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Working of Multiple Face Recognition Systems and the Techniques

Zainab Mohammed Ali[1], Yadav Pooja Sabhajeet[1], Srivaramangai R[2], Nikhil Pawanikar[3]
[1, 2, 3]Department of Information Technology, University of Mumbai, Mumbai, Maharashtra, India-400098

Abstract**—** *The technology of face recognition has been into existence since 1960's. Since then it never stopped evolving. New techniques, algorithms and methods were introduced by many researchers, some of them got old but some evolved with time. But they all had one thing in common, recognizing a human face. In early stages of face recognition technology, computers were used as a displaying system to manually detect the face on comparison of the pictures by experts. As the technology evolved, automatic biometric machines were invented which could transfer the acquired data to a centralized database where pattern matching algorithms were integrated with the system. This paper discusses the working of face recognition systems, applications of face recognition systems and the various techniques used for detecting and recognizing the face.*

Keywords**—** *Face Detection, Face Recognition, Viola Jones, PCA, LDA, Eigenface algorithm.*

I. INTRODUCTION

Human face is the one of the most important features for human identification. Science is developing new technologies with help of mathematical models and statistics which makes face detection easier than the earlier technologies. Face detection is prominently used in many fields. It can be for the purpose of security, identity, business and many more. India's 'Aadhaar' is known as the world's largest biometric database. 'Aadhaar' contains biometric—iris, fingerprints, facial image— which can be used in facial recognition [16]. With the pandemic situation, it has become mandatory to use face machines rather than finger print machines for biometric identification. Every human face has their own unique features like eyes, nose, shape etc., which plays a major role in face detection and recognition as shown in figure 1.

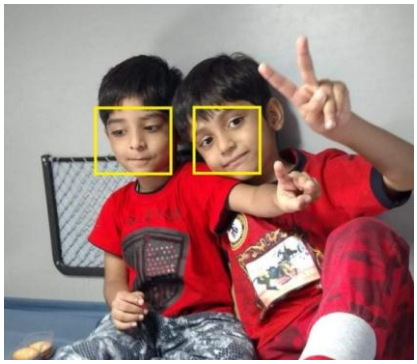

Fig. 1. Result of a face detection algorithm

"Facial detection" as the keyword itself reveals it's meaning that it is an analysis about where a face is located in an image. There are many constraints, such as single face or multiple faces, image rotation, posture, which need to be taken into consideration. False detected region of an image may happen while face detection in the face recognition system. There are lot of techniques available to resolve these problems; some of them are discussed in this paper.

II. WORKING OF FACE RECOGNITION SYSTEM

Face detection is a procedure through which we are able to extract face region from a human body. The concept of facial recognition can be implemented in various ways but mainly four steps are used for this implementation. Almost everyone is good at recognizing faces. Familiar facial features play a main role in identification of many people. For instance, a person finds it easy to identify the family members rather than those people he/she might have seen rarely. Similarly, a facial recognition system scans an image to find facial features but on a grand, algorithmic, mathematical scale. A face works as a data for a face recognition technology which can be saved. These data can be later accessed for future work. For instance, MORPH Longitudinal Database has the largest face recognition database with over 400,000 facial images of 70,000 subjects [17]. Their database is licensed for developmental and commercial uses. Technologies may vary but some basic steps are taken to work with facial recognition. These steps are illustrated in figure 2 and are as follows:

Step1. A picture of the face of person to be recognized is captured from a photograph or video or a biometric machine. Basically, a camera is used. The face in the image can be just a single person in image or a person in a crowd. The image may show the person looking straight ahead front or nearly in the profile.

Step 2. Face recognition software reads the structure of the face. It also calculates the distance between the eyes and the distance from forehead to chin which are the key factors. It also captures each and every feature on face, its attributes with the right measurements and statistical properties.

Step 3. Using mathematical formula, the analysis of the face is done which actually extracts elements known as face prints.

Step 4. Pattern matching is done with the faceprint against the registered face data in the database.

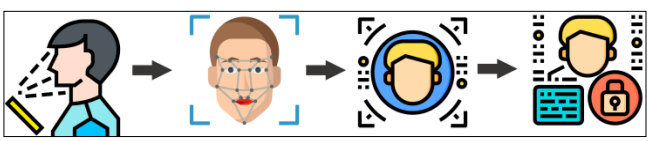

Fig. 2. Steps of Face Recognition System

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III. Applications of Face Recognition

The technology of facial recognition is used by many private as well as government organizations. It is also used for security purposes in malls, stadiums, event halls and other organizations. Apart from that it is used for attendance in schools, colleges, companies. One of the major applications for civilians is to have an identification document for various public services, like the 'Aadhaar' which is one of the world's largest biometric programme. Aadhar uses biometric—iris, fingerprints, facial image for the identification of a person. Almost 1.25 billion Indians have enrolled in this programme and obtained their identification card known as Aadhar card [15]. In February 2020, Delhi police used facial recognition with the help of 'Aadhaar' database to identify the personnel and arrest them [18]. Similarly, Apple was the first smartphone company who used facial recognition as a security feature in 2017. It uses FaceID which authenticates the user of the phone. According to Apple, the chance of your phone getting unlocked by a random face is one in a million [19]. Social media platforms like Facebook use the technology of facial recognition to spot faces when the user uploads an image. It asks the user to tag the person in the uploaded image. If the user says yes, it creates a link to the tagged person. The accuracy of DeepFace, the deep learning facial recognition system used by Facebook is almost 98% [20]. Retailers can combine surveillance cameras and face recognition system to scan the shoppers and avoid shoplifting. Airports in India are using Digi Yatra, an approach by Indian Government, to provide a hassle-free experience to the passengers travelling through flights. Passengers will be automatically proceeding to the next check points without have to wait in line. This new technology adopted by Indian Airports is useful in managing the long lines at security check-ins [21]. Facial recognition is used by banks across the world to provide excessive security. Some banks use Apple FaceID authentication to let the user access their mobile banking applications in mobile phones. Other mobile phones have also implemented this feature.

IV. Various Techniques of Face Recognition

The techniques of face recognition are based on four major methods namely holistic, feature based, model based and hybrid. We will be discussing the holistic and feature based approaches and compare their performance. In holistic approach, the entire face is considered and stored as input data for complete matching process. Some of the techniques under this approach are Principal Component Analysis, Linear Discriminant Analysis and Eigenfaces.

A. Prinicpal Component Analysis (PCA)

Principal Component Analysis is well-known technique for dimensionality reduction. This is also known as Hotteling transform or Karhunen Loeve trans-form. It is a statistical technique that was proposed by Karl Pearson in 1901 & H. Hotelling in 1933 as part of factional analysis. This technique has found the wide range of application in different field of research. PCA is a powerful & widely used linear technique in statistics, signal processing, image processing and so on. PCA is used to simplify the multidimensional dataset into a simple dataset. PCA consign to the explanation of the structure of variance and co-variance without losing the original information. It contains eigenvector & eigenvalue where eigenvector is vector which doesn't change when transformation is applied into it & eigenvalue is used to transform the eigenvector. It calculates Euclidean Distance, from the p variables as the measure of dissimilarity among the n objects. PCA derives the best possible k dimensional (p>k) representation of the Euclidean distances among objects. Each principal axis is a linear combination of the original two variables. Figure 3 shows an example of a PCA creation.

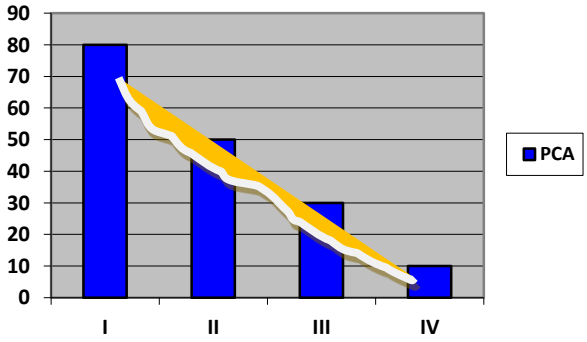

Fig. 3. PCA Creation

Here maximum features are fit into the first component, the next maximum to the second and so on. Eqn. 1shows the mathematical formula of how PCA are created.

$$PCi = ai1Y1 + ai2Y2 + \cdots + ainYn \quad (1)$$

Thus, it first standardizes the initial variables, then computes covariance matrix, followed by the computation of eigen values and eigen vectors of this covariance matrix in order to identify the PCA.

B. Linear Discriminant Analysis (LDA)

Linear Discriminant Analysis, a supervised classification approach, is a dimensionality reduction technique which reduces the number of irrelevant variables in a data set while maintaining the important variables. The data set can in the form of image, video, audio and many more. It projects the feature in higher dimension space onto the lower dimension space. For instance, LDA reduces the number of features in an image so that the image can be processed faster at the time of classification. When LDA used in a face recognition system, it treats classes as a person's face. Hence if there is *n* number of classes in a dataset, there will be *n* number of faces. Linear Discriminant Analysis maximizes the between-class scatter and minimizes the within-class scatter which means it calculates the difference of between-class scatters with eqn. 2,

$$S_b = \sum_{i=1}^{g} N_i\,(\overline{x_i} - \bar{x})(\overline{x_i} - \bar{x})^T \quad (2)$$

Then it calculates the interval between with-class scatter,

$$S_w = \sum_{i=1}^{g}(N_i - 1)S_i = \sum_{i=1}^{g}\sum_{j=1}^{N_i}(x_{i,j} - \overline{x_i})(x_{i,j} - \overline{x_i})^T \quad (3)$$

Then the lower dimension space is made which maximizes the between-class scatter and minimizes the within-class scatter hence,

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$$P_{lda} = args\ max \frac{|P^T S_b P|}{|P^T S_w P|} \quad (4)$$

C. Eigenface Algorithm

The Eigenface is the name given to the set of eigen vector which is used for Human Face Recognition on computer vision. EigenFace Algorithm is developed by Sirovich & Kirby in 1987 and this algorithm is used by Matthew Turk & Alex Pentland within the face classification. A covariance matrix is constructed using a basis set of all images formed using EigenFaces. Like PCA, Eigen face algorithm is also a method for dimensionality reduction where the system represents many subjects (dimensions) with a comparatively small set of information. Eigen face algorithm removes the noise from the input data with the help of mathematical tool called Principal Component Analysis. Eigen Face algorithm discriminate the input data of several persons. Input data are noisy prefer it have different poses, lighting etc. This algorithm transforms the original image of the training set into a set of Eigen Face. Afterward, it will calculate the weight for each image & stored in the set W. By observing an unknown image X, the weight calculated for that image & stored in vector Wx, and now Wx is compared with the weight of images (training set W). After that regarding each weight, vector as a point in space & calculate average distance D between the weight-vector Wx & weight-vector of unknown images. If the average distance is greater than the threshold value, then Wx of unknown image lies too far from weight of face. In this calculation unknown image X is not a face. Otherwise, Weight-vector is used for later image classification. Thus, the sequence of steps involved in Eigenface algorithm are given below.

1. Acquire face images for training set
2. Calculate the Eigen values and Vectors E
3. Calculate the weight of E with respect to the training set
4. Input test image (new image)
5. Calculate the weight with respect to E and new image
6. Calculate the Euclidean distance of both the weights
7. If the distance is negative then it's a face being identified otherwise its not a face
8. If the face is identified then save the new image to training set along with its weight.

The advantages of this algorithm are

- No low level or middle processes for data usage.
- No need of Geometrical knowledge on the data
- Very simple and efficient recognition method

In feature based approach, Viola Jones algorithms is most prominently used in face recognition.

D. Viola Jones Algorithm

This algorithm was proposed by Paul Viola and Michael Jones in the year 2001. The goal of this algorithm is to aim the problems occurring while face detection and to train the software so that it can detect the difference in objects. OpenCV, a library introduced by intel in year 2000, is implemented and its method cvHaarDetectObjects (), is used for face detection. Viola Jones Algorithm is the most preferred algorithm because of its robustness and fast full frontal upright face detection. The only downside of this algorithm is its longer training period. But because of the longer training period it is able to collect more accurate data so the time of detection is fast and the false positive rate is very low. Viola Jones Algorithm [3] classifies images based on the value of simple features instead of pixels. The reason to use feature-based system over pixel-based system is its speed. The simple features used in this algorithm are the reminiscent of Haar basis functions.

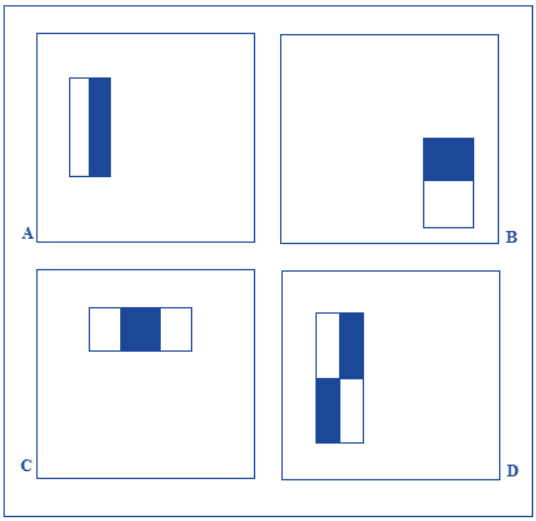

Fig. 4. Three features used in Viola Jones Algorithm

Mainly Viola and Jones [3] have used three features in their paper. According to them, the first feature, a two-rectangle feature has a value that is the difference between the sums of the pixels within each of the two rectangular regions. Those rectangular regions are same in size and shape and are adjacent to each other. In figure 4, A and B are to rectangle features. The second feature is three-rectangle feature. It has a value that is the total sum within two outside rectangles subtracted from the sum in a center rectangle. And the third feature is the four-rectangle feature. Here the difference between diagonal pairs of rectangles is computed [3]. Viola Jones Algorithm is best at recognizing frontal faces. To recognize a face it changes the colorful images to grayscale so that the facial features can be easily detected with the help of above mentioned features. These vertical and horizontal features are used to describe nose and eyebrows respectively. The base resolution set for the algorithm by Viola and Jones is 24x24 and 160,000 features combinations can be fit in that resolution. The calculation of so many features takes a lot of time so to overcome this difficulty *Integral Image* was introduced. The sum of the pixel values of original image is computed by the Integral Image. Consider a location (*x,y*) in the image. The integral image at this location will contain the sum of all pixels above and all pixels to the left of location, inclusive:

$$ii(x,y) = \sum_{x' \le x, y' \le y} i(x', y') \quad (5)$$

where *ii(x , y)* is the value of integral image and *i (x , y)* is the value of original image.

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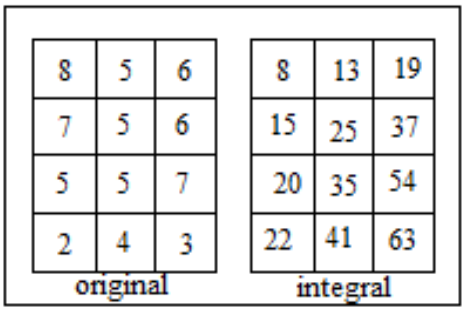

Fig. 5. Sample Integral Image Calculation

Viola and Jones trained their algorithm with 4,960 facial images and 9,544 images of non-facial objects so that their algorithm can easily differentiate between human faces and objects. This training of images to the algorithm was possible with the help of *AdaBoost*. AdaBoost is an Adaptive Boosting technique proposed by Freund and Schapire in 1996. This algorithm main focus is to make weak classifiers into strong classifiers so that the end result has minimum false positives. Viola and Jones used this algorithm with the Haar features to train their algorithm efficiently. They kept feeding their algorithms images both facial and non-facial until the algorithm finally give the positive results. Another layer of confirmation was added to Viola Jones Algorithm was *Cascading Classifiers*. These cascading classifiers are fed the positive results from AdaBoost to identify the face. Each classifier has to go through several stages of filters. If a classifier fails to give positive result at stage one it gets dropped out of the queue and next classifier starts the process. If it passes the first stage with positive results and proceeds to the next stage and the cascading keeps going until all the classifiers are checked.

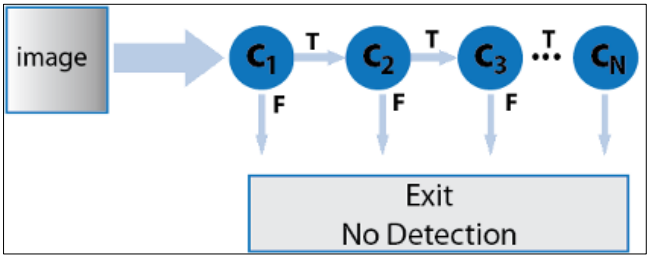

Fig. 6. Workflow of Cascading Classifier

V. DISCUSSION

Face recognition is the challenge of identifying whose face is in an input image whereas face detection is process of searching a face in the given input. The algorithms and method discussed above can be sorted and categorized into recognition and detection system as given in Table. 1.

The figure 7 gives an overall idea of the advantages and limitations of the four algorithms studied in this paper. Though Viola Jones algorithms seems to be outperforming than the other three, the choice of algorithm is relative to the area of application and source of data.

TABLE. 1. Comparison of the Performance of Techniques

Sr. No	Algorithm/ technique	Category	Accuracy
1.	Viola Jones Algorithm	Face Detection	The accuracy of Viola Jones Algorithm is high with very low false positive rate.
2.	Principal Component Analysis (PCA)	Face Recognition	The accuracy rate of Principal Component Analysis is 99.37% [11].
3.	Linear Discriminant Analysis (LDA)	Face Recognition	Linear Discriminant Analysis (LDA) have a very low false positive rate.
4.	Eigenface Algorithm	Face Recognition	• Accuracy rate of different number of eigenfaces. • The number of eigenfaces 1, 2, 3, 4, 6, 8, 10, 12, 14 correspond to 25.95%, 74.59%, 90.30%, 96.46%, 98.31%, 98.89%, 99.47%, 99.30%, 99.47%. [12]

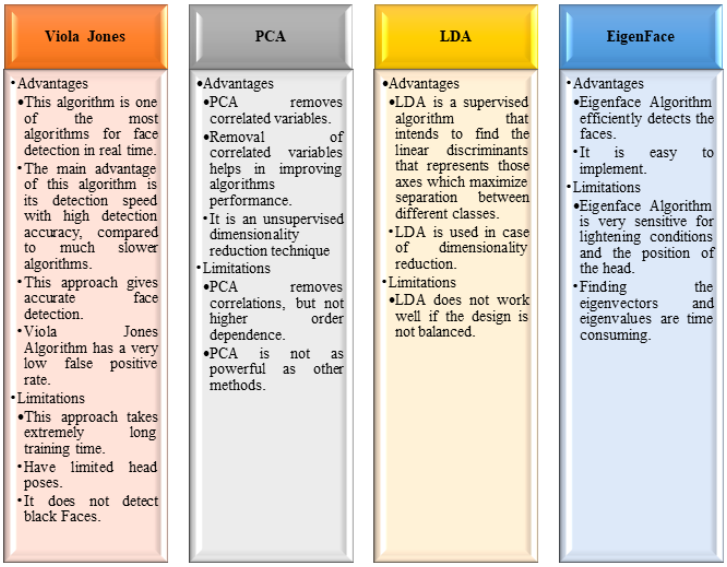

Fig. 7. Advantages and Limitations of the Four Algorithms

REFERENCES

[1] Bruce A. Draper, Kyungim Baek, Marian Stewart Bartlett and J. Ross Beveridge, "Recognizing Faces with PCA and ICA".

[2] Sunita Roy and Susanta Podder, "Face detection and its applications", *IJREAT International Journal of Research in Engineering & Advanced Technology*, Volume 1, Issue 2, April-May, 2013 ISSN: 2320 – 8791.

[3] Paul Viola and Michael J. Jones, "Robust Real-Time Face Detection", International Journal of Computer Vision 57(2), 137–154, 2004.

[4] Smriti Tikoo and Nitin Malik, "Detection of Face using Viola Jones and Recognition using Back Propagation Neural Network", International Journal of Computer Science and Mobile Computing, Vol.5 Issue.5, May- 2016, pg. 288-295.

[5] M Shujah Islam Sameem, Tehreem Qasim and Khush Bakhat, "Real Time Recognition of Human Faces", 2016 International Conference on Open Source Systems and Technologies (ICOSST).

[6] Vishwanath D. Chavan and Anil A Bharate, "A Review Paper on Face Detection and Recognition in Video", International Journal Of Innovative Research In Electrical, Electronics, Instrumentation And Control Engineering, Vol. 4, Issue 1, January 2016.

[7] Supriya D. Kakade, "A Review Paper on Face Recognition Techniques", International Journal for Research in Engineering Application & Management (IJREAM), ISSN : 2494-9150 Vol-02, Issue 02, MAY 2016.

[8] Kavita and Ms. Manjeet Kaur, "A Survey paper for Face Recognition Technologies", International Journal of Scientific and Research Publications, Volume 6, Issue 7, July 2016 , ISSN 2250-3153.
[9] Sujata G. Bhele and V. H. Mankar, "A Review Paper on Face Recognition Techniques", International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), Volume 1, Issue 8, October 2012, ISSN: 2278 – 1323.
[10] Turk, Matthew A., and Alex P. Pentland. "Face recognition using eigenfaces." Computer Vision and Pattern Recognition, 1991. Proceedings CVPR'91., IEEE Computer Society Conference on. IEEE, 1991.
[11] Turk, Matthew, and Alex Pentland. "Eigenfaces for recognition." Journal of cognitive neuroscience 3.1 (1991): 71-86.
[12] Bonyad, A., 2005. Multitemporal satellite image database classification for land cover inventory and mapping. J. Applied Sci., 5: 834-837.
[13] Hou Y-F, Sun Z-L, Chong Y-W, Zheng C-H (2014) Low-Rank and Eigenface Based Sparse Representation for Face Recognition. PLoS ONE 9(10): e110318. doi:10.1371/journal.pone.0110318
[14] Bledsoe, W. W. The model method in facial recognition. Tech. rep. PRI:15, *Panoramic research* Inc., Palo Alto, CA.1964
[15] Yin Zhang,(2010) " Cost-Sensitive Face Recognition", Biometrics Compendium, 32 , Issue: 10 , Biometrics Compendium, IEEE , 2010 , Page(s): 1758 – 1769
[16] https://timesofindia.indiatimes.com/india/aadhaar-worlds-largest-biometric-id-system/articleshow/47063516.cms, "Aadhaar world's largest biometric ID system", Apr 27, 2015
[17] https://uncw.edu/oic/tech/morph.html, "MORPH Facial Recognition Database, University of North Carolina Wilmington"
[18] https://indianexpress.com/article/cities/delhi/delhi-riots-police-cctv-7196291/, "Face recognition software used in 137 of 1,800 arrests in Northeast Delhi riots, says Police", February 20, 2021
[19] https://www.computerworld.com/article/3235140/apples-face-id-the-iphone-xs-facial-recognition-tech-explained.html, "Apple's Face ID [The iPhone X's facial recognition tech] explained", November 1, 2017
[20] https://www.deccanchronicle.com/nation/current-affairs/130519/face-value-of-facial-recognition-system.html, "Face value of facial recognition system", DECCAN CHRONICLE, May 13, 2019
[21] https://www.india.gov.in/spotlight/digi-yatra-new-digital-experience-air-travellers

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