Face Recognition Using PCA

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Abstract

Face recognition is the process of verifying any known person's face from the system's database, whereas face detection is the process of identifying a human face. As a result, human face detection and recognition is the process of identifying and verifying a known person's face by supplying an image of that person's face. This method allows you to use the facial expressions of a person to verify his identity in a secure system, for criminal identification, passport verification, terrorism detection, other purposes, and so on. The human face is a complex multidimensional structure that requires sophisticated computing tools to recognize. Face recognition is treated as a two-dimensional problem in our approach. Face recognition is accomplished using the Principal Component Analysis (PCA) algorithm in this study. This is a personal identification system that identifies a person's face based on the personal characteristics of that person's face. The implementation is also covered in this report.

KEYWORDS: Face Recognition, PCA, Biometrics

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CHAPTER 1: INTRODUCTION

Introduction

Face recognition requires good computational algorithms because it is a complicated multidimensional structure. Face recognition is treated as a two-dimensional problem in our approach. Face recognition is accomplished using Principal Component Analysis in this technique (PCA). Face photos are projected into a face space that encapsulates the most diversity among known face images. The face space is characterized by eigenfaces, which are eigenvectors of a set of faces that may or may not correspond to common facial characteristics like eyes, noses, and lips. The PCA is used in the eigenface technique to recognize images. The method works by projecting a pre-extracted face image onto a set of face space that represents substantial differences between known face images. If the user is new to the face recognition system, then his/her template will be stored in the database else matched against the templates stored in the database. The variable reducing theory of PCA accounts for the smaller face space than the training set of faces.

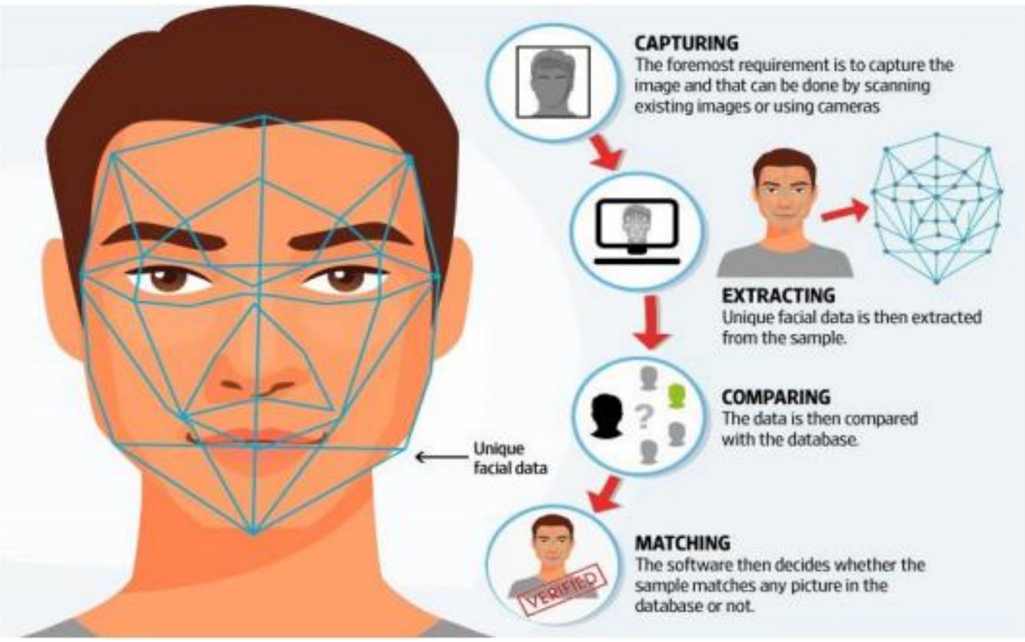

Fig 1: A general procedure of human face recognition system

The figure above depicts the general procedure of a human face recognition system. The practice of recognizing a person based on their facial picture is known as face recognition. This approach enables the use of a person's face photographs to authenticate him into a secure system for purposes such as criminal identification, passport verification, terrorist detection, and so on.

Biometrics

Biometrics is used to verify or identify that a person seeking a network resource is who he, or she claims to be, and vice versa. It makes use of the property that a human trait is connected with a person, such as a finger structure, face details, and so on. We can authenticate a person's identification by comparing the existing data with the incoming data [1].

Fingerprint recognition, face detection and recognition, iris recognition, and other biometric systems are used for human identification in surveillance systems and criminal identification. The advantages of using these traits for identification are that they cannot be forgotten or lost. These are unique features of a human being which is being used widely [2].

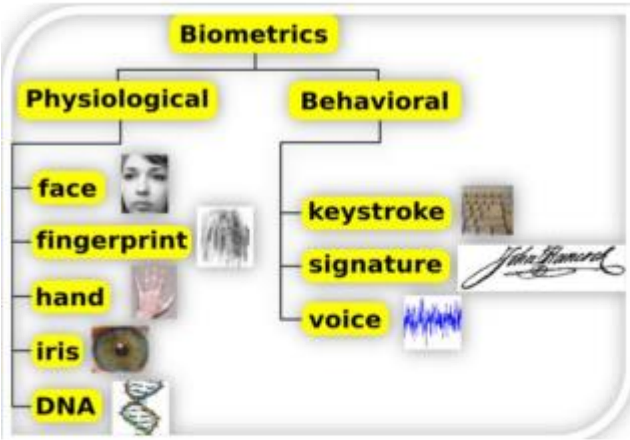

Fig 2: Types of Biometric

Face Recognition

Face recognition requires good computational algorithms because it is a complicated multidimensional structure. The face is our primary and first center of attention in social life, and it plays a significant part in an individual's identity. We can recognize a large number of faces that we have learned throughout our lives and can recognize them at a look even after years. Faces may alter as a result of aging and distractions such as beards, spectacles, and haircut changes.

Biometrics includes face recognition as a key component. Basic human qualities are matched to existing data in biometrics, and a human being's identity is traced based on the results of the matching. Facial features are extracted and implemented using efficient algorithms, with some changes made to improve the existing algorithm models.

Face-detection and recognition computers could be used in a range of practical applications, such as criminal identification, security systems, and identity verification. Face detection and identification are currently employed in a variety of venues, including image storage services and social networking sites. Face recognition and detection can be accomplished utilizing computer science methods.

Face features are extracted and compared to faces in the database that have been similarly processed. If a face is recognized, it is known; otherwise, the system may display a similar face already in the database. If an unfamiliar face shows more than once in a surveillance system, it is saved in a database for further recognition. These steps are quite helpful in identifying criminals. Face recognition techniques are divided into two groups based on the face representation they use: appearance-based, which uses holistic texture features and is applied to either the whole face or specific regions in a face image, and feature-based, which uses geometric facial features (mouth, eyes, brows, cheeks, and so on) and geometric relationships between them.

Challenges in Face Recognition

There are some challenges in our face recognition system that are as follows: -

- Pose of the face.
- The lighting or illumination of the photograph that was taken.
- The face's size in the image.
- Face expressions in the photograph.

As you can see, we have four points in our previous part, which we will now go over in detail. If I'm talking about facial expressions, this one should be in front. This is required since our technology recognizes the front aspect of a person's face. Similarly, lighting or lighting settings should be favourable because the image captured in those circumstances must be clearly visible for the system to recognize that person. In the image, the size of the face is also important. This is because when the face size is high, the image's backdrop area shrinks, and when the face size is small, the image's background area expands.

CHAPTER 2: LITERATURE SURVEY

Principal Component Analysis (PCA)

Karl Pearson invented principal component analysis (PCA) in 1901. PCA is a variable reduction approach that is useful when there is some duplication in the data. As a result, variables will be reduced to a smaller set of variables known as Principal Components, which will account for the majority of the variance in the observed variable.

When we want to do recognition in a high-dimensional space, we run into issues. The goal of PCA is to keep as much variety in our original data set as feasible while reducing the dimensionality of the data. Dimensionality reduction, on the other hand, entails information loss. The best principal components can be used to find the optimum low-dimensional space.

The main benefit of PCA is that it can be used in an eigenface approach, which reduces the amount of database needed to recognize test images. The images are stored in the database as feature vectors, which are discovered by projecting each trained image to the set of Eigenfaces obtained. To reduce the dimensionality of a large data set, PCA is used in conjunction with the Eigenface approach.

1. Compute the mean feature vector

   $\mu = \frac{1}{p}\sum_{k=1}^{p} x_k$, where, x_k is a pattern (k = 1 to p), p = number of patterns, x is the feature matrix
2. Find the covariance matrix

   $C = \frac{1}{p}\sum_{k=1}^{p}\{x_k - \mu\}\{x_k - \mu\}^T$ where, T represents matrix transposition
3. Compute Eigen values λ_i and Eigen vectors v_i of covariance matrix

   $Cv_i = \lambda_i v_i$ $\quad$ (i = 1, 2, 3,....q), q = number of features
4. Estimating high-valued Eigen vectors
   - (i) Arrange all the Eigen values (λ_i) in descending order
   - (ii) Choose a threshold value, θ
   - (iii) Number of high-valued λ_i can be chosen so as to satisfy the relationship

     $\left(\sum_{i=1}^{s}\lambda_i\right)\left(\sum_{i=1}^{q}\lambda_i\right)^{-1} \geq \theta$, where, s = number of high valued λ_i chosen
   - (iv) Select Eigen vectors corresponding to selected high valued λ_i
5. Extract low dimensional feature vectors (principal components) from raw feature matrix.

   $P = V^T x$, where, V is the matrix of principal components and x is the feature matrix

Fig 3: Principal Component Analysis (PCA) Algorithm

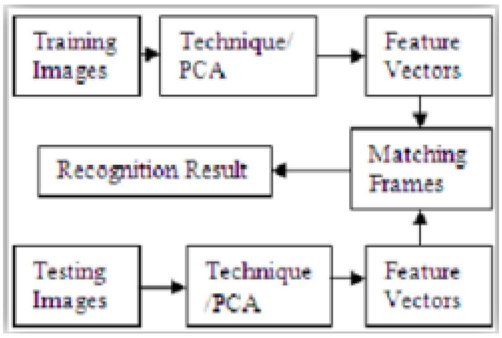

Fig 4: Block Diagram of PCA

Eigen Face Approach

It is an adequate and efficient method to be used in face recognition due to its simplicity, speed, and learning capability. Eigenfaces are a set of Eigenvectors used in the Human Face Recognition problem in Computer Vision. They refer to a face recognition approach based on appearance, which aims to capture variation in a collection of face images and use this information to encode and compare images of individual faces in a holistic manner.

The Eigenfaces are the Principal Components of a Face Distribution. Alternatively, the Eigenvectors of the face set's covariance matrix images, where an N-by-N pixel image is treated as a point in an N 2-dimensional space. Face recognition research in the past has largely ignored the issue of face stimulus presuming that predefined measurements were relevant and adequate This implies that facial image coding and decoding can provide information about face pictures highlighting the importance of features These characteristics may or may not be linked to the eyes, nose, lips, and hairs on the face. We want to extract the necessary information from a face image, efficiently encode it, then compare one face encoding to a database of similarly encoded faces. To extract the information contained in a face image, one simple method is to capture the variation in a series of face images.

We want to find the eigenvectors of the covariance matrix of the set of face images, or the Principal Components of the distribution of faces. Each picture location contributes to each Eigenvector, resulting in a face-like representation of the Eigenvector. Each facial image can be precisely represented by a linear combination of Eigenfaces. The training set's number of face images equals the number of conceivable Eigenfaces. The faces can also be approximated using the best Eigenface, which has the highest Eigenvalues and so accounts for the most variance within the set of face photos. The main rationale for employing fewer Eigenfaces is to save time on computation.

Eigen Values and Eigen Vectors

In linear algebra, the eigenvectors of a linear operator are non-zero vectors which, when operated by the operator, result in a scalar multiple of them. Scalar is then called Eigenvalue (λ) associated with the eigenvector (X). Eigenvector is a vector that is scaled by a linear transformation. It is a property of a matrix. When a matrix acts on it, only the vector magnitude is changed not the direction. AX = λX, where A is a vector function. (A − λI) X = 0, where I is the identity matrix. This is a homogeneous system of equations and forms fundamental linear algebra. We know a non-trivial solution exists if and only if Det (A − λI) = 0, where det denotes determinant. When evaluated becomes a polynomial of degree n. This is called the characteristic polynomial of A. If A is N by N, then there are n solutions or n roots of the characteristic polynomial. Thus, there are n Eigenvalues of A satisfying the equation. AXi = λiXi, where i = 1,2, 3...n If the Eigenvalues are all distinct, there are n associated linearly independent eigenvectors, whose directions are unique, which span an n-dimensional Euclidean space.

Face Image Representation

A training set of m images of size NxN are represented by vectors of size N2. Each face is represented by Γ1, Γ2, Γ3, ΓM. The feature vector of a face is stored in an N ×N matrix. Now, this two-dimensional vector is changed to a one-dimensional vector.

Mean and Mean Centered Images

The average face image is calculated by $\Psi = (1/M) \sum_{i=1}^{M} \Gamma_i$

Each face differs from the average by Φi = Γi−Ψ which is called mean-centered image.

Covariance Matrix

A covariance matrix is constructed as C = AAT, where A = [Φ1, Φ2, ΦM] of size N2 × N2.

The size of the covariance matrix will be N2 × N2.

Eigenvectors corresponding to this covariance matrix is needed to be calculated, but that will be a tedious task therefore, For simplicity we calculate ATA.

Consider the eigenvectors vi of AT A such that ATAXi = λiXi The eigenvectors vi of ATA are X1 and X2. Now multiplying the above equation with A on both sides we get

AATAXi = AλiXi => AAT (AXi) = λi(AXi) .

Eigenvectors corresponding to AAT can now be easily calculated now with reduced dimensionality where AXi is the Eigenvector and λi is the Eigenvalue.

Eigen Face Space

The Eigenvectors of the covariance matrix AAT are AXi which is denoted by Ui. Ui resembles facial images which look ghostly and are called Eigenfaces. Eigenvectors correspond to each Eigenface in the face space and discard the faces for which Eigenvalues are zero thus reducing the Eigenface space to an extent. The Eigenfaces are ranked according to their usefulness in characterizing the variation among the images.

A face image can be projected into this face space by $\Omega k = UT\ (\Gamma k - \Psi)$; k=1, … M, where $(\Gamma k\Psi)$ is the mean-centered image. Hence projection of each image can be obtained as $\Omega 1$ for projection of image1 and $\Omega 2$ for projection of image2 and henceforth.

Recognition Step

The test image, Γ, is projected into the face space to obtain a vector, Ω as $\Omega = U\ T\ (\Gamma - \Psi)$. The distance of Ω to each face is called Euclidean distance and defined by $2\ k = ||\Omega - \Omega k||2$; k = 1, …… M where Ωk is a vector describing the kth face class.

A face is classified as belonging to class k when the minimum k is below some chosen threshold Θc. otherwise, the face is classified as unknown.

Θc is half the largest distance between any two face images: $\Theta c = (1/2)\ \max,k\ ||\Omega j - \Omega k||$; j,k = 1,.....,M

We have to find the distance between the original test image Γ and its reconstructed image from the Eigenface $\Gamma f\ 2 = ||\Gamma - \Gamma\ f\ ||2$, where $\Gamma f = U * \Omega + \Psi$.

If $\geq \Theta c$ then the input image is not even a face image and not recognized. If $< \Theta c$ and $k \geq \Theta$ for all k then input image is a face image but it is recognized as an unknown face. If $< \Theta c$ and $k < \Theta$ for all k then input images are the individual face image associated with the class vector Ωk.

CHAPTER 3: IMPLEMENTATION

We have implemented the approach of facial recognition through PCA on the ORL dataset. It is a well-known face database that can be downloaded from Kaggle Source mentioned in the References section. It contains ten different images of each of 40 distinct people.

Data Generation Conditions

- For some subjects, the images were taken at different times, varying the lighting, facial expressions, and details.
- All the images have been taken against a dark homogeneous background with the subjects in an upright, frontal position.
- The face image should be normalized and frontal-view.

Training and Testing Dataset

We will be including a total of 389 images in our Training Dataset out of the 400 available in our Kaggle Dataset. We will be removing one image of any one of the people (say A) and all the images of the 40th person. We will be including these 11 images in our Testing Dataset and will test our code using these as queries.

Conditions for Proper Functioning of Code-

- If we give one image of A as a query, we should get only one of his images in the best match out of the 389 possible images in the Training Data.

- If we give any image of the 40th person, we must get the person which resembles him the most in facial features out of the 39 possible people as none of the images of the 40th person are already in the Training Dataset.

Steps for Implementation

1.Read all 400 images from the downloaded Zip File by importing the library- zip file.

2.Show 16 of the Sample Faces using the library- matplotlib.

Fig5:Output for Step 2

3. Print details including the pixel size of each provided image, the number of people detected, and the total number of images.

4. Iterate through the dataset and append only 389 of the 400 images in the list face matrix which will be our Training Dataset. 11 remaining images will be used as a testing dataset for generating queries as explained.

5. Create an NxM matrix with N images and M pixels per image.

6. Import PCA from Scikit Learn Library in Python.

7. Apply PCA and take the first K principal components as eigenfaces.

8. Show the sample eigenfaces generated from any 16 images.

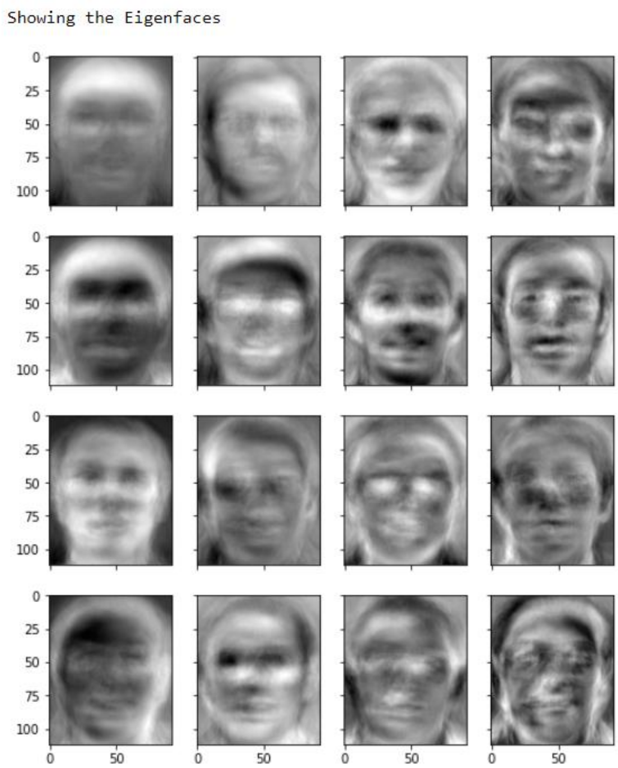

Fig:6 Sample Eigen Faces

9. Generate weights as a KxN matrix where K is the number of eigenfaces and N the number of samples.

10. Test the code by making use of the 11 separated images as queries, the results of which are pasted in the Results Section. You can also test it using random queries i.e, choosing any 11 of the 400 images as Testing Dataset for checking the proper execution of the code.

CHAPTER 4: RESULTS

The results which we are showing here are generated by excluding one of ten faces of the 8th and 28th person respectively from the training dataset to store it as a query and then test the code.

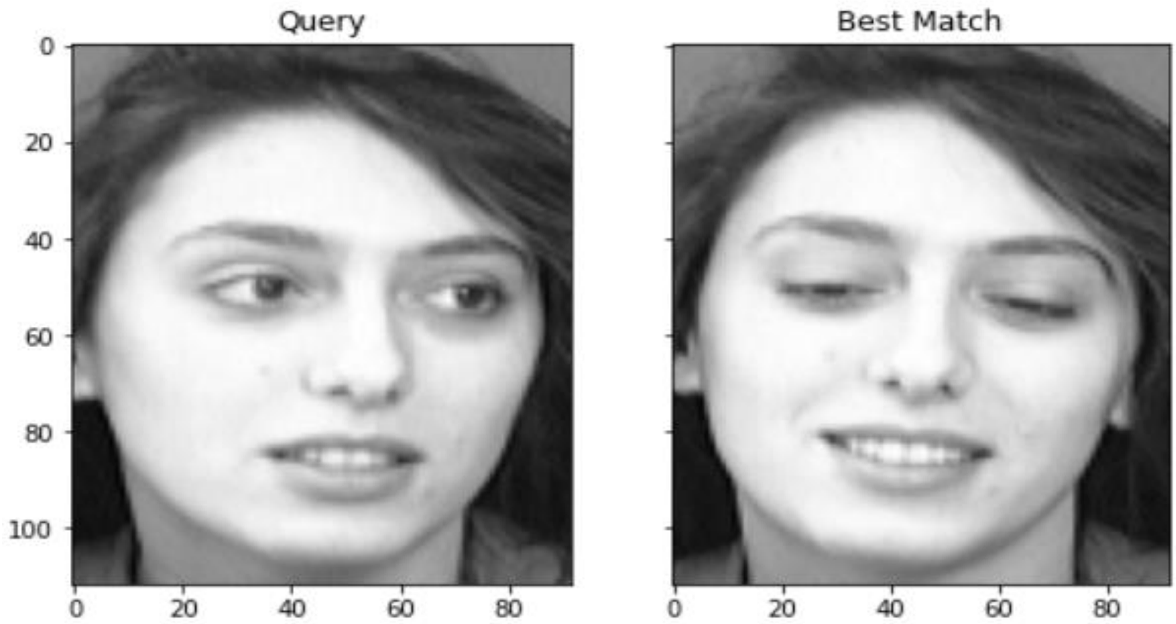

Fig 7: Result on Testing on 10th Face of 8th Person

Fig 8: Result on Testing on 10th Face of 28th Person

Results display the proper working of the code due to which it provides the image of the same person as the Best Match out of 389 images in the Training Dataset.
Now we will show results generated by excluding all ten faces of the 40th person from the training dataset to store all of them as a query and then test the code.

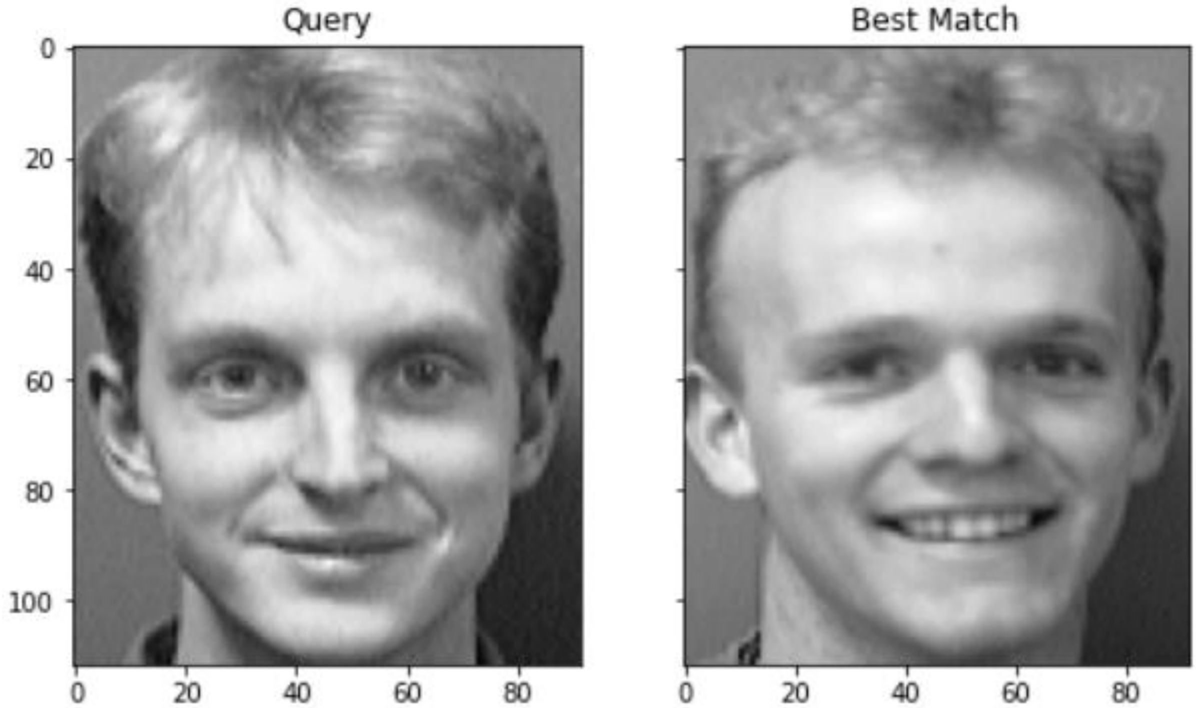

Fig 9: Testing on 6th face of 40th person

Results display the proper working of the code due to which it provides the image of the 5th person who highly resembles the facial features of the 40th person. As we have not included even a single picture of the 40th person in the training set, it gives the picture of the person who resembles him the most out of the 39 people.

CHAPTER 5: CONCLUSION

From the implementation and research, we have produced a project on human face recognition system. Finally, the PCA approach is used to recognize faces in this research. As a result, we discovered that our system successfully recognized human faces and performed better in various face orientations. But after varying the transformations, the accuracy of the model drastically decreases. More advanced methods like CNN would give better accuracy with varying transformations but are difficult to train and require a comparatively larger dataset.

REFERENCES

[1] Anil K. Jain, Robert P.W. Duin, and Jianchang Mao. Statistical Pattern Recognition: A Review. IEEE Transactions on Pattern Analysis and Machine Intelligence, 22(1):4 – 37, January 2000.

[2] Sunita Kumari, Pankaj K. Sa, and Banshidhar Majhi. Gender classification by principal component analysis and support vector machine. In ACM International Conference on Communication, Computing & Security, ICCCS 2011, pages 339 – 342, Rourkela, India, February 2011.

[3] Rafael Gonzalez and Richard Woods. Digital Image Processing. Addison Wesley, 1992.

[4] M. A. Turk and A. P. Pentland. Eigenfaces for Recognition. Journal of Cognitive Neuroscience, 3(1):71 – 86, 1991.

[5] https://www.kaggle.com/tavarez/the-orl-database-for-training-and-testing

[6] E. Hjelmås, and B. K. Low, "Face detection: A survey", Computer Vision and Image Understanding, Vol. 83, No. 3, Sept. 2001, pp. 236-274.

[7] A. Abdallah, M. Abou El-Nasr, and A. Lynn Abbott, "A New Face Detection Technique using 2D DCT and Self Organizing Feature Map" in Proc. of World Academy of Science, Engineering and Technology, Vol. 21, May 2007, pp. 15-19.

[8] J. Nagi, "Design of an Efficient High-speed Face Recognition System", Department of Electrical and Electronics Engineering, College of Engineering, Universiti Tenaga Nasional, March 2007.

[9] Dinesh Kumar Dimensionality.(May 2008),Reduction using SOM based on Technique for Face Recognition, Journal of Multimedia, Vol.3, No.1.

[10] Shemi P M, Ali M A, A Principal Component Analysis Method for Recognition of Human Face: Eigenfaces Approach, International Journal of Electronics Communication and Computer Technology (IJECCT), Volume 2 Issue 3 (May 2012).