Face Recognition Algorithms: A Review

Sneh Prabha[1], Rahul Bulchandani[1*], Rajiv Mishra[2], Sarthak Agarwal[3], Shreya Chauhan[4]

[1]*Assistant Professor, Dept. of Computer Science and Technology, Inderprastha Engineering College, Ghaziabad, India*
[2,3,4,5]*Student, Department of Information Technology, Inderprastha Engineering College, Ghaziabad*

Abstract— *Due to its applicability in different domains of life face recognition is a very fast growing area of research. In daily life, to receive information and interpret it and to identify familiar faces, face recognition is used. It is prevalent due to its simplicity and performance. In the last few years tremendous research has been carried out but still there are many challenges related to face recognition. In covid time it becomes challenging to identify a mask wearing face. This paper aims to provide an overview of some of the well known facial recognition algorithms and techniques used in research. Initially face recognition was implemented using Principal Component Analysis, Linear Discriminant Analysis, Support Vector Machine, Adaboost but nowadays to improve the quality deep learning is used.*

Key words: facial recognition, artificial intelligence, deep learning, image processing

1. INTRODUCTION

The face is an important part of human being which represents the unique identity, emotion and age. Societal intercourse and communication becomes possible through this essential part of the body. Quick and easy recognition of a person is possible through one's face. Face recognition is one of the most preferred technologies for biometric identification and verification of individuals. It is an efficient and more effective technique as compared to voice, iris, fingerprint, ear and hand gesture. Over the years after several researches, face recognition became one of the most studied research areas in the field of computer vision. It has been a fast growing and interesting area in real time application. It is a branch of pattern recognition and is an important part of the human perception system. Reliability is an important factor in face recognition algorithms or systems for the matter of security. Other methods for identification might be more accurate but face recognition has always been a major focus of research as it is the most preferred method by people for personal identification. In attendance management too face recognition is evolving as it requires bare minimum efforts. Even without any major participation or explicit action from the user side, face images can be acquired from a distance and after recognition attendance gets updated[3][4].Face recognition is really beneficial for security and surveillance checks. Moreover, it gets the better of other biometric techniques and data acquisition as the techniques which rely on hand gesture and fingerprint could turn useless if epidermis tissue gets damaged. In recognition through voice, noises in public places and fluctuations in voice causes issues. Identification through retina and iris scan requires expensive tools and are too sensitive to body motion. Modification of signatures can be easily done. However, facial images can be obtained easily and inexpensively. Effective face recognition algorithms with appropriate preprocessing can compensate for major problems in others like noise, body motion etc. It is even better than the technologies that use the same equipment for multiple individuals as it is more prone to transmission of germs and impurities. However, face recognition doesn't carry any such health risks[1]. Real-time and high detection accuracy are important factors in face recognition. It is a major step in identification, monitoring systems, criminal law, and human and computer interaction. The aim always remains for development of more accurate technology in this ever-evolving era[2]. Our goal is to understand the different algorithms, compare them and conclude based on the strengths and weaknesses discussed. After the final testing results will be compared. We will try to identify the key points of algorithms, see which got the best results and what makes them better[5].

2. KNOWN ALGORITHMS

2.1 Eigen Faces

Eigenfaces follows an appearance-based approach. In this method face detection and recognition is performed by detecting the variations of faces in a collection of images. This information is further used in a holistic manner to encode, decode and compare images. It does this process in a machine learning way which doesn't affect the computation and space complexity. To be precise, eigenfaces are the principal components of distribution of faces or the covariance matrix of the set of face images, in which an image with N pixels is considered a point in N dimensional space[6].
Sirovich and Kirby (Sirovich and Kirby 1987) and used by Turk and Pentland (Turk and Pentland 1991) developed the idea for face detection and recognition to use principal components for representing human faces. The Eigenface approach serves as the basis for the top commercial face recognition technique based products as it is the first working facial recognition technology.
Steps to perform this algorithm:
a)In input, the training set of images are given as to find eigenspace, let
$\Gamma_1, \Gamma_2, .., \Gamma_m$ with each image is $I(x, y)$. Each image to be converted into a set of vectors and a new full-size matrix(m×p), where m is the number of training images and p is x × y.
b) The average face image to be computed, using these images.

$$\Psi = \frac{1}{m}\sum_{j=1}^{m} \Gamma_j$$

c) The mean-subtracted face to be calculated

$\Phi_j = \Gamma_j - \Psi$, j = 1, 2,...,m

The matrix vector which is mean-subtracted is A = [Φ_1,Φ_2 ,...,Φ_m] with its size Amp .

d) Covariance matrix represents the difference of these images

$\underline{C_{mn}} = A_{mp} \text{x } A_{pm}^T$

where C,T are covariance and transpose matrices respectively.

e)This is used to calculate Eigenvectors and Eigenvalues. These Eigenfaces represent the various face features. Eigenvalues are to be sorted, and highest of them to be considered as they represent maximum variations.

f) Eigenvectors matrix to be applied, Vmm and adjusted matrix, Φm . Linear combinations of the training set images which form the eigenfaces is determined by these vectors, U_k by:

$U_k = \sum_{i=1}^{m} \Phi_i V_{kn}$, k = 1,2.....,m

We consider the image provided for training is more than 1 for each
individuals or class. Instead of using m eigenfaces, m'<m, m' is the total class used.

g)Each image have its face vector based on the eigenfaces:

$W_k = U_k^T(\Gamma - \Psi)$, k = 1,2,....,m′

and mean subtracted vector of size (p×1) and eigenfaces is $U_{pm'}$. The weights form a feature vector:

$\Omega^T = [w_1, w_2, ..., w_{m'}]$

h) By using the particular features which define a face, it can be reconstructed,

Ω^T

vector and previous eigenfaces, Um′ as :

$\Gamma' = \Psi + \Phi_f$

Where $\Phi_f = \sum_{j=1}^{m'} w_j U_j$

Weight vector or the Face Key are determined by the projection of the given two test images on the eigenspace for that particular image. Then Euclidean distance between the two face key vectors is calculated. Therefore, if this value is below some threshold value, then they belong to the same person as the images are matched[7].

2.2 Linear Discriminant Analysis

Illumination is considered as an important factor in the eigenface algorithm. So, this algorithm might consider light illuminations as a feature of the face which causes issues. It doesn't pay much attention to the features that represent the faces of the people. People's face features become less to use and could get discarded if the illuminations are considered as an important feature but this can be fixed by tuning eigenfaces such that it extracts separate individual features rather than treating them as a whole. This problem in the eigenface algorithm is addressed by developing an improvised version of the algorithm which is known as Fisher face algorithm or LDA. This algorithm focuses on the extraction of principal components which are unique to an individual. As the components and features are different, one person's features can't dominate another person's features. LDA is used to separate two or more classes through the segregating linear combination of features. It is used for dimension reduction and is used for modelling the difference between classes of data. With its class separation characteristics it is able to perform well even with illumination, different poses and facial expressions[9].

LDA performs the following steps in case of face recognition[8]:

1) Get images and classify them into
classes, C.

2) Mean Vector of the classes to be calculated, μ.

$\mu = \frac{1}{c}\sum_{j=1}^{c} \mu_i$

3) Within the classes, find the number of samples, M.

4) Scatter between matrix and scatter within the matrix to be calculated.

Equation to calculate scatter within matrix

$S_w = \sum_{i=1}^{C}\sum_{j=1}^{M}(Y_j - \mu_i)(Y_j - \mu_i)^T$

Equation to calculate scatter between matrix

$S_w = \sum_{i=1}^{C}(\mu_i - \mu)(\mu_i - \mu)^T$

5) Ratio of scatter between classes to within class is to be calculated.

6) Eigenvalue and corresponding Eigenvector is to be calculated.

7) Eigenvector to be normalized.

8) Weight and Euclidean distance to be calculated.

2.3 Linear Binary Pattern Histogram

The primary reason for the development of Linear binary pattern was for texture classification. This technique was later adopted for facial representation. T.Ahonen and others were among the first ones to use LBP for that same purpose. Since then many other researchers have proposed different variations of LBP. Some researchers like Barkan utilized multi-scale LBP for face description and LDA(Linear Discriminant Analysis for classification learning. This method is used in static images and has high accuracy[11].

In this method a single feature histogram is created by first dividing the face into small regions and then extracting and concatenating Local Binary Pattern features. The thought behind using LBP features is that images of the face is a collection of patterns which do not vary with respect to monotonic grey scale transformations. Combination of these patterns makes the global description of face[10].

Steps to perform this algorithm:

1)Having an image of NxM dimensions

2)This image is divided into regions of the same width and height such that the resulting image has mxm dimensions for every region.

3)The Local Binary Pattern operator is used for every region defined in a window of 3x3

$LBP(x_k, y_k) = \sum_{n=0}^{N-1} s(i_n - i_k)2^n$

Where$(x_k, y_k)$is the central pixel with intensity 'i_k' and the intensity of neighbouring pixel 'i_n' .

4)Taking the median value as a threshold , each pixel is compared to its neighbouring other 8 pixels using a

function s(x), if the value id greater than or equal to the central value it is set as 1 otherwise 0.
Where ,$s(x) = \{^{1,x\geq 0}_{0,x<0}$
Hence, binary values are obtained for the eight neighbouring pixels which are combined and translated to decimal values.
This decimal value is called the LBP value of pixel and it ranges from 0 to 255.

Later it was noted that a fixed neighborhood fails to encode details which vary in scale . Then the algorithm was improved to use different numbers of radius and neighbours and now it was known as circular LBP.

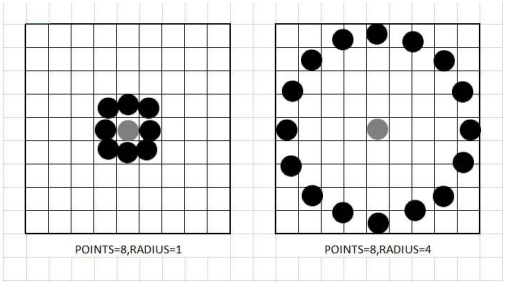

Figure 1: Circular LBP

The main idea behind circular LBP is to align a number of neighbours on a circle with a variable radius, such that the following neighbourhoods are captured:

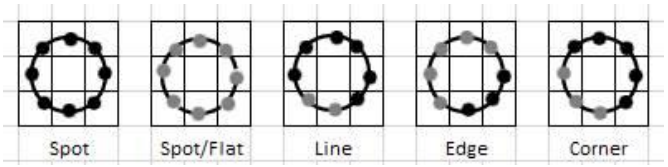

Figure 2: Circular LBP Neighbourhoods

(x_k, y_k) the position of the neighbour (x_n, y_n), where n belongs to N is calculated by:

$$x_n = x_k + R\,cos(\frac{2\pi n}{n})$$
$$y_n = y_k - R\,sin(\frac{2\pi n}{n})$$

Where R is the circle of the radius and n is the number of sample points
If the coordinate of a point does not correspond to to the coordinates of the image it is interpolated by bilinear interpolation

$$f(x,y) \approx [1-x\ \ x]\,[^{f(0,0)\ f(0,1)}_{f(1,0)\ f(1,1)}][^{1-y}_{y}]$$

Against monotonic gray scale transformations the LBP operator gives similar results.
LBP value histogram is created by counting the number of similar LBP values in the region. Feature vector of the image is created by merging all the histograms. The histogram of the images in the database and the histogram of the test images are then compared and the image with the closest histogram is returned. This is usually done by using techniques like Euclidean distance , chi-square and absolute value etc) Euclidean distance is calculated by comparing the features of the test image with the features stored in the dataset. Matching rate is the minimum distance between the original and test image

$$d(u,v) = \sqrt{\sum_{i=1}^{n}|u_i - v_i|^2}$$

If the test image matches the image from the database , we get a positive ID.

2.4 Convolution Neural Network

With further enhancement and study, CNN is used in the recognition field as well but earlier it was only used in face detection[15]. For different computation purposes, different neural network algorithms are available. For facial recognition, CNN is one of the neural network algorithms. CNN is like ANN and it has input, hidden and output layers. Convolution layers are the layers in CNN's hidden layer. CNN needs to have a training dataset of thousand or even more so as to work accurately[15]. CNN has convolution layers with rectified linear units, fully connected layers and rectified linear units[13]. With functionalities like weight sharing, pooling and receptive fields, image transformation operations can be performed more effectively[15].
CNNs and Viola-Jones method work in a series of steps. In Viola-Jones, steps are set while in CNNs, they are less structured. This might seem counterintuitive given that the results of one step are passed onto the next step, but the reality that there are usually multiple pass-throughs of the numerous steps makes every step have the appropriate records for its execution. There are 4 fundamental steps used in CNNs: convolution, pooling, and ReLu, and a fully-connected layer[12].

2.4.1 Convolution layer

Pixels in the picture are represented by a number in range -1 to 1. 1 is a bright pixel and -1 is a dark pixel and 0 is gray. Patterns are extracted from the picture which are used to detect the image. For example a this picture of 'X' patterns of cross, backward slash and forward slash is used as filters to be matched through the pictures.

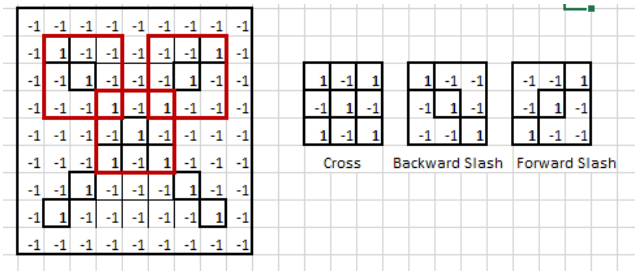

Figure 3. Representation of a picture of an "X" with the values corresponding to thecolor of each pixel.

A filter is chosen and compared to other blocks from the top left and this process is repeated through the entire picture by moving to next blocks. A Stride represents the number of pixels which are to be shifted from the current position. Stride of the same of the same size of the filter avoids overlapping

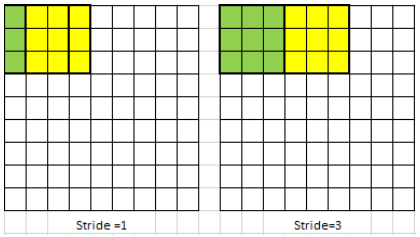

Figure 4. Visualization of a shift after a comparison with a stride 1 and a stride 3.A stride of the same size of the filter avoids overlapping.

The output square is much smaller than the input because each comparison will only give one number as a result. To find the output size the following formula is used:

$$Op = \frac{(w-k+2pd)}{st}+1$$

Op = output height/length
w = the input height/length
k = filter size
pd = padding size
st = stride value

Here , the padding size is used to control the size of the output.
In figure, the backward slash filter is being compared to a top left block. Values of each of the blocks are multiplied , sum is calculated and then divided by 9 to find the average. The resulting value is placed in the output.

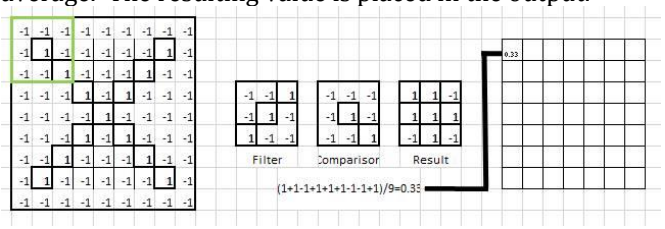

Figure 5. Visualization between a filter which is different to the compared block.

This process is repeated for all the blocks and for all filters. The result is a square is called the convolution layer. This is used as input in another layer.

2.4.2 Rectified Linear Units layer (ReLU)

Activation function is used after the convolution layer to add non-linear properties in the network since recognizing faces is not a linear problem and cannot be summarized into one linear function. Activation function gives a value from 0 to 1 , it is called active when the value is near 1 and inactive when near 0. The aim of this layer is to replace the negative numbers by 0.

2.4.3 Maximum Pooling layer

The role of Maximum pooling layer is to reduce the previous layer it receives as the input. Image is split in a number of nxn windows and only the maximum value in each window is kept. Max pooling layer preserves the main information but at the same time reduces the number of pixels significantly.

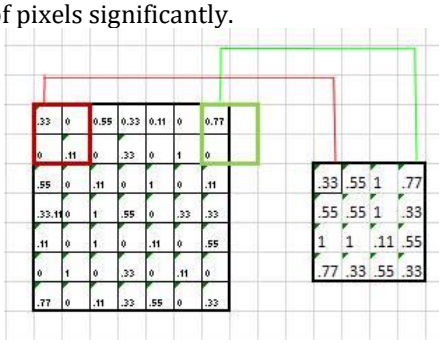

Figure 6. Visualization of the max pooling process

2.4.4 Fully connected layer

The initial picture is passed through the previous layers multiple times and the data of the last layer is used as input in the fully connected layer. The squares in the figure are results of our example for the backward slash , forward slash and cross filter. The results in the figure are the prediction of 'X'. If the pixel value is bigger it means the weight is bigger. Bigger value of pixel means thicker line which represents higher number of votes.

The same process is done for all the classes and averages of the thickest line for each class is calculated , the class having the biggest average is prediction of the CNN[5].

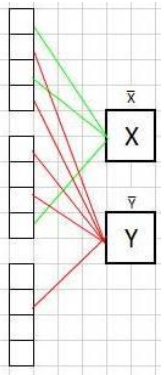

Figure 7. Visualization of the fully connected layer

3. REVIEW AND ANALYSIS

Paper	Methodology	Metric Used	Experimental Results
A New Method for Face Recognition Using Convolutional Neural Network[17].	In this paper, the overall recognition accuracy of the PCA, LBPH, KNN and proposed CNN is demonstrated.	Epoch, accuracy, ORL face database.	The convolutional neural networks achieved the best results. Using complex architectures, it is possible to reach accuracy rates of about 98.3 %

Animal Recognition System Based on Convolutional Neural Network[18].	The main aim of this paper is to compare the overall recognition accuracy of the PCA, LDA, LBPH and SVM with the proposed CNN method.	Precision, Accuracy, SVM classifier.	The proposed CNN gives the best recognition rate which is accuracy of about 98 %.
Face Recognition System Using Machine Learning Algorithm[19].	The author has performed the facing using machine learning approach and PCA. it has been implemented using linear discriminant analysis, multilayer perceptron, Naive Bayes, and support vector machine	Precision, Recall, F1-score,Accuracy	An accuracy of 100% was observed when configuration of 90:10 was used for testing and training data.
Deep learning-based Facial Detection and Recognition in Still Images for Digital Forensics[20].	The author has performed both the detection and recognition of faces using deep learning-based algorithms available within the dlib machine learning toolkit.	SVMs, K-Means clustering, Bayesian Networks.	An accuracy of 99.46% face detection and 98.10% for face recognition was observed when used with a restrained LFW dataset.
Fast Face Detection Algorithm Based on Improved Skin-Color Model[21].	The author has performed a method of face detection from a picture based on an improved skin-color model and computer vision.	Detection rate, Identification rate, SNR values, Computational cost	The proposed algorithm improves “reference white” method and is used to remove the interference caused by changes of Illumination and “remove non-face regions”
Face Detection Ensemble with Methods Using Depth Information to Filter False Positives [22].	The author has proposed a filtering approach based on processing the image with different wavelets for face detection in computer vision	Detection rate, Fast localization, False positives, normalized pixel difference, Single Scale-invariant Face Detector, Split up sparse Network of Winnows	The proposed algorithm achieves a perfect detection rate with some false positives.
Face recognition with Bayesian convolutional networks for robust surveillance systems[23].	The author has proposed an improved algorithm for face recognition using deep convolutional neural networks (DCNNs) and machine learning techniques.	Accuracy, Epoch.	The proposed algorithm outperformed other methods and achieved an improvement of 3–4% in the accuracy of face recognition.
An improved face recognition algorithm and its application in attendance	The author has proposed a new method using Local Binary Pattern (LBP) algorithm combined with advanced image processing techniques such as Contrast	False Negatives, Unknown faces, and False Recognition	The proposed algorithm shows that this method is very accurate, reliable and robust for face recognition systems and gives an

management system [24].	Adjustment, Bilateral Filter, Histogram Equalization and Image Blending to improve face recognition accuracy.		accuracy of 95%.
Comparing Face Recognition Algorithms to Humans on Challenging Tasks[25].	The author has used a face recognition algorithm created by fusing three top-performing algorithms from an international competition.	Similarity score and ROC curve.	Humans and machines results were found to be closely related by using the similarity score. Overall, machine algorithms were found more superior than the humans.
Research on Algorithms of Face Detection and Recognition across Cameras[26].	The author has used combination of Gabor wavelet and PCA to fulfil the recognition task of face image.	Light, expression, decoration, accuracy	The recognition rate is 94.5% when the face image dimension is 60.
Research on 3D Face Recognition Method Based on LBP and SVM[27].	The author has used a three-dimensional face recognition method combining LBP and SVM.	Accuracy, speed, radius of the LBP, size of the neighboring points	It is observed that the LBP + SVM algorithm used in this paper showcased 96.83% accuracy in recognition.
Face Recognition System Using Genetic Algorithm[28].	In this, the author has used a Genetic Algorithm (GA) based approach for face recognition. The proposed algorithm is then compared with known face recognition algorithms PCA and LDA.	Chromosomes, three different databases(ORL, UMIST and Indbase)	It is observed that proposed algorithm based method achieved following accuracy with different database: ORL- 98.57% UMIST- 100% Indbase- 98.33%
Face Detection and Recognition Based on Visual Attention Mechanism Guidance Model in Unrestricted Posture[29].	A visual attention mechanism guidance model is proposed by the author in this paper for face detection and recognition. The proposed algorithm is compared with algorithms s FACEILD, Faster-FCC, KSDD, DNET, ResNet, and ConvNet.	LFW, CMUFD, and UCFI databases are used. false positive per image, detection rate, false detection rate, performance, accuracy	The proposed method achieves a better balance between accuracy and speed. It shows an accuracy of 90.06%.
Deep Learning on Binary Patterns for Face Recognition[30].	The author has proposed an efficient and robust method for real-time face recognition. This method is a combination of Gaussian Filter, LBP and feature aggregator and is compared with other known recognition	Precision , Recall F1-score , Accuracy	The proposed method has been tested on four benchmark datasets which face challenges in illumination, pose, expression, scale and rotation of the head. This

	algorithms like PCA, LDA, LBP.		method delivers around 91% accuracy when tested on the datasets.
Joint Face Detection and Alignment using Multi-task Cascaded Convolutional Networks[31].	The author proposed a new nline hard sample mining strategy and used a deep cascaded multi-task framework which exploits the inherent correlation between them to boost up their performance..	Accuracy, False Positive, True positive rate, validation loss, iteration, precision, recall.	The proposed method has been tested on three benchmark datasets and it showcases 95.4% accuracy.
A Novel Approach to Detect Face Mask using CNN[32].	Proposed method uses features extraction and Convolutional Neural Network for classification and detection of a masked person.	Accuracy, Epoch.	Validation loss 0.0855 and accuracy of 98%.
A novel technique for automated concealed face detection in surveillance videos[33].	The proposed algorithm detects the presence of a human wearing the mask in the surveillance scene .Then the face is clustered to cluster patches. Then the presence or absence of human skin will be determined.	FMeasure, specificity, precision, false-negative ratio, false-positive ratio, recall.	Average detection rate of 97.51% for concealed faces.

4. CONCLUSION

In this paper, we have explained the working of different face recognition algorithms like PCA, LDA, LBPH, CNN and reviewed many papers which compared various face recognition algorithms. CNN was by far the best algorithm . The errors that were incurred during the testing can be easily minimized using a larger training data. CNN is very less impacted by changes in the environment as compared to other methods. Hence, we can conclude that facial recognition using Convolution Neural Networks is more efficient than using a statistical approach or searching for patterns.

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