

# A State-of-the-Art Survey on Face Recognition Methods

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## ABSTRACT

Face recognition is an efficient technique and one of the most liked biometric software application for the identification and verification of specific individuals in a digital image by analysing and comparing patterns. This paper presents a survey on well-known techniques of face recognition. The primary goal of this review is to observe the performance of different face recognition algorithms such as SVM (support vector machine), CNN (convolutional neural network), Eigenface-based algorithm, Gabor wavelet, PCA (principle component analysis), and HMM (hidden Markov model). It presents comparative analysis about the efficiency of each algorithm. This paper also figures out about various face recognition applications used in the real world and face recognition challenges like illumination variation, pose variation, occlusion, expressions variation, low resolution, and ageing in brief. Another interesting component covered in this paper is review of datasets available for face recognition. So, a needed survey of many recently introduced face recognition aspects and algorithms is presented.

## KEYWORDS

Convolutional Neural Network, Eigenface, Expressions Variation, Gabor Wavelet, Hidden Markov Model, Illumination Variation, Occlusion, Principle Component Analysis, Support Vector Machine

## INTRODUCTION

Face Recognition is a very important research direction in computer vision and pattern recognition. Nowadays many scientists and engineers have been focusing on establishing accurate and efficient algorithms and methods for face recognition systems. In our day-to-day life, there are thousands of applications (Huang et al., 2011)[2], which are used for face recognition in today's modern era.

The presented algorithms focus on the human face in a particular scene. For a human, it is easy to identify the faces of different people because they know how their faces look like, and of course, our brains are collecting data since birth. But for machines, it is too much difficult task to identify and recognize the face. The difficulties arise for finding the face because of different challenging situations like illumination conditions, variations in different types of the pose, occlusion conditions, excessive facial expressions, low resolution of the image, changes in facial features due to aging and complexity of the models (Yan et al., 2009)[8]. The machine works based on instructions given by the user. In the face recognition system, we have to train the model to identify and recognize the face from the given digital image. There are many algorithms or methods are available to train the model

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for the face recognition system. We have attempted to present the survey based on important and recent algorithms of the face recognition system.

This paper presents survey on face recognition techniques: SVM (Support Vector Machine) (Adegun & Vadapalli, 2020; Cherifi et al., 2019; Dino & Abdulrazzaq, 2019; Ghazal & Abdullah, 2020; Shi et al., 2020), CNN (Convolutional Neural Network) (Agrawal & Mittal, 2019; Ben Fredj et al., 2020; Ilyas et al., 2019; Jaiswal & Nandi, 2019; Ravi & Yadhukrishna, 2020), Eigenface Approach (Gupta et al., 2019; Hengaju & Sharma, 2020; Machidon et al., 2019; Mulyono et al., 2019; Zafaruddin & Fadewar, 2018), Gabor Wavelet Transform (Al-Obaydy & Suandi, 2018; Phan et al., 2019; Qin et al., 2020; Rashid & Abdulqadir, 2020; Zou et al., 2020), PCA (Principle Component Analysis) (Alahmadi et al., 2019; Arora & Kumar, 2020; Hu & Cui, 2019; Peter et al., 2018; Zhao et al., 2020) and HMM (Hidden Markov Model) (Ansari et al., 2018; Azar & Seyedarabi, 2019; Kiani & Rezaeirad, 2019; Rahul, Kohli, & Agarwa, 2018; Rahul, Matoria, Kohli et al, 2018).

The fundamental guideline of SVM is to map the linearly indivisible sample points in low dimension space to high dimension space by kernel function (Shi et al., 2020). The Convolution Neural Network (CNN) is utilized to handle picture datasets and separate features in the type of edges to have the option to perform characterization tasks over the edge features without depending upon the human-anticipated features (Jaiswal & Nandi, 2019). The Eigenface of the input image is formed for projecting the image into the subspace crossed by the Eigenvectors. Eigenface vector is a face vector that is produced by acquiring the common features of face image stored in the face database (Hengaju & Sharma, 2020). Gabor Wavelets are utilized for analyzing images due to their computational properties and biological relevance (Rashid & Abdulqadir, 2020). PCA is a technique used to lessen the number of variables or reduce the dimensionality of features (Arora & Kumar, 2020). HMM is a stochastic model which holds a Markov chain with an invisible or hidden sequence of states (Azar & Seyedarabi, 2019). This paper provides the comparison of the results of all studied papers which include details about authors, publication details, methods or techniques, dataset, and accuracy rates or recognition rate based on a research study for each algorithm. After that comparison of well-known datasets used in face recognition is presented.

## FACE RECOGNITION APPLICATIONS

In recent times, the use of biometric-based security applications has increased geometrically, especially in the area of face recognition. Hence, face recognition applications have become more popular to provide accurate and robust security for authorization. Huang T et al. (Huang et al., 2011) and Emuobonuvie E et al. (Emuobonuvie et al., 2020) presented applications used for face recognition systems across the world.

**Face ID:** Face recognition systems identify people by their face images. It directly compares the face images, doesn't use ID numbers to differentiate one from the others. This can be applied in driver licenses, privilege programs, migration, public ID, travel papers, elector enrolment, and government assistance enlistment.

**Access Control:** The face recognition system of this application is equipped for accomplishing high precision access control without a lot of co-activity from the client. It is utilized to screen consistently who is in front of a computer terminal at any time. Few applications border-crossing control, facility access, vehicle access, smart kiosk and ATM, computer access, computer network access, online transactions access, long-distance learning access, online examinations access, and online database access are using face recognition system.

**Security:** Security systems like terrorist alert, secure flight boarding systems, stadium audience scanning, computer security, computer application security, database security, file encryption, intranet security, web security, clinical records, secure trading terminals use face recognition systems.

**Surveillance:** Applications for surveillance like advanced video observation, nuclear plant observation, park observation, neighborhood watch, power grid surveillance, CCTV control, and portal control use the face recognition system.

**Smart Cards:** It contains authentication of users and stored value security. This is applied as stored value security, user authentication in a face recognition system.

**Law Enforcement:** It uses face recognition applied as crime inhibit and suspect caution, shoplifter recognition, suspect following and examination, suspect historical verification, distinguishing cheats and club undesirables, post-function investigation, government assistance extortion, criminal face recovery, and recognition.

**Face Databases:** There are several applications in which face database is used such as face indexing and retrieval, automatic face labeling, face classification.

**Multimedia Management:** In this application FR system use for face-based inquiry, event identification, face-based video division, and summarization.

**Human-Computer Interaction (HCI):** Interactive gaming, proactive computing use the face recognition system for HCI.

**Others:** In other applications like antique photo verification, very low bit-rate image and video transmission also use the face recognition system.

## FACE RECOGNITION CHALLENGES

Based on the study we show that there are some issues or challenges that exist which have a direct impact on face recognition system accuracy. Figure 1 displays various challenges.

**Illumination Variation:** Yan G et al. (Yan et al., 2009) presented the difference in illumination as yet a difficult and troublesome issue in face recognition under complex light conditions. The direction and intensity of the light source may cause the image too bright or too dark, which disturbs the face recognition algorithm of getting the information of facial accurately. Figure 2 shows the illumination variations condition (Li & Jain, 2009).

**Pose Variation:** The performance of the face recognition system also tends to fail, in the presence of pose variation in the input images as shown in Figure 3. In practices such as passport control, face images are mostly on a frontal view. However, in uncontrolled environments where the face image scanning process appears in various angles due to rotation, this can cause the face recognition system to fail (Oloyede et al., 2020).

Figure 1. Face Recognition Challenges



Figure 2. Illumination Variation (Li & Jain, 2009)



Figure 3. Pose Variation (Oloyede et al., 2020)



**Occlusion:** Occlusion can be characterized as the deterrent or blockage of a specific part of a picture or article. Hence, occlusion of the face picture can be portrayed as and when a piece of the face is secured or blocked either purposefully or inadvertently, in this manner bringing about a decrease of the exhibition of the face recognition system. The blockage of the face picture can be with glasses, shades, and scarf as appeared in Figure 4 (Oloyede et al., 2020).

**Expression Variation:** Human beings have the ability to display various facial expressions unless if the face image is in a static mode (Goyal et al., 2017). These expressions are used to represent different emotions and mental states of a particular person as shown in Figure 5 (Zhou & Xiao, 2018).

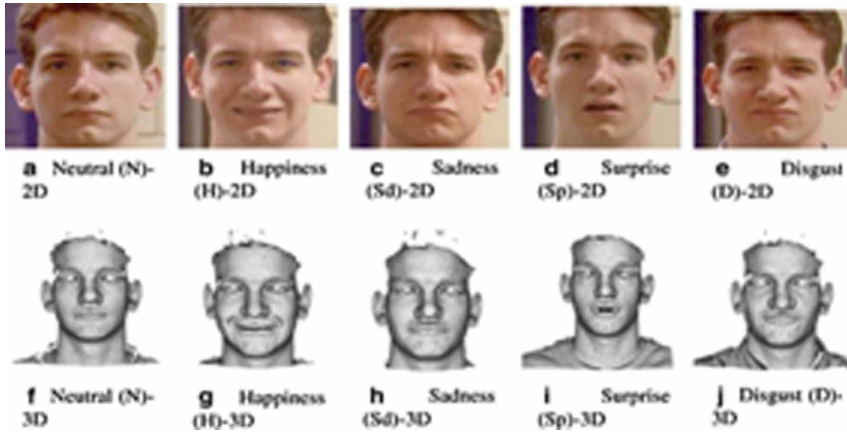
**Low Resolution:** The reason for low resolution in face recognition systems occur when the test face image has been taken with degraded quality. This results in losing important information on the face image across different individuals. This challenge affects face recognition systems especially in applications such as surveillance (Oloyede et al., 2020).

**Aging:** The issue of aging in the face recognition system is seen as a type of within-class appearance variation in the faces of humans and occurs where a much time difference exists between the targeted face images of the same person (Oloyede et al., 2020). Aging variation can have a

Figure 4. Occlusion (Oloyede et al., 2020)



Figure 5. Expression Variation (Zhou & Xiao, 2018)



significant effect on the overall facial structure of people as shown in Figure 6 (Farazdaghi & Nait-Ali, 2016).

**Model Complexity:** There are so many models available for the face recognition system. Based on the requirement of the system it is hard to pick the model which provides better accuracy with the least complexity.

## FACE RECOGNITION ALGORITHMS

### SVM (Support Vector Machine)

The basic principle of SVM is to map the linearly indivisible sample points in low dimension space to high dimension space by kernel function (Shi et al., 2020). It is commonly used for pattern recognition, classification, and regression analysis. The SVM relies upon structural risk minimization theory for constructing the optimal hyperplane segmentation in the feature space, making learning edit, or get the global optimization (Ghazal & Abdullah, 2020).

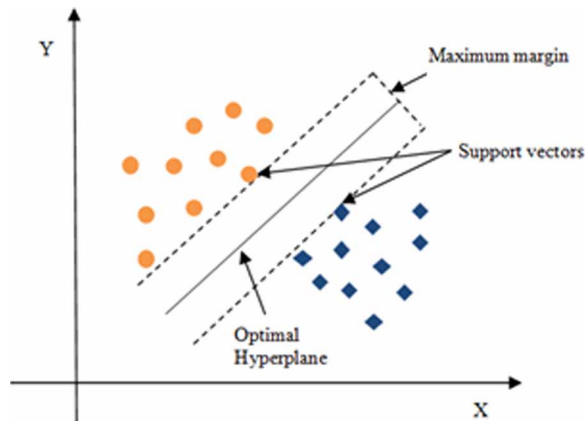
Figure 7 shows the general process of SVM. Here SVM classifier can classify the data in different 2 classes using optimal hyperplane and support vectors.

Shi L. et al. (Shi et al., 2020) proposes a three-dimensional face recognition method combining LBP and SVM. First, the LBP algorithm is used to extract the features of the 3-D face depth image, then the SVM algorithm is used to classify the features. The computer used for this experiment has

Figure 6. Aging Variation (Farazdaghi & Nait-Ali, 2016)



Figure 7. General Hyperplane Representation of SVM ()



a CPU is of 2.6GHZ with 4GB main memory. Experiments prove that the algorithm has a better recognition rate and shorter time consumption.

M Talal. et al. (Ghazal & Abdullah, 2020) proposed an algorithm for face recognition by combining Fast Discrete Curvelet Transform (FDCvT) and Invariant Moments with Support vector machine (SVM), which enhance the rate of face recognition in various situations.

Cherifi D. et al. (Cherifi et al., 2019) suggest that it is not always trivial to separate the classes at the point when they are not directly distinguishable or when we have multiple classes for these reasons we present what is called kernels.

Adegun I. P. et al. (Adegun & Vadapalli, 2020) proposed SVM as the baseline recognition model, but because of its slow learning rate, authors present ELM (Extreme Learning Machine) which has a faster learning rate. They have also discovered a method for micro-expression recognition. In this paper, features are separated from apex micro-expression frames utilizing Local Binary Patterns (LBP) and separated from the whole micro-expression videos using LBP-TOP. As a result efficiency of these two models (SVM and ELM) are compared on both static and temporal features and also their training time was compared.

Dino H. I. et al. (Dino & Abdulrazzaq, 2019) presented a method that uses the Viola-Jones algorithm for face detection. In this paper, SVM is used as a classifier. Another method used in this paper is the Histogram of Oriented Gradients (HOG) which is used as a descriptor for feature extraction and PCA is applied to diminish the dimensionality of the features, for getting the most pertinent features of the face image. In this paper, the authors have used three different classifiers which are SVM, NN, and KNN, then finally map the accuracy of each classifier.

Based on the study, a comparison for Face Recognition methods using SVM is mentioned in Table 1.

In Figure 8 we show the datasets wise accuracy comparison graph for the performance of each paper for the SVM algorithm.

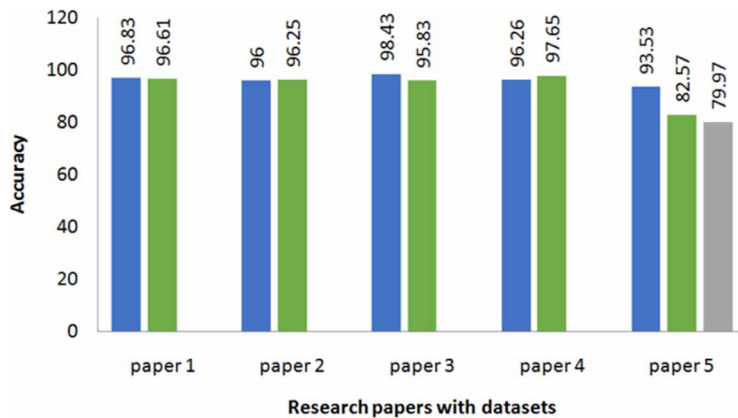
### CNN (Convolution Neural Network)

Generally, CNN is used to process the image dataset and extract features in the form of edges. It can perform classification tasks over the edge features without relying on the human-predicted features (Jaiswal & Nandi, 2019). The CNN method is used to identify the image depending on different features and distinguish images among available classes (Ravi & Yadhukrishna, 2020). There are different approaches available which are using CNN are presented here to study and compare the accuracy of each approach.

Table 1. Comparison for Face Recognition Methods using SVM

Authors	Method	Technique	Classifier	Dataset	Result (a:Accuracy/ t:Time)
Shi L. et al. (Shi et al., 2020)	LBP+ SVM	LBP is used to extract features of face image	SVM	Texas 3DFRD	a: 96.83%
					t: 1.88s
				Self- made Library	a: 96.61%
					t: 1.46s
M T Ghazal et al. (Ghazal & Abdullah, 2020)	FDCvT + SVM	Curvelet Transform is used to represent image edge discontinuities and Invariant moments	SVM	Yale	a: up to 96%
				ORL	a: up to 96.25%
Cherifi D. et al.(Cherifi et al., 2019)	HOG+ SVM	HOG is used for features extraction	SVM	Terravic Facial IR	a: 98.43%
				CBSR NIR	a: 95.83%
Adegun I. P. et al. (Adegun & Vadapalli, 2020)	LBP-TOP (SVM and ELM as Model)	ELM is used for micro-expression recognition and compared with SVM	SVM	CASME II	a:96.26%
					t: 0.3405s
					ELM
			t: 0.0409s		
Dino H. I. et al. (Dino & Abdulrazzaq, 2019)	HOG	SVM, NN, and KNN are used as the classifier	SVM	CK+	a:93.53%
	PCA				
				NN	a:82.57%
				KNN	a:79.97%

Figure 8. Accuracy graph of FR using SVM



Ravi R. et al. (Ravi & Yadhukrishna, 2020) presented a model developed using CNN and LBP. LBP is used to remove features of the face image and an SVM classifier is used to classify the extracted features of output from LBP. CNN architecture is used in this paper for scaling an image to a type that can be processed easily without compromising the vital characteristics in order to obtain correct predictions. In this paper, the CNN method is used by passing the input image into the set of various layers such as the Convolution layer, Rectified linear unit, Pooling layer, and Totally connected layer to provide a correct result (Ravi & Yadhukrishna, 2020).

Ben Fredj H. et al. (Ben Fredj et al., 2020) proposed a CNN system to learn robust face verification under an uncontrolled environment. They have used aggressive DA (Data Augmentation) methods including randomly perturbing information and complicated conditions for the appearance of faces. Authors have used the adaptive fusing strategy of softmax loss and canter loss, which is helpful to improve the performance and also to make the model more efficient and flexible. Authors have used a GoogLeNet style CNN model, called inception-v1, which includes the mainstream components of CNN architecture. In this model total of 18 layers are used namely; 2 Convolution layers, 4 Max pool layers, 1 Avg pool layer, 9 Inception layers, 1 Fully Connected layer, and 1 softmax layer called which helps to classify the tested images.

Jaiswal S. et al. (Jaiswal & Nandi, 2019) manufactured a model which can identify the emotions of an individual from an image progressively. The authors proposed a CNN model based on the Inception module. This proposed network contains 20 layers of convolution operation with ReLU and pooling. They compare its computation cost and efficiency over 8 different datasets namely Fer2013, CK and CK?, Chicago Face Database, JAFFE Dataset, FEI face dataset, IMFDB, TFEID, and custom dataset build in authors laboratory having various faces, backgrounds, poses, and age groups. The main reason to use multiple datasets is to validate the proposed network rigorously and create a benchmark for emotion classifier over efficiency and computation cost of the system. They have used NVIDIA GeForce GTX 680 GPU Server for experiments. Here computational cost was reduced from Vanilla CNN.

Agrawal A. et al. (Agrawal & Mittal, 2019) represented two novel CNN architectures based on the study of the FER-2013 dataset. Their work attempts to defeat this limitation by utilizing the FER-2013 dataset as the beginning stage to plan new CNN models. Here proposed CNN models are comparable with the VGGNet model that contains 17 Weight layers, 16 Convolution layers, Input size 64 x 64, and the size of the model is only 7.6MB. Training of network is done on NVIDIA 940MX GPU using Keras and Tensorflow. These architectures are not only simple but also it is unique in the terms of the selection of hyper-boundaries across network layers. Their studies demonstrate the kernel size and the number of filters have a significant impact on the accuracy of the network.

Ilyas B. R. et al. (Ilyas et al., 2019) proposed the approach to identify the facial expressions of people through their emotions. In this paper, the authors have combined methods Viola-Jones face detection algorithm, Facial image improvement using histogram equalization, Discrete Wavelet Transform (DWT), and Deep Convolution Neural Network. Extraction results of facial features using DWT are the input of CNN, which are used directly to train the CNN model. In this work, authors have proposed their model that network structure contains three convolution layers, two pooled layers, and one fully-connected layer.

The comparison of research studies for face recognition using CNN is shown in Table 2.

Figure 9 display the dataset-wise accuracy comparison graph for the performance of each paper for the CNN algorithm.

## Eigen Face Based algorithm

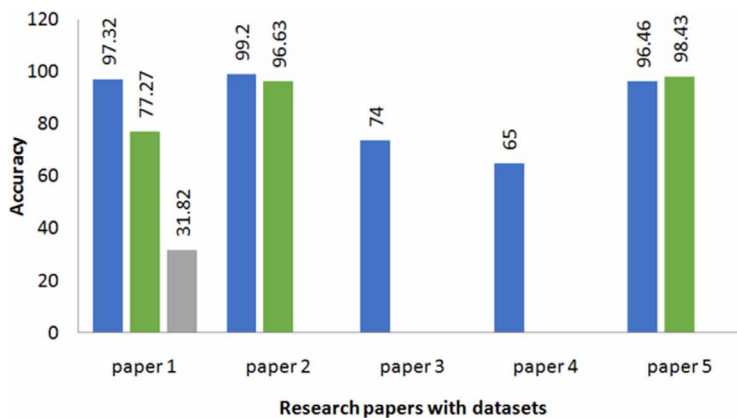
The Eigenface of the input image is formed for projecting the image into the subspace spanned by the Eigenvectors. Eigenface vector is a face vector that is generated by acquiring the common features of face images stored in the face database (Hengaju & Sharma, 2020). The Eigenface approach is quite



Table 2. Comparative Analysis for Face Recognition using CNN

Authors	Method	Technique	Dataset	Result (Accuracy)
Ravi R. et al. (Ravi & Yadhukrishna, 2020)	LBP+ SVM and CNN	LBP and CNN used to train the model	CK+	97.32%
			JAFFE	77.27%
			YALE	31.82%
Ben Fredj H. et al. (Ben Fredj et al., 2020)	DA Methods	Shows ability of CNN for imperfect facial data	LFW	99.20%
			YTF	96.63%
Jaiswal S. et al. (Jaiswal & Nandi, 2019)	Vanilla CNN	CNN model is used for predicting human emotion from an image	Fer2013	Training: 65%
				Validation:74%
			CK+	
			CFD	
			JAFFE	
			FEI	
			IMFDB	
			TFEI	
				Custom dataset
Agrawal A. et al. (Agrawal & Mittal, 2019)	CNN	Design new CNN models	FER-2013	>65%
Ilyas B. R. et al. (Ilyas et al., 2019)	Viola-Jones and	Features extraction results using DWT act as input for training CNN model	CK+	96.46%
	DWT			
			JAFFE	98.43%

Figure 9. Accuracy graph for FR using CNN



susceptible to head position uniqueness. Facial image variance happens for those face images which have significant head position disparity (Zafaruddin & Fadewar, 2018).

Wahyu Mulyono I. U. et al. (Mulyono et al., 2019) aim to examine the performance of eigenface algorithms to recognize facial images. In this research three databases are used, testing is based on

a publically available database of different facial images. Based on all experiments that have been carried out, it can be concluded that the eigenface algorithm is able to recognize face images properly under general conditions.

Machidon A. L. et al. (Machidon et al., 2019) used a geometrical approximated PCA (gaPCA) algorithm for computing the eigenfaces. The face recognition task is performed using an equality score dependent on the backward Euclidean distance for the initial two datasets and using a neural network in the third case. In this paper, all the outcomes are contrasted with the situation where standard PCA is used.

S. Gupta et al. (Gupta et al., 2019) mainly targeted the structure of the face recognition system by using PCA. PCA is a statistical impends utilized for reducing the number of dimensions in face recognition. In PCA, weighted eigenvectors known as eigenfaces are created for all images in the training set which are represented as a linear combination. These eigenvectors are acquired from the covariance matrix of the training image set. The weights are discovered after selecting a set of most important Eigenfaces. Least Euclidean distance estimation is used for sorting and analysis of test images on the subspace spanned by the eigenfaces is used for recognition.

Zafaruddin G. M. et al. (Zafaruddin & Fadewar, 2018) proposed a PCA-based face recognition system executed utilizing the idea of neural networks. This system has three stages which are preprocessing, PCA, and face recognition. In the first stage, preprocessing algorithm performs head orientation and normalization on the given image. In the second stage, calculation of the corresponding eigenfaces is done and at the third stage, it implements the face recognition. In this paper, the authors implemented an approach that varying the number of neurons in the hidden layer and varying the number of eigenfaces using neural networks.

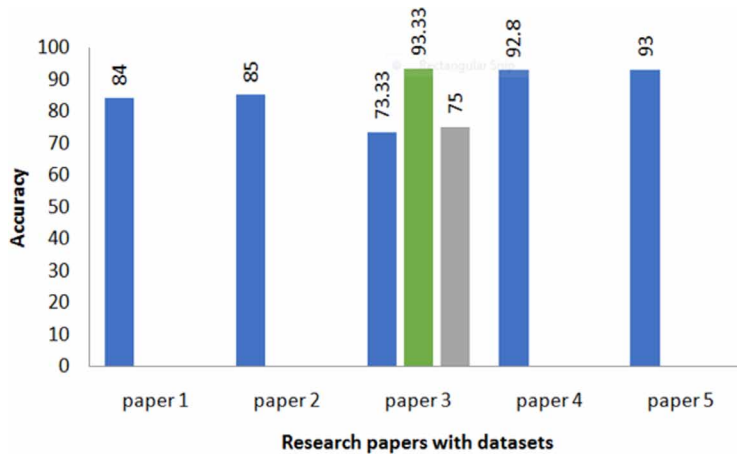
The comparative analysis of the face recognition research study based on EigenFace is shown in Table 3.

Figure 10 display the dataset-wise accuracy comparison graph for the performance of each paper for the Eigenface based algorithm.

**Table 3. Comparative Analysis for Face Recognition using EigenFace**

Authors	Method	Technique	Dataset	Result (Accuracy)
Sharma G. et al. (Hengaju & Sharma, 2020)	PCA	Algorithm based on NN based Haar classifier and Eigen face vector	Custom	84%
WahyuMulyono I. U. et al. (Mulyono et al., 2019)	PCA+ Eigen-face	Examine the interpretation of the PCA Eigenface method	ESSEX	Avg: 85%
			JAFFE	
			YALE	
Machidon A. L. et al. (Machidon et al., 2019)	gaPCA	Geometrical approximated PCA (gaPCA) algorithm for computing the eigenfaces	YALE	73.33%
			Cambridge dataset	93.33%
			LWF	75%
S. Gupta et al. (Gupta et al., 2019)	PCA	Focus on PCA, Use Eigenfaces	Celebrity	92.8%
Zafaruddin G. M. et al. (Zafaruddin & Fadewar, 2018)	PCA and NN	This method uses varying numerals of neurons in hidden layers and eigenfaces using neural networks	ORL	93%

Figure 10. Accuracy graph FR using Eigenface based algorithm



### Gabor Wavelet Transform

Gabor wavelet transform is used for analyzing the images according to their computational properties and biological relevance (Rashid & Abdulqadir, 2020).

S. J. Rashid et al. (Rashid & Abdulqadir, 2020) proposed a new model that combines the methods used in preprocessing, feature extraction, classification, and recognition to produce better results. The aggregation of Gabor Wavelet Transform, PCA, and SVM is proved effective in this face recognition system. All simulated experimentation used a personal computer with Core i5-2540M CPU 2.6 GHz and 8 GB of memory running under the Windows 7 operating system. Overall this paper has used a hybrid approach for face recognition.

Qin S. et al. (Qin et al., 2020), proposed an expression recognition method that combines Gabor wavelet transform and CNN. Subsequently various preprocessing tasks like face situating, picture trimming, histogram balance, and key edge extraction on the first picture succession performed. Generally, 40 Gabor wavelet parts are utilized to separate different appearance features. At that point after the effect of pictures are arranged and superimposed to accomplish the third-request tensors which are a contribution to the neural organization for training and classification of the facial image. This strategy has accomplished a very strong feature generalization capacity. The hardware environment of the experiment is as follows: CPU: Intel Core i7-9750H @2.60GHz, GPU: NVIDIA GeForce RTX 2070, RAM: HyperX 32.0GB (16GB\*2) DDR4 2666MHz, Hard Disk: Samsung SSD 970 EVO Plus 1TB.

Al. Obaydy W. N.I. et al. (Al-Obaydy & Suandi, 2018) introduced a method using a fuzzy ARTMAP neural network to take care of the issue of open-set single-example face recognition in a genuine video observation situation. Here proposed approach can recognize faces in close frontal perspectives under the different illumination conditions and facial expression conditions. In this paper facial features are extracted using histograms of oriented gradients (HOG) and Gabor wavelet, then it is fused using canonical correlation analysis to produce feature vectors that are robust against the aforementioned conditions. Here fuzzy ARTMAP classifier has been used for just a single individual to train the model.

Zou G. et al. (Zou et al., 2020) introduced a new multi-include combination system. First, they proposed a pixel-level data augmentation algorithm based on manifold subspace partition, which develops virtual samples in the original face picture space to find training sample expansion and diversity enhancement. The second technique they have proposed is feature-level data augmentation based on Gabor transformation, which can catch the multi-level facial features which include multi-

scale and multi-course Gabor filters to understand the facial expression in feature space. To remove the data redundancy and obstruction data created by Gabor feature augmentation, a Gabor feature encoding algorithm is proposed to develop the compressed Gabor feature vector. Also, the authors proposed a small-scale adaptive deep CNN model, which is reasonable for small sample datasets and can successfully extract nonlinear deep features of posture-shifted faces. At last, Gabor encoding features and nonlinear deep features are consolidated for small sample face recognition with a present variety (Zou et al., 2020). In this paper, the computer CPU used in the experiment is Intel core i5-4200 m, the basic frequency is 2.5GHZ, and the internal storage capacity is 16GB.

Phan A. C. et al. (Phan et al., 2019) presented a face recognition system using the Gabor Wavelet method and the Map-Reduce parallel processing model. The authors built up a face recognition system with the help of Gabor filters to extract features of the face. In addition, the authors used parallel processing for feature extraction and face recognition using the Map-Reduce model in the flash climate. Subsequently, the tasks of processing and storing intermediate data are performed on the primary memory (RAM).

The summary of this research study for face recognition using Gabor Wavelet Transform is shown in Table 4.

Figure 11 display the dataset-wise accuracy comparison graph for the performance of each paper for Gabor Wavelet Transform.

### PCA (Principle Component Analysis)

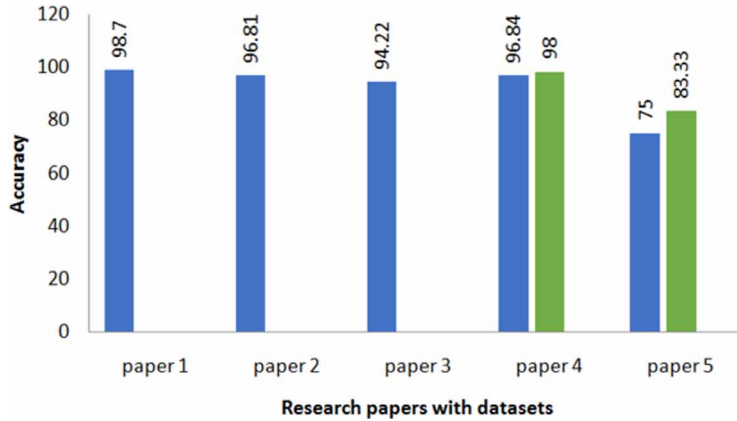
PCA is a technique used to reduce the number of factors or reduce the dimensionality of features. PCA manages the statistical process which utilizes symmetrical change to update the perceptions of interrelated factors into a group of standards of uncorrelated factors linearly which are notable and known as principal components (Arora & Kumar, 2020).

M. Arora et al. (Arora & Kumar, 2020) used PCA to get excellent element vectors for every classification of emotions. Swarm intelligence optimization is applied to get an optimized feature

Table 4. Comparative Analysis for Face Recognition using Gabor Wavelet

Authors	Method	Technique	Dataset	Result (Accuracy)
S J Rashid et al. (Rashid & Abdulqadir, 2020)	PCA SVM	Combines the methods used in preprocessing, feature extraction, and classification for face recognition	YALE	98.7%
S Qin et al. (Qin et al., 2020)	2-channel CNN	Combination of Gabor wavelet transform and the convolution neural network	CK+	96.81%
W N I Al-Obaydy et al. (Al-Obaydy & Suandi, 2018)	fuzzy ARTMAP neural network	HOG and Gabor filters used to extract the facial features which are dimensionally reduced using PCA	AR	94.22%
			FRGC	
			Choke-Point	
G Zou et al. (Zou et al., 2020)	Gabor algorithm, and CNN	Propose a new multi-feature fusion system	CMU-PIE	96.84%
			MIT-CBCL	98.00%
A C Phan et al. (Phan et al., 2019)	MapReduce model	FR approach utilizing the Gabor wavelet technique and the MapReduce parallel processing model	AT&T	75.00%
			YALE	83.33%

Figure 11. Accuracy graph for FR using Gabor Wavelet Transform



vector which is basic for classifying the features in the testing phase. The proposed system contains three significant techniques combination specifically; feature extraction, feature optimization, and classification.

Zhao F. et al. (Zhao et al., 2020) introduced a face image recognition algorithm based on a deep neural network. In this method, facial features are extracted with a convolution neural network. PCA is used for dimension reduction and for vector similarity Joint Bayesian method is used. The hardware used for experiments is based on the CPU image of Intel Xeon CPU E5-2620 v2@2.10 GHz, GPU for Nvidia Tesla K20m, 5G memory, and 32G memory.

Alahmadi A. et al. (Alahmadi et al., 2019) presented a novel unsupervised feature learning method PCAPool for a face recognition system. This paper combines PCA, local binary pattern (LBP), and pyramid pooling. The paper contains 3 layers (1) convolutional layer, (2) nonlinear layer, and (3) pooling layer. PCA is utilized to learn filters for the convolution layer. For the nonlinear layer, the LBP operator is employed on the feature maps for the activation of the convolutional layer. Then using multi-level spatial pyramid pooling, discriminative features from feature maps of the nonlinear layer are extracted.

Peter M. et al. (Peter et al., 2018) described the application of the Kernel-based PCA approach in the face recognition domain. The kernel is inherently multi-disciplinary in this domain. It is crucial to look into it from all fields and perspectives to have an insight on how to develop an efficient automatic 3D face recognition system. Experiment results proved that the Kernel-based PCA approach outperforms linear PCA in 3D face recognition.

Hu L. et al. (Hu & Cui, 2019) designed a Fractional-order-PCA-SVM coupling algorithm for digital face image recognition. This paper uses the fractional differential mask operator is used in this paper to deal, and handle the highly self-similar digital medical image. The average efficiency of the given Fractional-order-PCA-SVM coupling algorithm is 99.24% in four experiments. The overall execution time of the Fractional-order-PCA-SVM coupling algorithm is 4.152 seconds after the four experiments.

The summary of this research study for face recognition using PCA is shown in Table 5.

Figure 12. displays the dataset-wise accuracy comparison graph for the performance of given papers for PCA algorithm.

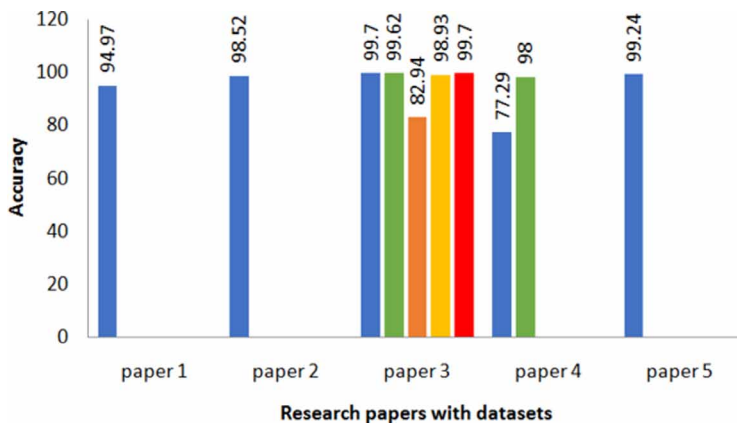
### HMM (Hidden Markov Model)

HMM is a stochastic model which contains a Markov chain with an imperceptible or hidden grouping of states (Azar & Seyedarabi, 2019). In this approach, the observation vectors sequence of face images

Table 5. Comparative Analysis for Face Recognition using PCA

Authors	Method	Technique	Dataset	Result (Accuracy)
M. Arora et al. (Arora & Kumar, 2020)	Gradient filter and PCA + PSO	PCA is utilized to get high-quality feature vectors for each section of emotion	JAFFE	94.97%
Zhao F. et al. (Zhao et al., 2020)	CNN+ PCA	CNN for extract facial features and use of PCA for the feature dimensionality reduction	CAS-PEAL	98.52%
Alahmadi A. et al. (Alahmadi et al., 2019)	PCAPool	Consists of three layers convolutional layer, nonlinear layer, and pooling layer	FERET	99.70%
			AR	99.62%
			Multi-PIE	82.94%
			Yale	98.93%
			Extended Yale	99.70%
Peter A. et al. (Peter et al., 2018)	Kernel-based PCA	Use of non-linear kernel approach in 3D face recognition	Imperial College London 3D face	77.29%
Hu L. et al. (Hu & Cui, 2019)	Fractional-order-PCA-SVM coupling algorithm	A fractional differential mask operator is used to deal and handle the highly self-similar digital medical image.	ORL	99.24%

Figure 12. Accuracy graph for FR using PCA



is described using their statistical distribution. A sequence of ‘states’ is assigned to each image. The classification is done based on estimating the state parameters to ‘best’ describe the observation vectors of each class (Kiani & Rezaeirad, 2019).

Azar S. G. et al. (Azar & Seyedarabi, 2019) introduced a Dynamic Persian sign language recognition system. Hand trajectories alongside three-hand shape information were separated from video frames utilizing a region thriving method. HMM with Gaussian mixture observations was

utilized to model these trajectories and their temporal patterns. This study is being an initial study on dynamic PSL recognition has only focused on the trajectories of the signs.

Kiani K. et al. (Kiani & Rezaeirad, 2019) proposed a face recognition system based on the ergodic HMM and DWT coefficients. A Gaussian mixture model is used to represent the observation probability of the model. Due to the axis-symmetrical structure of the face, authors have used half of the image instead of the whole image to identify the person. Using only half of the input images, authors have improved the accuracy & speed of the recognition algorithm and decreased the computational complexity of the model. The proposed model is robust to recognize the person when half of the input image is not available or destroyed.

Rahul M. et al. (Rahul, Mamoria, Kohli et al, 2018) introduced the first system for partition-based method as feature extraction and modified HMM as a classifier for facial expression recognition. The newly introduced multistage HMM consists of two layers in which the bottom layer speaks to the atomic expression made with eyes, nose, and lips. Further upper layer speaks to the mix of these atomic expressions. Six basic facial expressions are recognized, i.e., anger, disgust, fear, joy, sadness, and surprise. Because of the generative nature of HMM, it is a weak classifier when contrasted with other discriminative classifiers, for example, SVM.

Ansari H. et al. (Ansari et al., 2018) introduced a novel approach to detect depression based on the content rating by the subject using HMM. Series content is given to the subject and reliant on whether the subject reacts to skip it, they predict that subject is depressed or not. The analysis shows that the proposed DCR-HMM model produces very attractive results. The authors have tested the performance of the proposed DCR-HMM model on a Computer system in Window 7 environment, DDRAM 4GB and 2.27GHz speed processor with MATLAB 2016a version. The proposed model is used for content rating, a methodology like what is followed by an enormous number of web-based media platforms.

M. Rahul et al. (Rahul, Kohli, & Agarwa, 2018) proposed a system using the moment invariants with modified HMM to recognize six basic facial expressions. In HMM, Baum-Welch, Viterbi, and Forward Procedure methods are used for parameter estimation, calculating the optimal state sequence, and for probability algorithm of the observed sequence respectively. This system firstly derives linear Moment Invariants then modified HMM into two stages. This proposed system is able to identify facial movements and deformations of facial features easily. From the recognition results, it can observe that Moment Invariants with discrete HMM are less accurate than this proposed algorithm. This shows that both displacement and deformation of facial features are crucial in facial expression recognition.

The summary of this research study for face recognition using HMM is shown in Table 6.

Figure 13 display the dataset-wise accuracy comparison graph for the performance of each paper for HMM algorithm.

## REVIEW ON DATASET

There are several publicly available face databases for the research community. This approach to setting up the database is very familiar with face biometric research. It is used to evaluate the performance of face recognition algorithms. Here we present basic information about the following datasets: FERET, ORL, CMU Multi-PIE, CAS-PEAL, AR, CASIA –Face V5, MMI, LWF, PaSC, JAFFE, YALE, FFHQ, UTKFace. We show Table 7 for details of datasets.

## CONCLUSION

In this article, we present an analysis of recently available algorithms for face recognition. It contains 6 types of algorithms which are SVM, CNN, Eigenface based algorithm, Gabor Wavelet, PCA, and

Table 6. Comparison of methods for Face Recognition using HMM

Authors	Method	Technique	Dataset	Result (Accuracy)
Azar S. G. et al. (Azar & Seyedarabi, 2019)	A dynamic Persian sign language recognition system	Hidden Markov model with Gaussian observations is used to model the extracted time-varying trajectories	Dynamic Persian sign language	98.13%
Kiani K. et al. (Kiani & Rezaeirad, 2019)	HMM and DWT	A Gaussian mixture model is used to represent the observations probability of the model	AR	98.90%
			YALE	97.54%
			Faces94	100%
Rahul M. et al. (Rahul, Mamoria, Kohli et al, 2018)	Modified HMM	The partition-based technique is used for feature extraction and extension of HMM is used as a classifier	JAFFE	82%
Ansari H. et al. (Ansari et al., 2018)	DCR-HMM model	Introduced a novel approach to detect depression based on the content rating by the subject using (HMM)	Custom	95.6%
M. Rahul et al. (Rahul, Kohli, & Agarwa, 2018)	Modified HMM	Used moment invariants with modified HMM to recognize six basic facial expressions	JAFFE	84%

Figure 13. Accuracy graph for FR using HMM

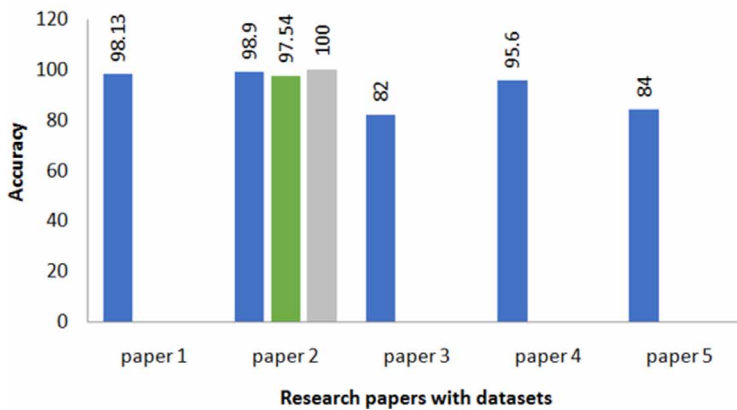




Table 7. Comparison of Various Facial Datasets

Name	Total Image	Resolution	Subject	M	F	Age	Description
FERET	14126	32*32	200	-	-	-	Variation of expression, illumination, and poses in image
ORL	400	92*112	40	-	-	-	Varying the lighting, facial expressions (open/closed eyes, smiling / not smiling), and facial details (glasses/ no glasses).
CMU Multi-PIE	750000	32*32	337	-	-	-	Feature points depending on the pose
CAS-PEAL	99594	-	1040	595	445	-	Large scale Chinese face database
AR	4,000	-	13	70	56	-	Different facial expressions, illumination conditions, and occlusions
CASIA-FaceV5	2,500	640*480	500	-	-	-	Typical intra-class variations include illumination, pose, expression, eye-glasses, imaging distance, etc...
MMI	2900	-	75	-	-	-	Maja Pantic, Michel Valstar, and Ioannis Patras as a resource for building and evaluating facial expression recognition algorithms
LWF	13233	250*250	-	-	-	-	Labeled Faces in the Wild
PaSC	9,376	1280*720	-	-	-	-	People carrying out relatively ordinary actions such as picking up an object or throwing a ball.
JAFFE	213	256*256	60	-	10	-	(The Japanese Female Facial Expression Database) 7 facial expressions (6 basic facial expressions + 1 neutral) pose
YALE	165	-	15	-	-	-	Greyscale images in GIF format
FFHQ	70,000	1024*1024	-	-	-	-	(Flickr-Faces-HQ Dataset) Images were crawled from Flickr and then automatically aligned and cropped
UTKFace	20,000	-	68	-	-	0-116	Faces from a wide age range, face images with age, gender, and ethnicity annotations.

HMM. This paper describes the performance and comparative analysis of each algorithm which are shown in Tables 1 to 6. This paper has also covered a survey of challenges and applications in real-world scenarios. Finally, a summary of popular datasets is addressed in Table 7. Overall, this article will serve as a quick reference for face recognition algorithms for both newcomers and experts.

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