our approach in minimizing the error rate and the number of features. We use the Pareto Principle to view the form of final solutions known by optimal solutions. Those solutions will help the decision maker to have just one optimal solution. Diversity and convergence are the tow criteria used in this experimentation. We make following observations: The proposed technique for features selection called pbMOPSO gives more relevant features for face recognition on ORL and Caltech databases compared with Genetic Algorithm and mRmR technique. pbMOPSO highlights features selection for 10 features. The 1 selected features are very relevant in face recognition task which is confirmed also by GA and mRmR algorithm. Using the 10 selected features, we carried out our recognition using these relevant geomtric features. The Curves below illustrated that our proposed techniques for features selection based on on pareto bi-direction multi-objective swarm intelligence is more interesting than GA and mRmR in both cases: Verifcation and Identification.

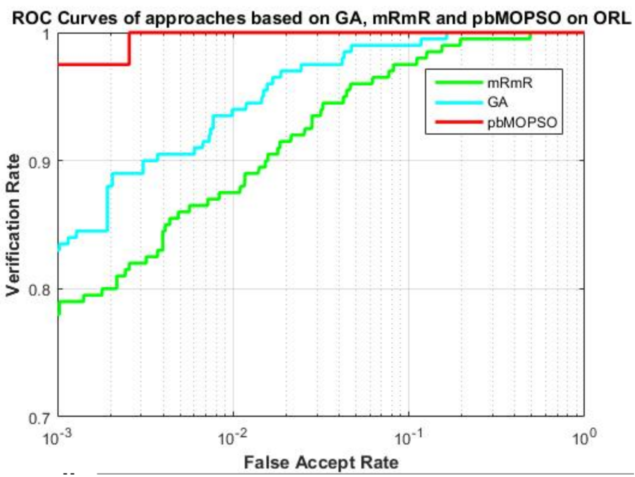


**Figure. 16**: ROC Curves of approaches based on GA, mRmR and pbMOPSO on ORL Database

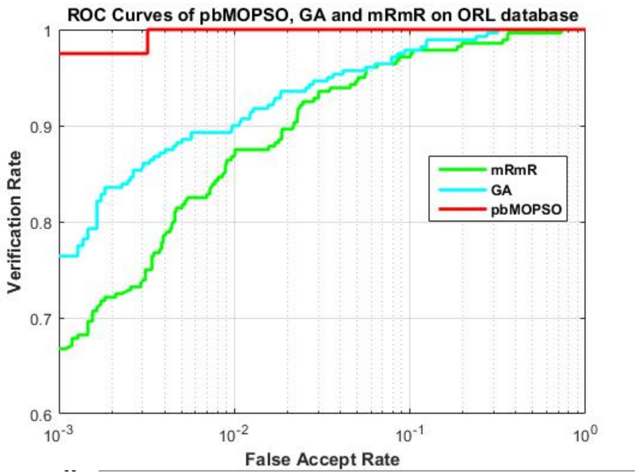


**Figure. 17**: ROC Curves of approaches based on GA, mRmR and pbMOPSO on Caltech Database

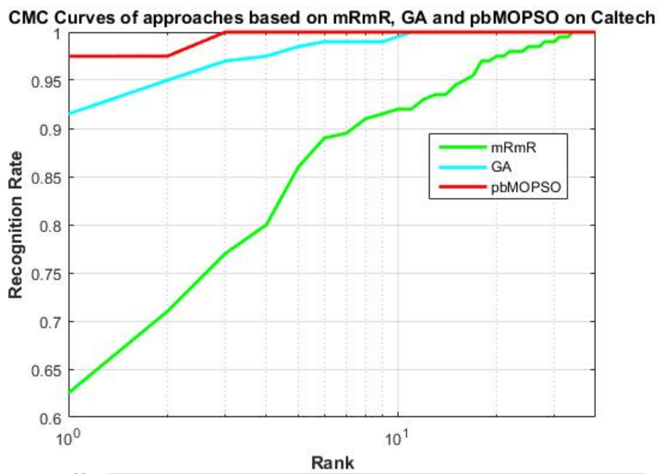


**Figure. 18**: CMC Curves of approaches based on GA, mRm-R and pbMOPSO on ORL Database

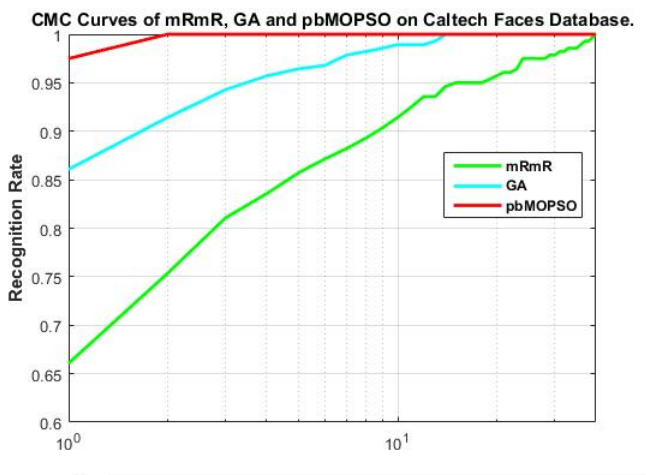


**Figure. 19**: CMC Curves of approaches based on GA, mRm-R and pbMOPSO on Caltech Database

## V. Conclusions

In this paper, we apply, we present a new application of a MOPSO in the Face recognition field, particularly with a feature selection problem. We tested the performance of pb-MOPSO with the state of the art GA and mRmR Algorithms according to the ORL database and Caltech database. The experimental study shows that our approach perform well.

## Acknowledgments

The authors would like to acknowledge the financial support of this work by grants from General Direction of Scientific Research (DGRST), Tunisia, under the ARUB program.

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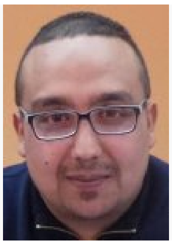

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