

# A Non-domination Pareto-based Scale-Invariant Approach for Face Recognition

Taqdir Kaur and Renu Dhir

**Abstract**—Human face recognition has presented a major challenge to the researchers from different domains enabling to enhance the security and pattern analysis. The different orientations, lighting, pose and facial expression of a human face constructs an array of similar images with variations. The identification of face under different circumstances has been the focus of the researchers from a decade to the present time. For face recognition higher the number of feature may not lead to high recognition rate. Hence, the selection of the optimum features becomes primary concern. It reduces the feature size and increases the recognition rate. Many algorithms have been proposed that fulfilled the goal of face recognition system but also comprises of some drawbacks. In this paper a novel Pareto-Optimized Evolutionary Approach with Scale Invariance Discrimination has been proposed. The algorithm extracts the set of relevant features from the given image. The optimization of the features is performed for finding the features that enhances the recognition rate. The algorithm performs the classification of the test image, given the set of training images to obtain the accuracy of human face identification. The recognition rate is evaluated to show the performance of the proposed approach with conventional methods.

**Index Terms**—Face Recognition, Discrete Wavelet Transform, Principle Component Analysis, Pareto front, Linear Discriminant Analysis

## I. INTRODUCTION

Face recognition has emerged as an area of interest over past few years. The broader area of application such as surveillance systems, identification system, human computer interaction and many more led the researchers to focus in this domain. A human face is a dynamic object having variation in appearance, pose and orientation that makes the face identification problem more difficult [1].

The face recognition system comprises of three major steps such as Face Detection, Feature Extraction and Face Recognition [1]. The first step is to find the existence of a human face in the image and to locate them. The pre-processing is performed with scaling and orientation of the image. In the second step, image is converted into vector representing set of fiducial points and their location on the face. Finally, face recognition is performed in two step process as face verification, a matching process of the face template with face image and face identification, a

match of a face image against all the template images in the database [2]. The test image features are compared to the feature of the images in the database and similarity is determined for finding the match.

Evolutionary Optimization (EO) algorithms are a population-based search approach where more than one solution participates in iteration that evolves new population of solutions. The “E.O.” is simple to implement as they do not require any directive information. Any multi-objective optimization problems results in Pareto-optimal solutions. The Pareto-optimal criteria (POC) [3] can be represented in the problem as solution having the decision vector  $\vec{x}$  in form of  $\vec{x} = (x_1, \dots, x_n)$  in the space  $X$ . The objective function produces two solutions  $\vec{y} = (y_1, y_2)$  in objective space  $Y$ . Therefore, the Pareto criteria can be states the dominance of one objective function over another ( $y_1 < y_2$ ) if the components of  $\vec{y}_1$  is greater than the components of  $\vec{y}_2$  and the function  $f(\vec{x}_1)$  dominates  $f(\vec{x}_2)$ . Such set of solutions are named as Pareto front as shown in Fig.1.

In this paper an Evolutionary algorithm with the Pareto-front optimality is proposed that encompasses the image variation with discrimination value. The algorithm extracts optimal set of features from the set of features that are matched with images in the training set for obtaining the recognition rate. The recognition accuracy is analysed for comparing the performance of the algorithm with conventional methods.

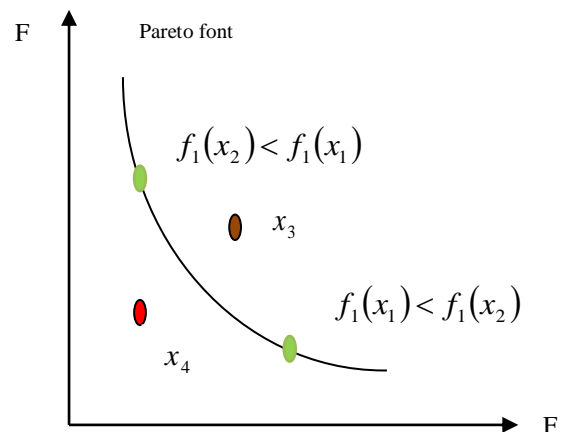


Fig. 1. Non-Dominated Solutions

## II. LITERATURE REVIEW

Over a decade, numerous techniques for the recognition have been developed. In early 1970s, the techniques were quite rigid to the frontal face detection from the background. From 1999 onwards the research towards the

Manuscript published August 31, 2016.

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face recognition gained a pace and introduced various segmentation methods, statistical approaches and holistic methods for detection.

Reference [4] proposed an approach that performs the fusion of "D.W.T." sub bands namely, horizontal, vertical and diagonal sub band. The "S.I.F.T." descriptors on fused wavelet are computed to obtain the feature vectors. The classification of the test image for the recognition of the similarity with the training set is obtained by finding the angle distance similarity.

Reference. [5] presented a neural based algorithm in which the dimensionality of the image is reduced with "P.C.A." followed by the Back Propagation Neural Network (BPNN). for recognition. The algorithm performs by obtains the Eigen faces that is the variation of the between the faces. The face is computed the face is reconstructed using weighted combination of Eigen faces. The new face is combined by projecting the image into Eigen face vectors. "B.P.N.N" is multilayer feed forward supervised learning. The random weights and threshold of the network are initialized. These values are updated in each iteration thereby minimizing the total squared error of target and output vector. The final output recognizes the input image as face image or other object.

Reference [6] proposed a Genetic algorithm (GA) based neural network approach that initially reduces the high dimensionality using "P.C.A." The feature extraction is performed with "L.D.A." followed by the features selection by optimizing the set of features with "G.A." The chromosomes represent the feature space and the "0 and 1" value indicates selection of feature is done or not. Roulette wheel strategy is performed to choose the individual from the intermediate population. A two-point crossover is performed for formation of the next population in each iteration. The resultant feature set is applied to the "B.P.N.N." classifier for recognizing the faces.

Reference [8] proposed a simple method for face recognition. The method illuminates the computation of Eigen values and eigenvectors which reduces the complexity. For set of training images, a polynomial characteristic is computed that obtains the features for each image. These features of training image are stored in a matrix form known as companion matrix. Similar procedure is repeated for a test image. A sequence of vectors for both the test image matrix and training image matrix is computed. The determinant of the symmetric matrix is calculated for finding the singularity. If the matrix is singular the test image is similar to training set else no common features are detected. The maximum value of nullity of matrix shows recognition of unknown face. The method reduces the computation complexity and the problem of high dimensionality of data is resolved but requires more number of steps for computations.

Reference [9] proposed an Optimal Directional Face (ODF) recognition method that extracts the directional information using the image directive. An image derivative enhances the facial features that have characteristics information. The method performs image derivative with Local Polynomial Approximation (LPA) which is a directional filter at multiple scales. As the

directional features captures increases the dimensionality, hence the Intersection of Confidence Interval (ICI) is applied for selection of scale at each pixel. The textural features are extracted by applying modified Local Binary Pattern followed by partitioning the feature image and finally the histogram of each feature values are computed and concatenated together. After portioning the "O.D.F." at different level, the "L.D.A." is applied for reducing in dimensionality; finally the "S.V.M." is applied for classification.

Reference [10] developed a method that is robust to partial variations by extracting the features through Scale Invariant Feature Transform (SIFT). The method is test on different bench mark datasets with facial image expression and occlusions. Facial image is represented with local features using "S.I.F.T." that uses scale-space difference of Gaussian to detect key points in the image. The "S.I.F.T." is applied on set of training image and test image and estimation of probability density function is performed. With the density function weight of each descriptor. The smaller weight value represents occluded area. Once the weight for feature values for test image are computed, the K-NN classifier is applied for finding the similarity and assign the test image to a class. However, the method when applied for occluded images and partial variations results in high dimensionality and improper results with local variations.

Reference [11] tries to address the problem of overlapping features in spontaneous expression with geometric and appearance features. This causes a major problem for the classifiers to separate the boundaries. The proposed method utilizes specificity and sensitivity model that contains mislabelled expression existing in the training data with different annotators. The Expectation-Maximization (EM) procedure is deployed to estimate the true label of expression by computing the likelihood with a metric. An adaptive online metric learning is proposed to solve optimal positive semi-definite metric with the steepest descent method. The method performs the classification by simple means of voting process based on training examples, however the annotator labelling is dependent on the facial expression that transitively depends on correlation among expression that reduces the performance due to same labelling in some cases.

Reference [12] considers the problem of human face recognition with variations such as illumination and occlusions and proposed method deal with them. The method can be directly applied on face despite of any feature selection procedure. Two descriptors namely Sparsity descriptor and Smoothness descriptor are proposed followed by the recognition process.

Sparsity descriptor computes the sparsity of image matrix to find the degradation of the image with noise and error. With the error image, the image of an individual looks smooth in some non-occluded regions. The sparsity descriptor is computed in pixel domain whereas the smoothness descriptor assumes to in gradient domain. These two descriptors jointly determine the true identity. There are two recognition methods namely, ration based-the ratio of normalized sparsity and smoothness descriptor

value and weighted based method-based on a trade-off value between sparsity and smoothness value.

Reference [13] proposed a method that extracts the features of each part of the face such as eye, nose, and lips independently. The Self-organizing map is deployed for the classification as it maintains the topology of input which helps in face recognition. The high dimension gets compressed. The normalized feature vector is train to classify the data into six different expressions. The network output is passed through sigmoid function and each dimension of network output vector.

Some basic approaches for face recognition are also discussed with their advantages and disadvantages. These methods are evaluated on different datasets for analysing the performance accuracy in face recognition.

Discrete Wavelet transformation (DWT) [14] is one of the basic approaches for face recognition. The method is a multi-resolution time frequency based localization analysis. With the wavelets low frequency signals can be analysed at higher resolutions. The 2D-DWT is carried over the image for the sub bands from the 1D-DWT. The calculation is done in row and column pixel positions in the image. This calculation decomposes the image into four sub bands as Low-Low (LL), High-Low (HL), Low-High (LH), and High-High (HH). The "L.L." band is the most upper layer of the image. The "H.L." and "L.H." are the sub bands that changes with vertical and horizontal directions [15]. The "H.H." band is the higher frequency component of the image.

The advantages of wavelet transform [14] are that it provides a simultaneous localization in time and frequency domain result in informative signal which can easily decompose into component wavelets, makes computationally very fast for transformation. It also compresses the signal without degrading it. Therefore, a good approximation can be obtained for any given function by using a few coefficients. This technique is capable of revealing various aspects such as trends, breakdown points, discontinuities in higher derivatives and self-similarity for analysing the data.

Principal Component Analysis (PCA) is employed to overcome the problems exiting with the correlation methods that incur more computational cost and memory storage. It is applied to locate the aspects of face which are important for identification. In the "P.C.A." approach, the component matching relies on a set of training data to build Eigen faces. Eigenvectors are calculated from the training face images [7]. The Eigen values are arranged in such a way that the largest Eigen value finds the most variance in the image. Therefore, an image can be classified using the Eigen face which has smallest Euclidean distance from the input face. Test face images are projected onto the space expanded by Eigen faces and represented by weighted sum of the Eigen faces. These weights are used to identify the faces [16].

A set of representing N dimensionality vectors for the approximated images,  $x_1, x_2, \dots, x_m$ , calculating their mean vector  $\mu$  and obtain covariance matrix C:

$$C = \frac{1}{m} \sum_{n=1}^m (x_n - \mu)(x_n - \mu)^T \quad (1)$$

$$\mu = \frac{1}{m} \sum_{n=1}^m x_n \quad (2)$$

PCA can deal with low noise sensitivity and has great efficiency with smaller dimension of the data [17]. However, construction of the covariance matrix is difficult and unless the training data is given, the invariance cannot be calculated.

Linear Discriminant Analysis (LDA) is used for finding the combined features that does the separation of the classes [16]. The method does the dimensionality reduction and further a classification is done for the face recognition. LDA performs the encoding of information that are not orthogonal. It is also more capable of distinguishing image variation due to identity from variation due to other sources such as illumination and expression.

Mathematically, a set of n dimensional vectors  $x_1, x_2, \dots, x_m$  belongs to l classes of faces:

$$\max_w \frac{w^T S_B w}{w^T S_w w} \quad (3)$$

$$\text{where} \\ S_B = \sum_{i=1}^l n_i (\mu^{(i)} - \mu_{total})(\mu^{(i)} - \mu_{total})^T \\ S_w = \sum_{i=1}^l \left\{ \sum_{j=1}^{n_i} (x_j^{(i)} - \mu^{(i)})(x_j^{(i)} - \mu^{(i)})^T \right\} \quad (4)$$

$\mu$  is the mean of the total training image.  $n_i$  is number of images in  $i^{th}$  class,  $\mu^{(i)}$  is average vector of  $i^{th}$  class.  $S_w$  is within class scatter matrix and  $S_B$  is between-class scatter matrix.

In case of LDA for face recognition in high dimensional data, a small sample size problem arises where the number of training images is less than the dimensionality of sample space. As LDA assumes Gaussian distribution of the data, therefore it fails when discriminatory information is not in the mean of the data but in invariance of the data. The advantage of LDA. technique [16] is that it is efficient for analysing the homogeneous texture though it has the disadvantage that this approach does not take part for local contrast of the neighbourhood region and rotation of bits performs lead to quantization of data

Coefficient of Correlation [18] approach establishes the degree of probability that a linear relationship exists between two measured quantities. The correlation coefficient (CoC) is defined as follows:

$$r = \frac{\sum_i (x_i - x_m)(y_i - y_m)}{\sqrt{\sum_i (x_i - x_m)^2} \sqrt{\sum_i (y_i - y_m)^2}} \quad (5)$$

where,  $x_i$  and  $y_i$  are intensity values of  $i^{th}$  pixel in 1<sup>st</sup> and 2<sup>nd</sup> image and  $x_m$  and  $y_m$  are mean intensity values of that images respectively. If the two images is identical, then the correlation coefficient value  $r$  is 1. The value of  $r$  is 0 if the images are completely uncorrelated and -1 if they are completely anti-correlated.

The “C.o.C.” approach condenses the 2D image to single scalar value and is invariant to linear transformations of  $x$  and  $y$ . Hence the scalar value is insensitive to the variations in brightness and contrast across an image. However, this approach restricts the image registration and is highly sensitive to skewing, pin cushioning and vignette that inevitably occurs in images.

Structural Similarity Index Metrics (SSIM) [17] is another method of finding the quality of the test image by comparing it with the reference image. To measure similarity between them the task is separated into three comparisons: luminance, contrast and structure. The “S.S.I.M.” is combined of three components resulting as equation.

$$S(x, y) = f(l(x, y), s(x, y), c(x, y)) \quad (6)$$

These three components are independent. Hence the change in luminance may affect little on structure and contrast where (Table I) shows the advantages and disadvantages of feature based and holistic approaches.

### III. PROPOSED WORK

#### A. Introduction

Over the last few years, face recognition has become a popular area of research in computer vision and one of the most successful applications of image analysis. Because of the nature of the problem, not only computer science researchers but neuroscientists and psychologists also are interested in this field to provide useful solutions. As the face recognition problem can be formulated with the given still or video images of a scene or identifying one or more persons in the scene using the trained databases.

- Recognition of face with Non-domination solutions
- Development of improved statistical approaches for evaluating enhanced recognition
- Effect of algorithm and system training on covariate performance

The proposed method has been designed that overcomes the challenges that occur in face recognition.

TABLE I: ADVANTAGES AND DISADVANTAGES OF FEATURE AND HOLISTIC APPROACHES

Methods	Advantages	Disadvantages
Feature based Approach	Robust to position variations in the input image.	Automatic feature detection may select some wrong feature points due to presence of noise.
	These methods can be made invariant to size, orientation and/or lighting.	Lack of discrimination cannot compensate for deficiency
	Compactness of representation of the face images and high speed matching	
Holistic Approach	Does not destroy any information	False assumption of having all pixels of same importance
	Considers input as set of values	Requires high degree of correlation between test and training images
		Results are inaccurate when images have variations in pose, scale.

A multi-objective optimization problem constructs of multiple number of objective functions that needs to be either maximized or minimized [3]. Such problem gives rise to a set of optimal solutions that have conflicts the outcomes among different objectives. Given a set of solutions a solution can be better for one objective function requires to compromise with other objective function. Therefore, selection of a single solution with respect to an objective function is difficult. A solution is to find multiple non-dominated points with Pareto front and diverse information. Evolutionary Algorithms (EAs) are population based algorithms having a wide search space with diverse set of solutions. The proposed algorithm is described in steps. The basic idea describes the pre-processing of image and averaging of image. The second step discusses the search problem. The third step demonstrates the density estimation and metric for finding similarity among the solutions [19]. Finally, the classification is done to recognition the face image.

#### B. Basic Idea

The proposed work initiates with an input image as test image from the set of training images. The pre-processing of the image is done by clipping and applying median to enhance image quality. The feature points are detected by searching peaks in the scale-space from a difference of Gaussian function [20]. For the invariance that exists due to illumination the orientation planes are defined. The image is smoothed by Gaussian filter and thereby sampled over 4x4 grid with 8 orientation planes. From the set of feature points obtained, the optimal feature points are extracted for that participates in classification process is obtained.

#### C. Population Generation

A parent population is created randomly and sorted according to their non-domination [21]. The solutions are assigned fitness according to their non-domination level. The minimization of the objective function is performed iterating the solution in selection, recombination and mutation stage to create offspring [22]. The combined set of solutions is assigned the best non-domination and should be memorized for further generation. If the set of population is less than the total population size, all member from the population set are chosen for participation. The remaining members are chosen from non-dominated front according to their ranks [23]. The process continues until no members are left. The solutions are sorted from the higher to lower ranking based on average distance with density estimation and the best solution that fill all population slots is chosen.

#### D. Non-domination and Distance Metric

Each solution in the population set is assigned two values, domination count, and the number of solutions that dominate the solution and the set of solution that

dominates [23]. Initially all the solution have zero as their domination value. As each solution is visited the count is reduced by one and the solution is put in a separate list that belongs to second non-dominated front. This process continues until all fronts are identified resulting in a Pareto- front optimality.

The distance metric for sorting the non-dominated solutions is average distance with density estimation around a solution in Pareto-front. The value of the objective function is sorted in ascending order of magnitude. The objective function with boundary solutions is assigned an infinite value and the intermediate solutions are assigned normalized difference of two adjacent solutions. The number of points on the cuboids formed around a solution by the nearest neighbour on vertices is averaged. This distance metric guide differencing the non-domination ranks in a uniformly spreaded Pareto-optimal front.

#### E. Recognition

A set of training images are normalized which simplifies the computation for recognizing the face. By minimizing the incremental discriminate distance metric, the features are reduced in dimensionality space thus increases the classification process. A sample from the training set is drawn randomly for evaluating the Eigen space and eigenvectors. These vectors results in better accuracy for the recognition system. Therefore, the discrimination differences are reflected for achieving better classification accuracy.

#### Algorithm

Input: Set of training images  $T_m$

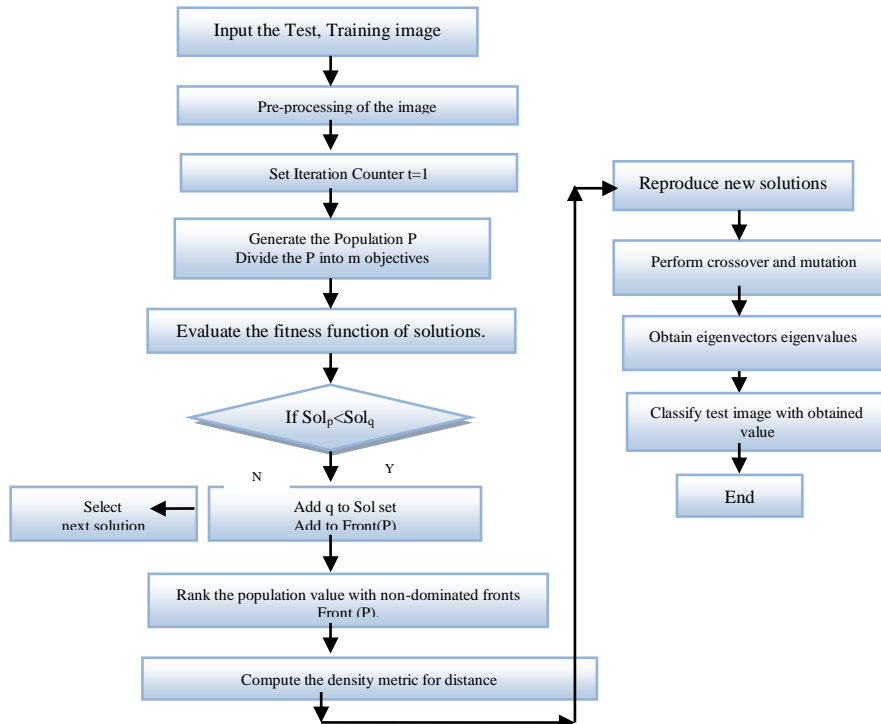


Fig. 1. Flowchart of proposed method

Test image  $T_i$

Output: Recognition rate  $R$

Input the  $T_m$  and  $T_i$

Perform Pre-processing of the image

Set  $T$  be number of iterations

Generate  $N$  solutions ( $Sol$ ) to form initial population  $P$

Divide the  $P$  into  $m$  objectives.

Evaluate the fitness function of each solution

For each  $p, q \in P$

If  $(p < q)$

Add  $q$  to  $Sol$  set

Else

Select the next solution

Each solution  $D_{count} (P=0)$

Add to  $Front(P)$

Rank the population based on objective function value with non-dominated fronts  $Front(P)$ .

$Density(Sol)$  be averaging the distance points along objectives

$Distance (Sol) = 0$

For each point

$Distance (p) = Distance (p) + Objective(Sol_{p+1}) + Objective(Sol_{p-1})$

Perform crossover and mutation to create offspring  $P_{t+1}$  of size  $N$

Increment the next iteration

Perform the dimensionality reduction

Compute the eigenvectors and eigen values with sample from training set

Perform the classification with the training set

#### IV. RESULTS AND ANALYSIS

All the experiments were performed on “2.65 GHz” Intel core processor with “2 GB RAM” running Windows 7. The algorithms were implemented in Mat Lab programming.

The “O.R.L.” database [26] contains 10 different images of 40 distinct individuals. For some of the individuals, the images were captured at the different intervals of time, varying the poses, lighting, facial expressions (smiling/ non-smiling, open or closed eyes) along with or without glasses. All the images were taken against a dark homogeneous background with the individual upright frontal position. The Yale database contains 165 gray scale images of 15 different persons. There are 11 images of each person having different facial expression under

The ORL database [26] contains 10 different images of 40 distinct individuals. For some of the individuals, the images were captured at the different intervals of time, varying the poses, lighting, facial expressions (smiling/ non-smiling, open or closed eyes) along with or without glasses. All the images were taken against a dark homogeneous background with the individual upright frontal position. The Yale database contains 165 gray scale images of 15 different persons. There are 11 images of each person having different facial expression under various conditions (centre-light, left-light, right-light, with glasses, without glasses, normal, happy, sad, sleepy, surprised and wink). The proposed approach has been tested on different datasets “O.R.L.” Database, the Yale

Database for finding recognition accuracy on different criterion. The method is compared with the conventional holistic method such as “P.C.A.”, “D.W.T.”, “L.D.A.” and correlation methods, “S.S.I.M.” and “CoC.” the set of training images is given in (Table II) and (Table III). A comparative study of the test images is done for analysing the performance of proposed approach with the conventional statistical approaches. Here (Table IV) shows the recognition rate of proposed approach is 97.22% as the feature set is optimized with the evolutionary algorithm, finding the optimal solution from the non-dominated Pareto-front, the classification attains better results with such optimized feature set. The stated conventional methods however try to attain the maximum recognition rate nearby 95.98%. The statistical methods when combined, reduces the dimensionality, enhancing the feature selection and classification rate. Using (Table IV). The recognition rate of the conventional methods maximizes at 89.91%. The test image analysed with the proposed methodology with the training set (Table IV) and (Table V), searches for the optimal fiducial features, resulting in 92.22% of accuracy. The recognition process of conventional and proposed methods attaining 93.76% and 95.51% respectively. From the results shown above, it is inferred that the non-domination Pareto-based scale-invariant discriminate methodology achieves an average of 95.00% accuracy for recognizing the face image. The plot for recognition accuracy is represented in Fig. 3 and Fig. 4 for the Yale database and “O.R.L.” database respectively.

TABLE II: TRAINING SET OF YALE DATABASE

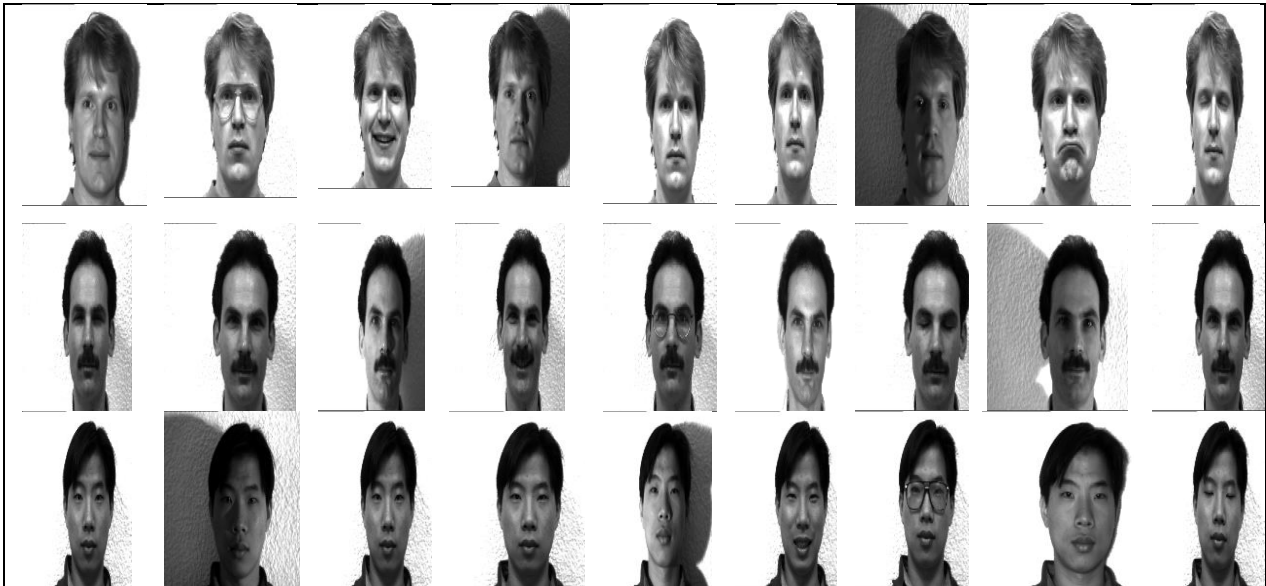




TABLE III: TRAINING SET ORL DATABASE



TABLE IV: RECOGNITION ACCURACY FOR YALE DATABASE

Methodology	Yale Face Database			
	Recognition Rate (%)			
	Test Image 1	Test Image 2	Test Image 3	Test Image 4
CC	86.4335	88.4896	92.2317	89.2317
CC+DWT	86.5439	88.7891	92.2145	88.2145
DWT	95.9819	89.9126	93.7571	91.7571
DWT + LDA	95.9583	89.8779	93.7322	90.7322
DWT + PCA	95.9598	89.8798	93.7339	91.7339
SSIM	58.8798	62.8283	58.3830	61.3830
Proposed	98.2180	97.2179	98.5135	98.5135

TABLE V: RECOGNITION ACCURACY FOR ORL DATABASE

Methodology	ORL Face Database	
	Recognition Rate (%)	
	Test Image 1	Test Image 2
CC	88.4896	92.2317
CC+DWT	90.0126	93.2060
DWT	89.9126	93.7571
DWT + LDA	91.8779	94.7322
DWT + PCA	92.8798	96.7339
SSIM	62.8286	69.3830
Proposed	99.00	99.07

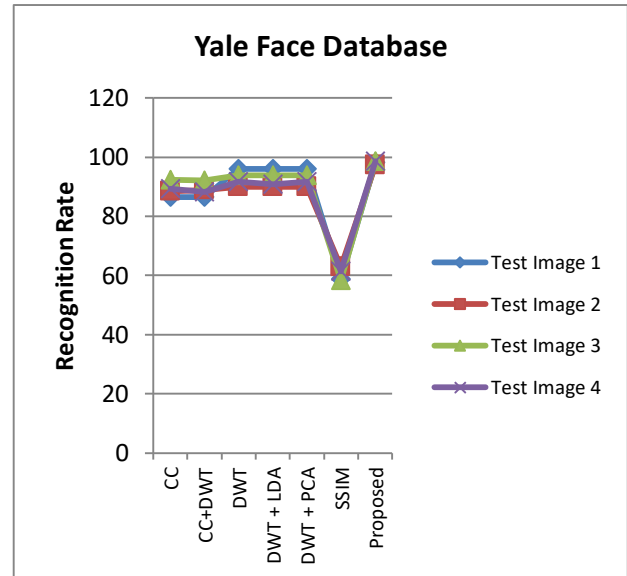


Fig. 3. Comparison graph for Yale database

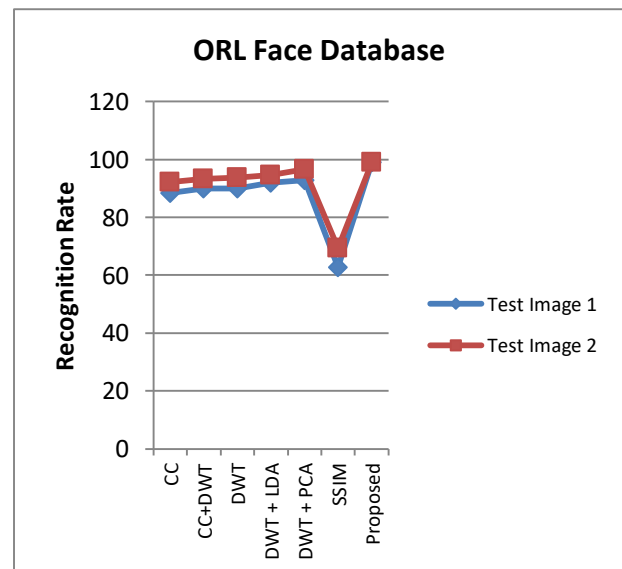


Fig. 4. Comparison graph for ORL database

## V. CONCLUSION

The face recognition has gained such popularity because the insecurity and accessibility of the property of an individual has become very much active now a day. There have been numerous models developed for face recognition. All the approaches have some advantages and disadvantages. The prime concern for the face recognition is the dimensionality of the images and various other factors such as light, illumination and occlusion are some more add-ons to them. The broad application in areas such as credit card verification, surveillance images, bank security etc. has made this area of image processing vital for research. In this paper an Evolutionary algorithm with the Pareto-front optimality is proposed that encompasses the image variation with discrimination value. The test image analysed with the proposed methodology, searches for the optimal fiducial features, resulting in 96.22% of accuracy.

## ACKNOWLEDGMENTS

The authors are greatly thankful to the Department of Computer Engineering, Regional Campus Gurdaspur, GNDU Amritsar for providing excellent lab facilities that make this work possible.

## COMPETING INTERESTS

The authors declare that they have no competing interests.

## AUTHORS' CONTRIBUTIONS

Both the authors collectively developed the algorithm, implemented and written the manuscript.

## REFERENCES

- [1] [1] Yong zhongLu, Jingli Zhou, Sheng shengYu, "A Survey Of Face Detection, Extraction And Recognition", Computing and Informatics, vol. 22, 2003
- [2] Kresimir Delac, Mislav Grgic and Marian Stewart Bartlett, Recent Advances in Face Recognition.
- [3] Lixin Tang, and Xianpeng Wang, "A Hybrid Multiobjective Evolutionary Algorithm for Multiobjective Optimization Problems", IEEE On Volutionary Computation, vol. 17, no. 1, 2013.
- [4] Amrita Biswas and M.K. Ghose, "Expression Invariant Face Recognition using DWT SIFT Features", *International Journal of Computer Applications*, vol. 92, no.2, pp. 30-32, 2014.
- [5] P. Latha, Dr. L. Ganesan and Dr. S. Annadurai, "Face Recognition using Neural Networks", *Signal Processing: An International Journal (SPIJ)*, vol. 3, pp. 153-160, 2009.
- [6] Vivek Pali and Lalit Kumar Bhaiya, "Genetic Algorithm Based Feature Selection and BPNN Based Classification for Face recognition", *International Journal of Advanced Research in Computer Science and Software Engineering*, vol. 5, pp. 269-273, 2013.
- [7] P. Aishwarya and Karnan Marcus, "Face recognition using multiple eigenface subspaces", *Journal of Engineering and Technology Research*, vol. 2, no. 8, pp. 139-143, 2010.
- [8] Vilas H. Gaidhane, Yogesh V. Hote , Vijander Singh, "An efficient approach for face recognition based on common eigenvalues", *Pattern Recognition*, vol. 47, pp. 1869-1879, 2014.
- [9] Rakesh Mehta, Jirui Yuan, Karen Egiazarian, "Face recognition using scale-adaptive directional and textural features", *Pattern Recognition*, vol. 47, pp. 1846-1858, 2014.
- [10] Jeongin Seo, Hyeyoung Park, "Robust recognition of face with partial variations using local features and statistical learning ", *Neurocomputing*, Vol. 129, pp.41-49, 2014.
- [11] Shaohua Wan , J.K. Aggarwal, "Spontaneous facial expression recognition: A robust metric learning approach", *Pattern Recognition*, vol. 42, pp. 1859-1868, 2014.
- [12] Xiao Luan , Bin Fang , Linghui Liu , Weibin Yang , Jiye Qian, "Extracting sparse error of robust PCA for face recognition in the presence of varying illumination and occlusion", *Pattern Recognition*, vol.47, pp. 495-508, 2014.
- [13] Anima Majumder, Laxmidhar Behera, Venkatesh K. Subramanian, "Emotion recognition from geometric facial features using self-organizing map", *Pattern Recognition*, vol. 47, pp. 1282-1293, 2014.
- [14] Pallavi D. Wadkar and Megha Wankhade, "Face Recognition using Discrete Wavelet Transform", *International Journal of Advanced Engineering Technology*, vol. 3, pp. 239-242, 2012.
- [15] V. Vidya, Farheena Nazia, K Manikantana, S Ramachandran, "Face recognition using threshold based DWT feature extraction and selective illumination enhancement technique", 2<sup>nd</sup> International Conference on Communication, Computing & Security, no.6 pp. 334-343, 2012.
- [16] Sha S. Fan, Yang Du, Jia Zhao, Qiang Wang, Fei Guo, "Comparative Research of PCA+AdaBoost and PCA+LDA for Face Recognition Technology", *International Industrial Informatics and Computer Engineering Conference*, pp. 1009-1013, 2015.
- [17] Kanokmon Rujirakul, Chakchai So-In, Banchar Arnonkijpanich, Khamron Sunat and Sarayut Poolsanguan, "PFP-PCA: Parallel Fixed Point PCA Face Recognition", *IEEE 4th International Conference on Intelligent Systems, Modelling and Simulation*, pp. 409-414, 2013.
- [18] Javier Galbally, Sebastien Marcel and Julian Fierrez, "Image Quality Assessment for Fake Biometric Detection: Application to Iris, Fingerprint and Face Recognition", *IEEE Transactions on Image Processing*, vol. 23, no.2, pp.710-724, 2014.
- [19] Isra'a Abdul-Ameer Abdul-Jabbar, Jieqing Tan, and Zhengfeng Hou, "Adaptive PCA-SIFT Matching Approach for Face Recognition Application", *Proceedings of the International MultiConference of Engineers and Computer Scientists*, vol.I, pp. 1-5, 2014.
- [20] A. Azeem, M. Sharif, J.H. Shah, M. Raza, "Hexagonal scale invariant feature transform (H-SIFT) for facial feature extraction", *Journal of Applied Research and Technology* no.13, pp.402-408, 2015.
- [21] Tushar Gajame, C.L. Chandrakar, "Face Detection with Skin Color Segmentation & Recognition using Genetic Algorithm", *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, vol.3, pp. 132-136, 2013.
- [22] Kalyanmoy Deb, "Multi-Objective Optimization Using Evolutionary Algorithms: An Introduction", "KanGAL Report", pp. 1-12, 2011.
- [23] Sameh Fakhfakh-Ghribi, Ameni Yengui-Jammoussi and Dorra Sellami-Masmoudi, "A Multi Objective Genetic Algorithm based Optimization of Wavelet Transform Implementation for Face Recognition Applications", *World Academy of Science, Engineering and Technology*, pp.1590-1593, 2011.