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A Systematic Review of Feature Dimensionality Reduction Techniques for Face Recognition Systems

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ABSTRACT

In this research, a comparison of the various techniques used for face recognition is shown in tabular format to give a precise overview of what different authors have already projected in this particular field. A systematic review of 40 journal articles pertaining to feature dimensionality reduction was carried out. The articles were reviewed to appraise the methodology and to identify the key parameters that were used for testing and evaluation. The dates of publication of the articles were between 2007 and 2015. Ten percent (10%) of the articles reported the training time for their system while twenty four percent (24%) reported their testing time. Sixty seven percent (67%) of the reviewed articles reported the image dimension used in the research. Also, only fourty eight percent (48%) of the reviewed articles compared their result with other existing methods. The main emphasis of this survey is to identify the major trade-offs of parameters and (or) metrics for evaluating the performance of the techniques employed in dimensionality reduction by existing face recognition systems. Findings from the review carried out showed that major performance metrics reported by vast amount of researchers in this review is recognition accuracy in which eighty six percent (86%) of the authors reported in their experiment.

Keywords: Optimal Subset, High Dimension, Face Recognition, Biometrics, Feature Vector

1. INTRODUCTION

Face is the most distinctive and widely used key to a person's identity. A human face has an inherent property of high dimension and this call for the need to project the face image data to a lower dimensional subspace so that automated face recognition can be realized. Feature dimensionality reduction encompasses two vital approaches - feature extraction and feature selection [1]. To classify an object in an image, we must first extract some features out of the image. The features of human faces are either geometrical or statistical based. Feature extraction in a face data pullout best discriminate features which are not sensitive to arbitrary environmental variations such as variations in pose, scale, illumination, and facial expressions [2]. Feature selection removes the irrelevant, noisy and redundant data thus leading to a more accurate recognition of face. Feature selection is an optimization technique used in face recognition technology. Considerable progress has happened in face recognition with newer models especially with the development of powerful models of face appearance. These models represent faces as points in high-dimensional image spaces and employ dimensionality reduction to find a more meaningful representation, therefore, addressing the issue of the "curse of dimensionality". Dimension reduction is a process of reducing the number of variables under observation [3]. The need for dimension reduction arises when there is a large number of univariate data points or when the data points themselves are observations of a high dimensional variable.

Furthermore, the key observation is that although face images can be regarded as points in a high-dimensional space, they often lie on a manifold (i.e., subspace) of much lower dimensionality, embedded in the high-dimensional image space. The main issue is how to properly define and determine a low-dimensional subspace of face appearance in a high-dimensional image space. This survey illustrates different state-of-the-art feature dimensionality reduction practices for face recognition. It gives an epigrammatic description of methods of dimensionality reduction employed by numerous researchers in face recognition. It also identifies some major parameters considered for evaluation of the techniques used in the development of the face recognition systems. The remainder of this paper is organized as follows. In Section II, the notion of feature dimensionality reduction in face recognition was presented. Contemporary feature dimensionality reduction techniques employed by numerous researchers in face recognition were discussed in Section III. In Section IV, a comparison of various techniques was presented and in Section V, the concluding remark was stated.

2. THE NOTION OF FEATURE DIMENSIONALITY REDUCTION IN FACE RECOGNITION

Dimensionality reduction is the process of reducing the number of random variables under consideration, i.e. $R_N \rightarrow R_M$ where $(M<N)$ [4]. The face data is a non-linear manifold made up of high dimension and the entire face may not be absolutely needed for feature representation for face recognition application. Hence deriving a subset of data to achieve objective function is desirable. Faces must be represented in a way that best utilizes the available face information to distinguish a particular face from all other faces. The problem of dimensionality reduction arises in face recognition because an X by Y face image is reconstructed to form a column vector of XY components, for computational purposes. As the number of images in the data set increases, the complexity of representing data sets increases. Analyzing images with a large number of variables generally consumes a large amount of memory and computation power. Feature extraction is creating new features from existing ones. i.e. For vector [x1 x2 ... xn], after feature extraction gives [y1 y2 ... ym].

Feature selection is choosing a subset of all the features. i.e. vector [x1 x2 ... xn] yields [xi1, xi2 ... xim] after feature selection. In either case, the goal is to find a low-dimensional representation of the data while still describing the data with sufficient information for efficient recognition. A typical flow of a face recognition system is shown in Figure 1 below.

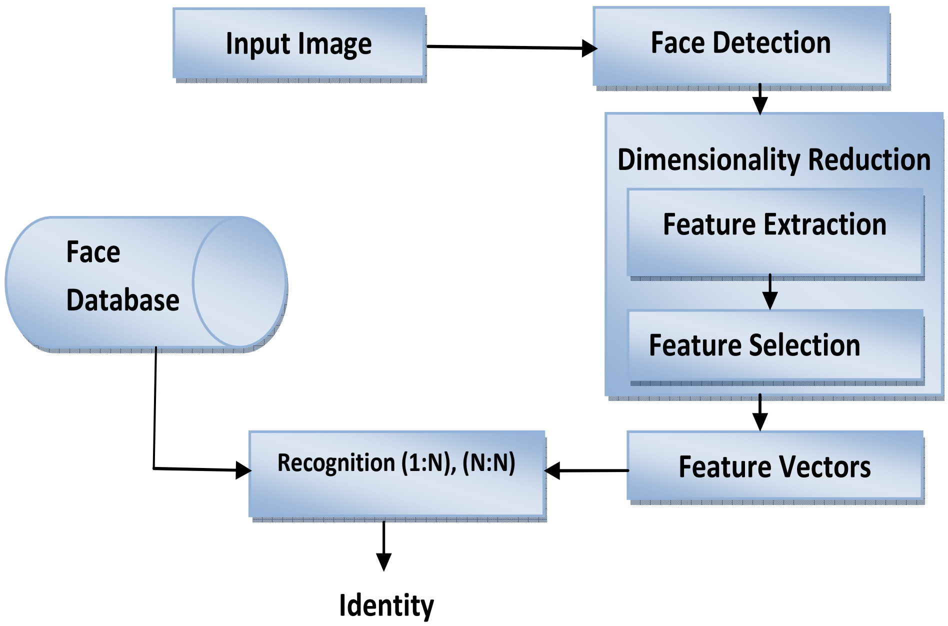

Figure 1: Basic Flow of Face Recognition System [5].

Feature dimensionality reduction techniques project the training sample faces to a low dimensional representation space where the recognition can be easily carried out. The main assumption behind this procedure is that the face space (given by the feature vectors) has a lower dimension than the image space (given by the number of pixels in the image), and that the recognition of the faces can be performed in this reduced space.

3. EXISTING FEATURE DIMENSIONALITY REDUCTION TECHNIQUES FOR FACE RECOGNITION

The representation of features in a lower dimensional space through feature extraction and optimal feature selection leads to an efficient dimensionality reduction process. Numerous face dimensionality reduction techniques have been carried out using several algorithms. Some research carried out feature extraction, in which only the extracted features were used for recognition of faces (one-level dimensionality reduction) as seen in Figure 2.

This technique is a face recognition system that makes use of local binary pattern (LBP) for feature extraction. The model, consisting of three major parts, namely face representation, feature extraction and classification as shown in the Figure used LBP extracted features for face recognition directly without carrying out any form of feature subset selection. It represents the local feature of the face and matches it with the most similar face image in the database. The model achieves significant recognition accuracy.

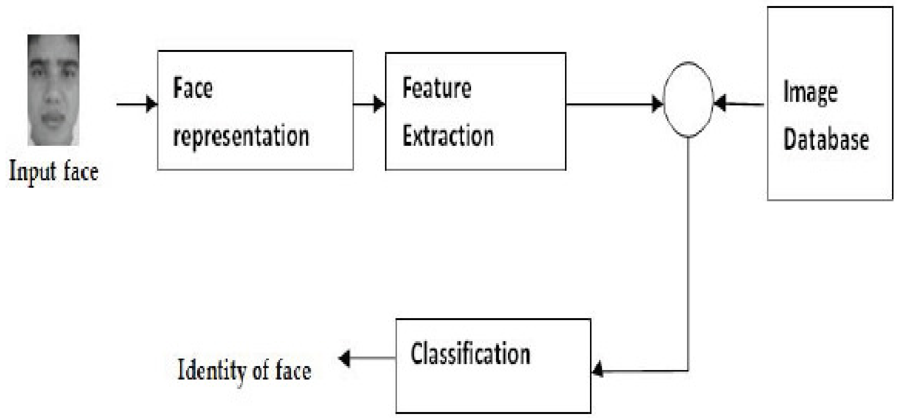

Figure 2: Principle of an identification process with face recognition [2].

Furthermore, dimensionality reduction has also being achieved in a two-level approach whereby feature extraction as well as optimal feature subset selection was carried out. [6] presented a face recognition system that uses discrete cosine transform (DCT) to extract features and ant colony optimization (ACO) algorithm for feature selection.

The work uses k-Nearest Neighbour classifier to evaluate the selected feature subsets in a wrapper mode. The block diagram of this system is shown in Figure 3. The method yielded a high recognition accuracy (98.5%) by carrying out both feature extraction and optimal feature subset selection. However, the time requirement for dimensionality reduction and recognition time of a tested face was not specified in the report.

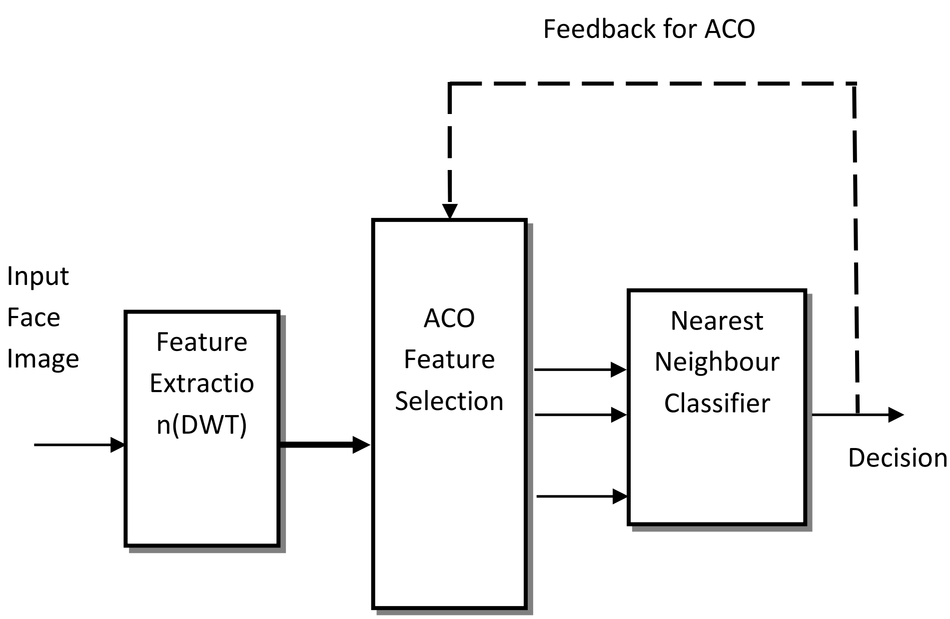

Figure 3: Block diagram of the face recognition system [6]

[7] carried out an assessment of PCA and DCT algorithms for access control system. It was discovered that PCA proved to be a better algorithm for access control and recognition system based on the high percentage (90.43%) of correctly classified faces and its strict attendance to both FAR and FRR (0.1077, 0.0609) respectively. [8] developed an improved facial recognition algorithm in a web-based learning system. The methodology involves implementing an optimized principal component analysis (OPCA) and a web-based learning system using hypertext preprocessor (PHP) scripting language. Asynchronous Java Script and XML (AJAX) was used to enhance chatting, macromedia flash and other relevant applications. The architectural framework of the secured web-based learning is shown in Figure 4.

It consists of the face capture module and face verification module. The result of the implementation of the technique shows that the performance of OPCA wais better in terms of recognition rate (98.7%) and time requirement for executing the algorithm (0.55sec) than that of PCA

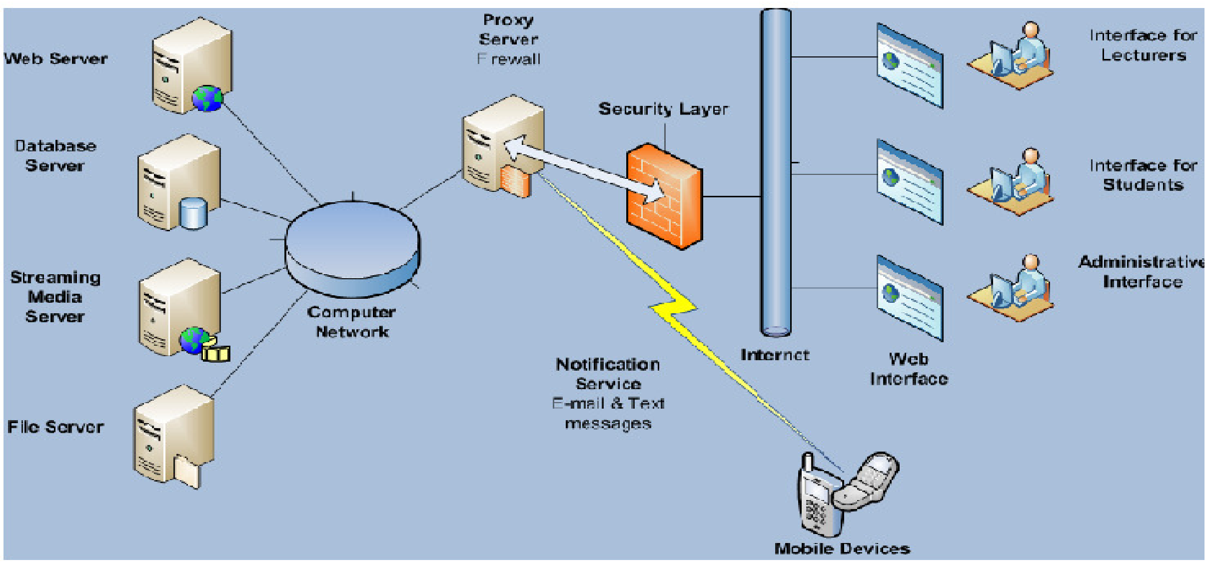

Figure 4: Secured Web-based learning Architectural Framework [8]

[9] developed an algorithm for one-sample face recognition using HMM Model of Fiducial Areas. The work used two dimensional discrete wavelet transform (2D DWT) to extract features from images and hidden Markov model (HMM) was used for training, recognition and classification. Feature subset selection was not carried out. Tested on a subset of the AT&T database, 90% correct classification and false acceptance rate of 0.02% was achieved. The technique yielded a better performance when compared with Viola Jones recognition system.

In [10], PCA was used for feature extraction and memetic algorithm (MA) was used for feature selection. MAs are evolutionary algorithms applying a separate local search process to refine individuals to improve their fitness. The unique aspect of MAs is that all chromosome and offspring are allowed to gain some experience through a local search before being involved in the evolutionary process. Simulations were performed over ORL and YaleB face database using Euclidean norm as the classifier. The result revealed that PCA-MA outperforms PCA-GA, LDA-MA, KPCA-MA with high recognition accuracy of 100%. The recognition rate for different number of selected features was better than that of the eigen face method.

[11] developed an approach to recognizing faces based on eigen vectors and a hybrid metaheuristic feature selection. Initially the face images were projected unto face space and using PCA, the eigen vectors with the high eigen values were extracted to reduce the dimension of feature vectors. Selecting the optimal feature vectors which increases the classification accuracy was done by using hybrid genetic algorithm (GA) and bacteria foraging optimization (BFO) algorithm. Support vector machine (SVM) and back propagation neural network (BPNN) were both used for classification. The classifiers were trained and tested separately using the frontal face images of AT&T. SVM produces 82.6% recognition rate and BPNN produces 83.3% recognition rate.

[12] developed a local feature-based faced representation method based on two-stage subset selection where the first stage finds the informative region and the second stage finds the discriminative features in those locations. The key motivation is to learn the most discriminative regions of a human face and the features in there for person identification, instead of assuming a priori any region of saliency. In the research, multi-frequency wavelets were used as local feature extractors to obtain local image descriptors which were placed carefully over the face region. Moreover, depending on the locations of these image descriptors, useful frequencies and orientations should be found since specific parts of a face contain high frequency information (such as eyes) and some other parts contain low frequency information (such as cheeks). Learning discriminative facial locations and obtaining optimal local feature extractor parameters was formulated as a feature subset selection problem. The highest recognition accuracy realized was 88.8%.

[13] implemented a face recognition system based on eigen face, PCA and ANN. PCA was used for extraction of the relevant information in the face images. The feed forward back propagation neural network was used for recognition. The method was tested on ORL face database. Eigen faces are calculated by using PCA algorithm and the experiment was performed by varying the number of eigen faces used in the face space to calculate the face descriptors of the images. The number of networks used was equal to the number of subjects in the database, therefore 40 networks; one for each person was created. Among the 10 images, first 6 was used for training the neural network while 4 was used for testing. The result was compared with k-means, fuzzy Ant with fuzzy c-means and the technique gives better recognition rate of 97% with 50 eigen faces.

[14] implements a face recognition system which uses genetic algorithm for feature selection and k-nearest neighbor as a classifier in a swap training. In the technique, the training dataset was partitioned into GA train dataset and GA test dataset so that the GA can learn what features are unique and select the efficient ones. The fitness function swaps the GA test and train data in each generation and obtained fitness was evaluated as shown in figure X . This means that the GA test for the first chromosomes is used as the GA train of the second one and vice versa. The performance accuracy in terms of recognition rate achieved using the PCA with swap training GA-kNN was 97.8%.

[15] developed a combination of PCA and Local Preserving Projection (LPP) to capture the most discriminative features which was used for face recognition. The work employed the combination of global feature extraction technique, PCA and local feature extraction technique LPP to achieve a high quality feature set called Combined Global and Local Preserving Projections (CGLPP). The CGLPP features are the discriminative features among the samples considering the different classes in the subjects. Considerable improved result in facial image representation was obtained and recognition rate of 87% was realized on AT&T face database.

[16] developed a face recognition algorithm based on Adjacent Pixel Intensity Difference Quantization (APIDQ) in rectangular coordinate plane. To obtain feature vectors, intensity variation vectors for all the pixels in an image were first calculated, then each vector was quantized directly in (dIx, dIy) plane. A histogram was created by counting the number of elements in each quantized area in the (dIx, dIy) plane. The histograms obtained by the APIDQ are the features. A rough location information of facial parts was used to divide the facial area into 5 individual parts (forehead, eyes, nose, mouth, jaw) before applying APIDQ on each facial component. Recognition results were obtained from each different parts separately and the combined by weighted averaging. Experimental result with FERET face database achieved recognition rate of 97.8%.

[17] presented a face detection and recognition system based on neural network for skin colour segmentation. It was discovered from the work that skin model is the most prominent method of face detection required in video surveillance and other feature based individual recognition. The work also revealed that as the number of images increase, results obtained are more accurate.

[18] developed a face recognition system using harmony search-based selected features. Harmony Search Algorithm (HSA) is based on the idea of musician's behavior in searching for better harmonies. PCA was used for feature extraction and HSA was employed for the selection of optimal subset of features. The two-level approach to dimensionality reduction as shown in Figure 5 was compared with the standard PCA over a set of images from the AT&T face database. The results obtained with the HSA gives an accuracy of 94% in face recognition. However the Computational time requirement was not reported.

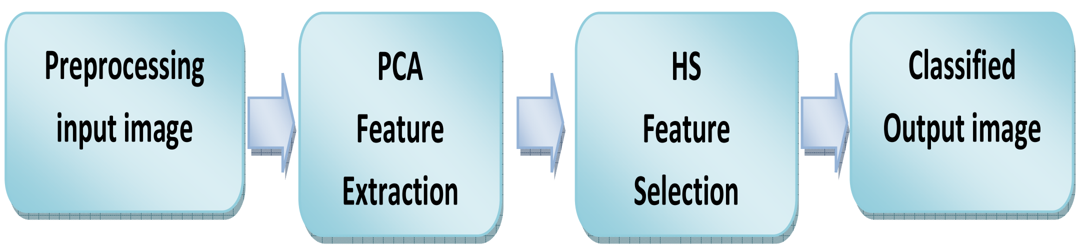

Figure 5: Block diagram of HS-based face recognition system [18]

[19] carried out a performance evaluation of optimized PCA (OPCA) and Projection Combined PCA $(PC)^2A$ methods in Facial Images based on recognition accuracy, total training time and average recognition time. The result obtained indicated that OPCA performed better than $(PC)^2A$. [20] proposed a new method for face detection based on wavelet transform function for feature extraction and used ant colony optimization technique for selection of facial image feature for classification by support vector machine. The proposed method was compared with PCA and SVM method for detection of group image. The empirical result showed better performance in comparison with PCA and Support Vector machine. The recognition time as well as recognition accuracy achieved were not explicitly stated.

[21] developed a novel method for pose robust face recognition towards practical applications, which was fast, pose robust and worked well under unconstrained environments. Firstly, a 3D deformable model was built and a fast 3D model fitting algorithm was proposed to estimate the pose of face image. Secondly, a group of Gabor filters were transformed according to the pose and shape of face image for feature extraction. Finally, PCA was applied on the pose adaptive Gabor features to remove the redundancies and Cosine metric was used to evaluate the similarity.

Experimental results of the method on FERET and PIE face database shows the proposed method significantly achieves comparable performance with state-of-the-art methods by reporting mean recognition rate of 95.31% on 12 facial poses

[22] proposed a method of GA based neural network for feature selection. In the method which consists of four stages, PCA was used for dimensionality reduction, LDA was used for feature extraction, GA was used for feature selection and finally Back Propagation Neural Network (BPNN) was used for the classification of face images. A recognition rate of 97.5% with execution time of 10-20ms was achieved. [23] developed a framework for pose adaptive component-based face recognition system. The framework dealt with illumination, expression, pose variation and occlusion. In the developed system, facial landmark localization was first done on the face images using 3D Camera Kinect Sensor device for capturing the scene.

In the second step, facial component extraction was done. The components extracted from the face region are forehead, eye brow region, left eye, right eye, nose, mouth and chin region. These components were extracted from the facial region by setting a rectangular bounding box around the component as region of interest (ROI). In the next step, preprocessing of facial images was done and facial pose estimation was carried out, followed by fusion of pose adaptive classification of components. By employing pose adaptive classification, the recognition was carried out on some part of database, based on estimated pose, instead of applying the recognition process on the whole database. The experimental result shows that the component-based recognition techniques used provide better recognition rates when face images are occluded compared to the holistic method, with recognition rate of 92% on frontal faces as well as different poses.

[24] developed a novel feature selection algorithm based on Bacteria Foraging Optimization (BFO) for face recognition system. BFO is an optimization algorithm based on the social foraging behavior of E coli bacteria which propel themselves by rotating their flagella to move forward, counterclockwise or clockwise. In the developed system, features of images were extracted using DCT technique. The extracted features were reduced further by using BFO to remove redundancy and irrelevant features. The resulting feature subset obtained by BFO is the most representative subset and was used to recognize the face from the face gallery. A high recognition rate of 100% was realized.

[25] developed a face recognition system for person identification and verification using PCA with BPNN. The method was tested on AT&T face database. The result shows that using PCA for feature extraction and BPNN for image classification and recognition provides an accuracy of 90% and a fast execution time which was not quantitatively reported. The recognition performance increases as the training image set increases. [3] carried out a performance evaluation of selected Principal Component Analysis-Based techniques for face image recognition. The systems were subjected to three selected eigenvectors: 75, 150 and 300 to determine the effect of the size of eigenvectors on the recognition rate of the systems. The performances of the techniques were evaluated based on recognition rate and total recognition time. The performance evaluation of the three PCA-based systems showed that PCA – ANN technique gave the best recognition rate of 94% with a trade-off in recognition time.

[26] presented a new way for automated attendance system which makes use of Principal Component Analysis (PCA) along with Artificial Neural networks (ANN). Automated attendance management system using face recognition is a smart way of marking attendance which is more secure and time efficient as compared to already existing (manual) attendance systems. The system automatically detects the student when he/she enters the class room and marks the attendance by recognizing his face. A threshold value is set so that the faces which did not match with those faces which are stored in database can be rejected.

In the research, global feature extraction was done using PCA which was based on calculating Eigen face and the recognition part was done using feed forward Artificial Neural Networks with back propagation algorithm. The system was made of four phases; Database Making, Feature Extraction, Face Recognition and Attendance Marking. As soon as a face is recognized, attendance is marked in the database corresponding to the matched face as the information is already stored in database in the first step. If an unknown face is tested the result shows no match found. However, quantitative result of the performance was not reported.

[27] presented a face recognition method based on PCA and RBF neural networks. Facial features were extracted by the PCA method, which reduces the dimensionality of the original face images while preserving some discriminating features within the training images. After performing the PCA, structural information was acquired corresponding to each person from lower dimensional training images. This structural information was used to model the hidden layer neurons of the RBF-NN. The proposed method was evaluated on the AT&T and the UMIST face databases using three different testing strategies; randomly partitioning the database, n-folds Cross Validation test and leave-one-out method. The experimental results obtained on both the face databases were found to be quite promising and better than some of the PCA-based methods earlier reported.

[28] developed a face recognition system based on textural features and nature inspired computation optimization techniques. In the research, Local Binary Pattern was used to extract local primitives such as lines, curves and edges from the face. The Process flow of the technique is shown in Figure 6. The features were converted to image data matrix and subjected to ant colony optimization algorithm for optimal feature subset selection. Recognition of faces was based on Mahalanobis distance metrics. Evaluation of the technique on locally acquired face database gave 98.08% recognition accuracy and on American Telephone & Telegraph face database gave 95.00% recognition accuracy.

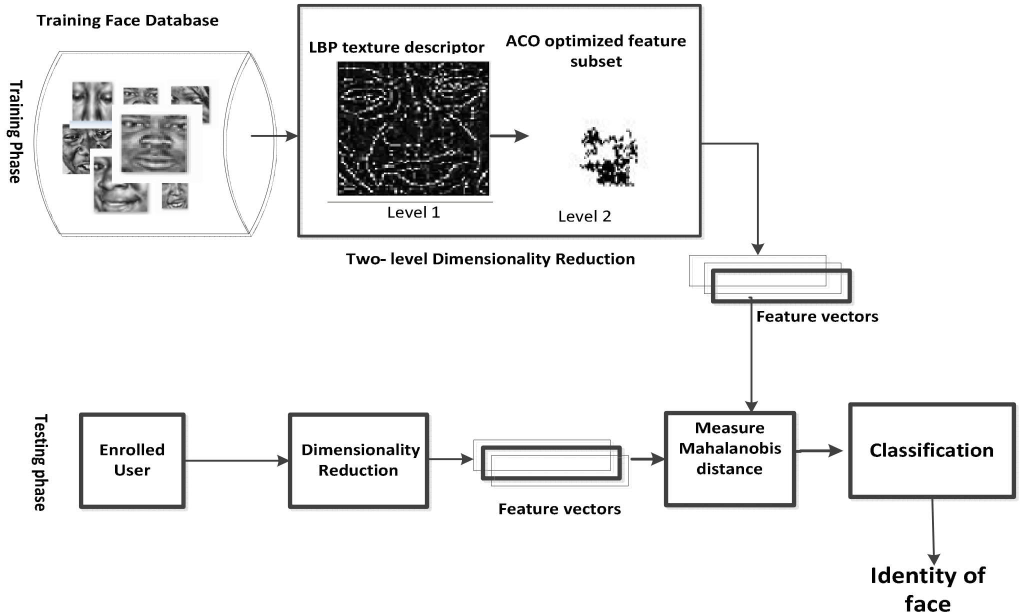

Figure 6: Process flow Ant Colony Optimized Local Binary Pattern Technique for Feature Dimensionality Reduction in Face Recognition System [28].

[29] developed a face recognition system using a hybrid of GA and ACO. The two algorithms were used to perform feature selection and the fused features were passed unto GA for recognition of unknown face. The work produced a recognition accuracy of 93.3%. However information about the training time and recognition time were not reported. A brief analysis of the aforesaid techniques is structured in a tabular format in Table 1. The Table shows some existing dimensionality reduction techniques for face recognition, along with the description of approaches used as well as some of the parameters for evaluation reported by the researches. The major trade-offs of the existing work is the computational requirement in terms of the time taken to train and test (recognize) faces by the system which were not reported in a number of the reviewed existing face recognition systems.

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Table 1: Review Of Existing Feature Dimensionality Reduction In Face Recognition Systems

Authors	APPROACH			PARAMETERS							
	Feature Extraction	**Feature Selection**	**Classifier**	**Size of training set**	**Size of testing set**	**Training time**	**Recognition time**	**Recognition Accuracy**	**Size of Image used**	**Database Used**	**Comparison with other method**
[6]	DWT	ACO	k-NN	N/A	N/A	N/A	N/A	98.5%	92*112	AT&T	N/A
[7]	PCA	N/A	Euclidean Distance	184	92	N/A	N/A	90.4%	102*127, 104*167	Black Face Database	DCT
[29]	N/A	Hybrid ACO, GA	N/A	N/A	N/A	N/A	5.2s	93.3%	320x420	N/A	N/A
[13]	PCA	N/A	BPNN	240	160	N/A	N/A	97.0%	92*112	AT&T	K-means, Fuzzy Ant, Fuzzy C-means
[9]	DWT	N/A	HMM	N/A	N/A	N/A	0.15s	90%	N/A	BFDB, AT&T	Viola Jones
[18]	PCA	HS	Euclidean Distance	100	100	N/A	N/A	94%	92*112	AT&T	PCA
[11]	PCA	GA, BFOA fuss features	SVM, BPNN	50-500	N/A	N/A	N/A	SVM(82.6%), BPNN(83.3%)	92*112	AT&T frontal Face image	N/A
[8]	N/A	N/A	PCA	N/A	N/A	0.58s	0.55s	98.68%	100x100	Black Face Database	N/A
[14]	**PCA**	**GA**	**k-NN**	**8**	**3**	**N/A**	**N/A**	**97.8%**	**N/A**	**Yale Face Data base**	**PCA-GA**
[22]	PCA, LDA	GA	BPNN	80	40	N/A	10-20min	97.5%	180*200	Collected faces	N/A
[2]	LBP	N/A	LBP	2000	2000	N/A	N/A	90%	N/A	Collected faces	N/A
[23]								92.0%	640*480	Collected faces	Holistic method
[25]								90%			
[24]				160	240			100%	20*20, 30*30, 40*40, 50*50	AT&T	PSO
[15]								AT&T 87%, UMIST 77%	50*50	AT&T, UMIST	PCA, LPP
[16]					1196			97.8%	46*65, 46*40, 46*35, 46*30	FERET	N/A
[12]				N/A	N/A	N/A	N/A	N/A	150*130	FERET	N/A
[26]				N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
[21]				N/A	N/A			95.3%	480*640	FERET, PIE	LFW
[28]	LBP	ACO	Mahalanobis Distance	480 140	300 100	0.55 0.34	0.22 0.18	98.08% 95.00%	40*40 50*50 60*60 70*70	LAFD AT&T	DWT-ACO and PCA

4. CONCLUSION

In this paper, a review of techniques used in building face recognition systems has been critically summarized. The paper presents a mini-review, far from being minor, which is intended to attract the attention of face recognition researchers in general and feature dimensionality reduction methods in particular. The major trade-offs of the existing work is the computational requirement in terms of the time taken to train and test (recognize) faces by the system which were not reported in a number of the reviewed existing face recognition systems. This review gives an imperative information to other authors carrying out research in this regard. It is hoped that this review can provide the readers a better understanding about face recognition techniques already and frequently researched, readers and interested researchers are directed to the references for more needed details on the reviewed techniques.

5. DIRECTION FOR FUTURE WORKS

Computational complexity metrics such as training time, recognition time and image resolution/dimension are some performance metrics for face recognition systems that needs to be given more attention by future developers of such systems. Additionally a survey of the condition of capture of the face images used in face recognition experiments will be researched into. The idea is that images captured under controlled environment tends to yield better performance for the recognition system than images captured in an uncontrolled environment. The ultimate goal is to develop face recognition systems with operational data which mimics real life scenario and various situation of human face that are commonly encountered in practical life.

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