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# PCA Based Rapid and Real Time Face Recognition Technique

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**Abstract:** Economical and efficient that is used in various applications is face Biometric which has been a popular form biometric system. Face recognition system is being a topic of research for last few decades. Several techniques are proposed to improve the performance of face recognition system. Accuracy is tested against intensity, distance from camera, and pose variance. Multiple face recognition is another subtopic which is under research now a day. Speed at which the technique works is a parameter under consideration to evaluate a technique. As an example a support vector machine performs really well for face recognition but the computational efficiency degrades significantly with increase in number of classes. Eigen Face technique produces quality features for face recognition but the accuracy is proved to be comparatively less to many other techniques. With increase in use of core processors in personal computers and application demanding speed in processing and multiple face detection and recognition system (for example an entry detection system in shopping mall or an industry), demand for such systems are cumulative as there is a need for automated systems worldwide. In this paper we propose a novel system of face recognition developed with C# .Net that can detect multiple faces and can recognize the faces parallel by utilizing the system resources and the core processors. The system is built around Haar Cascade based face detection and PCA based face recognition system with C#.Net. Parallel library designed for .Net is used to aide to high speed detection and recognition of the real time faces. Analysis of the performance of the proposed technique with some of the conventional techniques reveals that the proposed technique is not only accurate, but also is fast in comparison to other techniques.

***Keywords:*** Biometrics, Face Detection, Eigen Face.

## I. INTRODUCTION

Face recognition systems are finding wide range of applications already along with many other popular biometric forms like DNA and fingerprint biometric. Face recognition systems are commercially deployed in any laptops, PDA, Smart phones in application ranging from authentication to, face template based biometric and so on. With many public and Government documents in many counties adopting face recognition based systems, their application and adoptability is increased significantly.

First step in face recognition system is to extract the face part from the image frames. Out of various standards and techniques already available in the market for face detection and face localization Haar Cascades [2][3][4] based techniques have been widely popular.

Due to the tailor made approach of Haar classifiers for real time applications; it is widely used in face detection and recognition techniques. One of the primary advantages with Haar cascade based face localization is that the speed of the algorithm is fast enough to localize the faces at a speed greater than the frame acquisition rate by standard WebCams.

The face recognition system is divided into primarily four parts which is as shown in Figure 1.

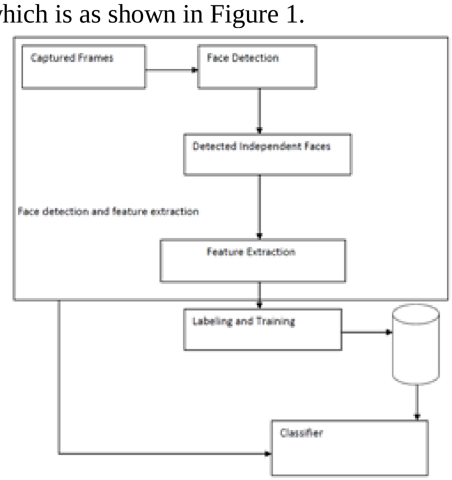



**Figure 1: Conventional stages in face recognition system**

Once the faces are localized, segmented faces are passed to the classifier which checks the closeness of the faces with the face objects stored in the database and finds the best match. The class of the best matching features of the database is the face being recognized.

Face feature extraction and analysis is divided into smaller fine grain details like a) Face Detection b) Face Landmark detection c) Gender Analysis from face d) Eye Tracking e) Age analysis of Face f) Emotion detection. Hence it is important to have an overview of all the mentioned aspects in order to understand the problem.

*a) Face Detection:* Face detection is one of oldest computer vision techniques under research. Effective face detection is important aspect of modern games. It is also significant in face recognition research.

Out of many other techniques, the one proposed by Voila and Jones [1] has become most popular due to very high accuracy of detection. One of the reasons of popularity of this technique over several other techniques was simplicity of feature selection. The work relies on simple pixel difference based features of rectangular windows in image. These features were easy to calculate in any platform. Even though method proposed by [2] is simple, rule based detection suffer under non homogeneous background. Red color dress and background with colors similar to chromatic color range of skin part suffers great misdetection. Voila [3] has also contributed towards a unified learning algorithm that is capable of detecting face region, gender, ethnicity based on rectangular features extracted with Haar basis function.

OpenCV and later much computer vision software adopted this technique with different changes in features like LBP, ABLP replacing simple rectangular window features.

Important aspects to be understood in this direction are invariance in pose, light intensity and distance from camera in detecting faces.

*b) Face Landmark Detection:* Landmarks are the important markers in a face. For example eyes, nostrils, and mouth are important landmark points. These are also invariably the 'Holes' in face image. Landmark points significantly presents face orientation, eye openness state, lips/mouth openness state, face shrinkage ( during fear and dislike expressions) which further leads to associative study in facial expression recognition. Efraty and Papadakis et Al. [4] presents a boost classifier based technique for facial landmark detection. This approach is more popular over some of the other techniques including SVM classifier because it uses the same strategy that of Voila and Jone's face detection adopts. However with introduction to Microsoft's Kinet camera and many other 3D tracking system 3D facial landmark tracking is successfully implemented and adopted by several software systems. Perakis et. al. [5] presents a 3d facial landmark tracking system from depth map data. As the depth map requires specialized hardware, we restrict our interest to 2D facial landmark tracking system based on theory proposed by [4].

*c) Gender Analysis from Face Images:* Gender detection is broadly a classification problem. Once the face part of an image is localized, gender can be detected using any good classifier with features ranging from textures and face landmark data. Gender analysis is broadly performed as Component based analysis like PCA, ICA [6] or landmark data combined with texture patterns [7]. However as the detection broadly uses cascade based classifiers, using global features for gender recognition may not be suitable for a homogeneous system that extracts both landmark and gender from the face image. Gender analysis further depends upon several aspects like ethnicity, age and so on. For example texture based gender recognition is unsuitable for Asian-Mongolian origin persons. Similarly Gender recognition might not give accurate result for kids or aged adults.

However gender analysis can be performed very accurately by analyzing the area above lips and chin part. Alessandro [8] uses an efficient pixellete based technique to recognize gender in human subjects. The pixallation minimizes the finer face image and presents aggregated fixed pixels as feature vectors. It is another popular technique for gender analysis. It is proved through different studies though that gender analysis remains an active area of research and results obtained may vary depending upon the mentioned features.

*d) Eye Tracking:* While facial landmark deals with extracting facial points, eye tracking deals with capturing the details of eye movement and gaze. Eye openness, direction of look is other significant areas of study that can be derived from eye detection. Eye tracking is more challenging than face tracking as size of eye is very small in comparison to the face part and chances of misdetections are very high due to very low area of localization of the eye part. The challenge becomes broader when implemented on real time video frames. Zhu [8] proposes a very effective technique for eye detection. It depends upon differentiating two different video source viz IR and normal camera to track the pupil part. This technique also overcomes the challenges posed by intensity variation and face. However the method still needs a depth camera. As our focus is entirely to implement the system without any specialized hardware, we deviated from the original proposal by [8]. Our method implements eye tracking by combining facial landmark points with continues frame difference and further uses the local histogram features as presented by [10].

We used landmark points as local points for eye part. These landmark points significantly marks the eye area. The tracking needs a local variation analysis of the area. Therefore we segment the eye area across the landmark points and apply the technique proposed by [10] over the difference of current and previous frame as suggested by [9].

e) Age detection: Age detection is an important aspect of characteristic analysis. Age detection can be broadly seen as age group classification problem. Age perspective differs from person to person, many appear more matured at a tender age and yet many appear childish through their behavior and facial appearance. Age detection study was significantly propelled after 1999 proposal and study by Kwon and Vitoria [11]. Their technique is based on wrinkle analysis of distinct part of the face. They proposed to detect facial points like eyes, and lips and then obtaining area of forehead, chin, chicks and performing textual wrinkle ratio analysis and test on these areas. As our proposed system relies on detecting both eye as well as face landmarks, the technique suited our method. Extracting the wrinkles is done using simple LBP analysis combined with contour extraction of local face part.

*f) Emotion detection:* Human emotion detection is probably most significant area of study in overall human characteristic study. If human face and mentioned facial features are tracked over a time period t then human plays the most prominent part of analysis over the same time window. A natural emotion for significant time period elaborates that the person suggests that the person is serious during that interval. Serious emotion with very steady head suggests that the person is nervous. A fearful emotion with continues head movement suggests that the subject is shaky and low in self-confidence. Carlos [12] elaborates a technique for facial expression recognition based on multi modal analysis. But importantly their technique involved detecting of facial points around the landmark points we detected and then running a classifier or a thresholding technique to recognize emotions. A more generalized approach is presented by Aruna and Amit [13] where the authors have proposed to segment several facial parts and then detecting the emotion based on a fuzzy inference system. We combined the techniques proposed by [12] and [13] to appropriately track the emotion. However our broad objective is human characteristic analysis. Therefore we limited our emotion based study to detecting smile. Hence the smiley and non-smiley faces are only emotion categorization that we used in this work.

## II PROBLEM FORMULATION:

Facial features are essentially statistical features. If we consider that the source of face acquisition system remains constant than each face will form an independent histogram and the pixels in the face will form a pattern. For example mean, standard deviation, moments, DCT coefficients, Gabor Coefficients forms the feature set which are unique for a person in the database. But based on the distance from camera, pose and intensity of the light at the time of acquisition, the features varies from one instance to another instance. Hence rather than matching the features directly, a statistical model extraction from the features are better suited for efficient detection. PCA is considered as one of the most reliable methods for extracting models from large statistical data with huge number of classes. Hence PCA is obviously widely preferred feature selection technique is face recognition system.

One of the most popular methods of calculating the inter-dependability of the features belonging to the features of same person in the database and the features belonging to the other person is by extracting Eigen faces. An Eigen face is mean shifted face of all the faces that are present in the database. Eigenvectors or principle components extracted from Eigen faces are good measure of one's facial features. Therefore in the proposed work we select Principle components extracted from Eigen faces for the recognition. Another measure to be considered at the time of real time face detection system is the speed of the system. Though there are several other statistical models like LDA, KPCA, due to simplicity in calculation, face recognition using PCA is selected. As the ultimate target is to achieve parallelism, and PCA's calculations present easy parallel able instructions, it is the choice of the proposed system.

## III. PROPOSED MODEL:

The proposed work is divided into following main modules:

1) Frame grabbing and parallel face detection

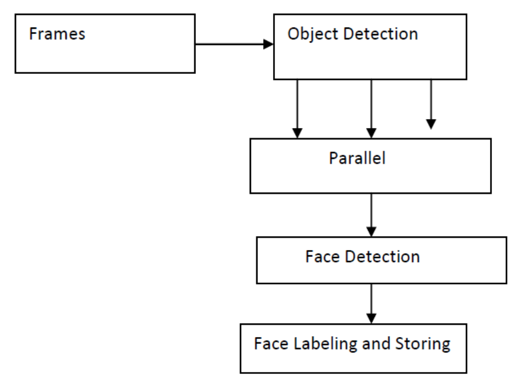



Figure 2: Face extraction for training

2) Parallel Facial feature extraction and training
3) Frame capture, extraction of facial objects parallel and recognizing them in parallel

In the first module the grabbed frames are compared with Pre stored face object database called Cascades. Cascades are essentially pixel properties over a bound rectangle (here the object boundary). In the proposed work we consider Ada Boost based Local binary pattern for matching the face features.

The facial features are stored as XML nodes in the database and are matched with the features within the rectangle enclosing the object using a fast Haar classifier. If the features are matched beyond the threshold specified in the node, than the features are said to belong to a face object and the detected object is marked as face object.

PCA is a commonly used method of object recognition as its results, when used properly can be fairly accurate and resilient to noise. The method of which PCA is applied can vary at different stages so what will be demonstrated is a clear method for PCA application that can be followed. It is up for individuals to experiment in finding the best method for producing accurate results from PCA. To perform PCA several steps are undertaken:

- Stage 1: Subtract the Mean of the data from each variable (our adjusted data)
- Stage 2: Calculate and form a covariance Matrix
- Stage 3: Calculate Eigenvectors and Eigenvalues from the covariance Matrix
- Stage 4: Chose a Feature Vector
- Stage 5: Multiply the transposed Feature Vectors by the transposed adjusted data

**Stage 1: Mean Shifted Eigen Face**

This data is fairly simple and makes the calculation of our covariance matrix a little simpler now this is not the subtraction of the overall mean from each of our values as for covariance we need at least two dimensions of data. It is in fact the subtraction of the mean of each row from each element in that row.

(Alternatively the mean of each column from each element in the column however this would adjust the way we calculate the covariance matrix)

**Stage 2: Covariance Matrix**

The basic Covariance equation for two dimensional data is:

$$cov(x,y) = \frac{\sum_{i-1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{(n-1)}$$

Which is similar to the formula for variance however, the change of x is in respect to the change in y rather than solely the change of x in repeat to x . In this equation x represents the pixel value and $\bar{x}$ is the mean of all x values , and n the total number of values. The covariance matrix that is formed of the image data represents how much the dimensions vary from the mean with respect to each other. The definition of a covariance matrix is:

$$C^{n*n} = (C_{i,j}, C_{i,j} = cov(Dim_i, Dim_j))$$

Now the easiest way to explain this is but an example the easiest of which is a 3x3 matrix. Now with larger matrices this can become more complicated and the use of computational algorithms essential.

$$C_{mat} = \begin{pmatrix} cov(x,x) & cov(x,y) & cov(x,z) \\ cov(y,x) & cov(y,y) & cov(y,z) \\ cov(z,x) & cov(z,y) & cov(z,z) \end{pmatrix}$$

$$I1 = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix} \qquad C(I1) = \begin{pmatrix} cov(1,1) & cov(2,5) & cov(3,9) \\ cov(4,1) & cov(5,5) & cov(6,9) \\ cov(7,1) & cov(8,5) & cov(9,9) \end{pmatrix}$$

**Stage 3: Eigennvectors and Eigenvalues**

Eigenvalues are a product of multiplying matricies however they are as special case. Eigenvalues are found by multiples of the covarience matrix by a vector in 2 dimensional space (i.e. a Eigenvector). This makes the covarience matrix the equvilant of a transformation matrix. It is easier to show in a example:

$$Covarience\ Matrix = \begin{bmatrix} 2 & 3 \\ 2 & 1 \end{bmatrix}$$

$$Eigenvector = \begin{bmatrix} 6 \\ 4 \end{bmatrix}$$

Multipied:

$$\begin{bmatrix} 2 & 3 \\ 2 & 1 \end{bmatrix} * \begin{bmatrix} 6 \\ 4 \end{bmatrix} = \begin{bmatrix} 24 \\ 16 \end{bmatrix} = 4\begin{bmatrix} 6 \\ 4 \end{bmatrix}$$

Eigenvectors can be scaled so ½ or x2 of the vector will still produce the same type of results. A vector is a direction and all you will be doing is changing the scale not the direction. Eigenvectors are usually scaled to have a length of 1:

$$Resultant\ Eigenvalues = \begin{bmatrix} 0.6392 \\ 0.7691 \end{bmatrix}$$

The Eigenvalue is closely related to the Eigenvector used and is the value of which the original vector was scaled in the example the Eigenvalue is 4.

**Stage 4: Feature Vectors**

Now a usually the results of Eigenvalues and Eigenvectors are not as clean as in the example above. In most cases the results provided are scaled to a length of 1. So here are some example values calculated:

$$\begin{bmatrix} 2 & 3 \\ 2 & 1 \end{bmatrix} * \begin{bmatrix} 3 \\ 2 \end{bmatrix} = \begin{bmatrix} 12 \\ 8 \end{bmatrix} = 4\begin{bmatrix} 3 \\ 2 \end{bmatrix}$$

$$\begin{bmatrix} A \\ B \end{bmatrix} \quad becomes \quad \begin{bmatrix} A/(\sqrt{A^1 + B^2}) \\ B/(\sqrt{A^1 + B^2}) \end{bmatrix}$$

Once Eigenvectors are found from the covariance matrix, the next step is to order them by Eigen value, highest to lowest. This gives the components in order of significance. Here the data can be compressed and the weaker vectors are removed producing a lossy compression method, the data lost is deemed to be insignificant.

**Stage 5: Transposition**

The final stage in PCA is to take the transpose of the feature vector matrix and multiply it on the left of the transposed adjusted data set (the adjusted data set is from Stage 1 where the mean was subtracted from the data).

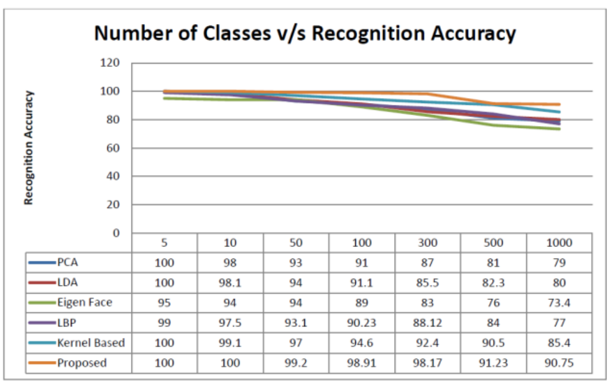
Features extracted from each face are deemed unique and group able under one unique class.

**Stage 6: Classification**

Once the features from the acquired faces are extracted, these features are given to the classifier. The classifiers matches the features with the faces stored in the database and finds the closest match.

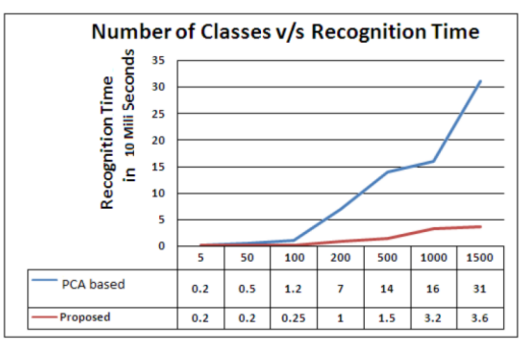
## IV RESULTS:

Figure 3: Comparative Performance of Different Face




| | 5 | 10 | 50 | 100 | 300 | 500 | 1000 |
|---|---|---|---|---|---|---|---|
| PCA | 100 | 98 | 93 | 91 | 87 | 81 | 79 |
| LDA | 100 | 98.1 | 94 | 91.1 | 85.5 | 82.3 | 80 |
| Eigen Face | 95 | 94 | 94 | 89 | 83 | 76 | 73.4 |
| LBP | 99 | 97.5 | 93.1 | 90.23 | 88.12 | 84 | 77 |
| Kernel Based | 100 | 99.1 | 97 | 94.6 | 92.4 | 90.5 | 85.4 |
| Proposed | 100 | 100 | 99.2 | 98.91 | 98.17 | 91.23 | 90.75 |

Recognition Technique against Number of Classes




| | 5 | 50 | 100 | 200 | 500 | 1000 | 1500 |
|---|---|---|---|---|---|---|---|
| PCA based | 0.2 | 0.5 | 1.2 | 7 | 14 | 16 | 31 |
| Proposed | 0.2 | 0.2 | 0.25 | 1 | 1.5 | 3.2 | 3.6 |

Figure 4: Number of Classes vs Recognition time in a 10 ms scale.

Figure 3 demonstrates the recognition accuracy of number of faces in a five simultaneous faces in the scene. The faces of college students are registered and five faces are incorporated in the scene. As the system is real time, it detects the faces continuously. Therefore experiment is conducted to measure number of faces detected par frame and number of correct detection. The segmentation accuracy for 1000 tests is found to be 98% which is quite satisfactory. The result shows that as the classes or the registered user increases, the recognition accuracy is decreased. This is partly due to number of comparisons in the classification stage and mainly due to many features being correlated among different classes. Further the experiments were conducted where the users were asked to change the position and posture without leaving the scene. The performance deviation observed in all the techniques was minimum. Hence it can also be inferred that the position and posture has little effect on the accuracy of the face recognition accuracy.

The same test was performed by changing the intensity of the room. We switched on different number of 100 watt bulbs to get different luminance for the room. It is observed that for medium to high intensity, the result were very much similar. However for low intensity scene, the results observed were poor. This is partly due to the fact that in low intensity, Eigen face is more blurred which does not allow clear features to be extracted from independent faces.

Further, the experiment was conducted where we start with one face and user is requested to enter the scene after arbitrary period of time. We observed that if the faces are not overlapped they are segmented accurately and recognition of each segment or face results in almost similar accuracy irrespective of number of faces in the scene.

One test was conducted to see the effect of number of training instances on the accuracy of the system. We consider a 10 class problem and trained the system with one test instance to ten test instance. For training samples less than five instance par class, accuracy degrades to about 50% of the original and for 10 training instance, it attains the highest value as presented in the result above.

Even though the proposed system is derived from real time PCA system, PCA takes way too much time as the number of classes are increased. The complexity is O(n)=nlog(n) . This is expected as number of comparison increases to great deal with increased number of classes. But the proposed system enables to attain better recognition rate by dividing the recognition to multiple parallel detection and hence attains a complexity of O(n)=log(n). Hence for huge increase in number of classes, the increases in recognition time is optimum.

## V CONCLUSION:

The face recognition algorithms based in PCA (Principal Component Analysis) do multiple comparisons and matches between a face detected and the trained images stored in binary database for this reason and to improve the

accuracy of recognition several images of the same person in different angles, positions and luminance conditions was added. This training do this prototype solid and very accurate. Though the features can be effectively used to train neural network or a support vector machine, a distance based classifier was used to speed up the process and for simplicity of implementation. It is found that the classifier is fast and accurate as evidenced by the results. One of the reasons being this is that the PCA features acts like templates and a distance based classifier is simply a template matching technique if designed carefully.
Results show significant improvement of the algorithm over both face detection speed and recognition speed and accuracy. Neural network/SVM can further be used with this system to analyze the efficiency and speed variations in detection.

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