Human Face Recognition and Age Estimation with Machine Learning: A Critical Review and Future Perspective

Review Paper

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Abstract *– Face Recognition (FR) applications are becoming more and more common these days. Face recognition, techniques, tools, and performance are all shown in this work, along with a literature review and gaps in many areas. Some of the most common uses of the FR include medical and government sectors as well as educational institutions. The FR technique can identify an appropriate individual through a camera. Online courses, online FDPs, and Webinars are becoming more interactive nowadays. Using Machine Learning, it is possible to quickly and securely determine a student's unique id to administer virtual online tests. The paper is an analysis of Machine learning and deep learning algorithms as well as tools such as Matlab and Python. The paper covers a survey of different aspects such as face detection, face recognition, face expressions, and age estimation. Hence, this is helpful for researchers to choose the right direction for their research. Future face recognition research is also considered in the paper which is now trending in face recognition systems. Data from recent years are used to evaluate the performance.*

Keywords*: Face Recognition, Face Expression, Age Estimation, Machine Learning, Python*

1. INTRODUCTION

Face recognition is a real-time application that has been considered a process of identifying individual faces by employing a distinct framework with different poses on datasets. [1] Nowadays, FR is an exciting field despite challenges also for researchers for decades. Facial recognition is the task of doing identification of a human face in a picture or video image for an existing database of faces. It starts with detecting different human faces from other images and after that, works on the identification of the detected image faces Face recognition is a tough task for identifying and verifying a person in a photograph; to detect a face from the number of faces with different expressions and emotions [2].

FR has a prominent role performed by humans in different circumstances such as photos captured under different effects of light and faces are changed with a change in obstructed or accessories like facial hair or change by age [3]. In FR, the age and gender of a human can also be predicted [4,5]. It remained challenging that faces a problem to predict older face images from a given children's face image, which might be very helpful to find the missing children after several years or presently he/she has in adult age. Commercial applications effectively operate faces that have the age of 18 yrs or greater than 18 [6]. Nowadays, iPhone considers the age to be 15 yrs. Therefore, age estimation also becomes challenging. Many researchers used various techniques to deal with children. For this purpose, a deep convolution network (CNN) was used to detect newborn babies' databases [7-10]. Face recognition has a wide range of applications, including access control, identity verification, educational institutions, businesses, banks, smartphones, security systems, surveillance systems, social media networks, and many more.

2. MACHINE LEARNING (ML)

ML has the subset of artificial intelligence (AI) where machines are trained by learning and improving without the interference of humans, adjust actions accordingly and themselves have the power of decision making. It endues the system the ability to work automatically and make decisions from experience except doing

any external programming [12]. It is the study of algorithms in computer science for accurate predictions and evaluation to behave intelligently. For this, Machines train to learn from prior knowledge existing in the knowledge base. Moreover; It is the building of programs that allows firstly to analyze data patterns and then classify patterns of images to find out behavior and make decisions for new input environments or uncertain situations in the real world. There is a various algorithm in Machine Learning that uses statistical techniques to predict patterns and then carry out actions on the patterns. The classification is processed based on past experiences and records. Three types of ML algorithms exist supervised, unsupervised, and reinforcement learning. For a new result, supervised ML algorithms are used for the labeled instances and known training datasets. For this, the first starts with the training dataset, and the learning algorithm produces an inferred function to estimate the predictions for the output data values. This system is learned with various new inputs and finds out the outcome and then the outcome is compared with the correct and desired outcome and errors are also find out to modify the system respectively so that the system becomes more powerful. Supervised learning is task-driven. Classification and Regression are solved with supervised learning and firstly; data is used for the training dataset and after that tested with a dataset that is similar or different to check the accuracy of the model. This algorithm is mainly used in Predictive Modeling. Popular Algorithms are Linear Regression, Logistic Regression, Naive Bays, Nearest Neighbor, DT, KNN, SVM, Convolution Neural Networks, and many more. Unsupervised Machine Learning algorithms apply to the unlabeled examples and information is not classified to train a model. In unsupervised learning, the algorithm produces an inferred function to represent a hidden structure. To draw a hidden structure; the system didn't evaluate the correct outcome; rather it can explore the data and can make interpretations with datasets from unlabeled data. This learning algorithm is mainly used in Descriptive Modeling. This learning is data-driven and used in Clustering, for Anomaly Detection. Popular algorithms are k-means and Association rules. Reinforcement Machine Learning algorithms are used to interact with the environment and search to find out the best possible path/outcome. Use the training dataset for the desired new result; learned from the experience and knowledge to produce correct decisions based on the received feedback. This is based on the hit & trial method and learns automatically with time variation. This algorithm is modeled as a Stock trading system, the Markov model and the most popular algorithms used in reinforcement learning are Q-Learning, Deep Networks, Computer games; Chess and GO, Self-driving cars, etc. [16-18].

3. FACE RECOGNITION

Face Recognition is a method of recognition that is capable to match the identity of an individual face from a given data set. There are so many methods of identification that may be more accurate, despite face recognition taking place an important role for researchers because of the non-interfering, powerful, and most natural way to detect a human face for confirmation of identification. Face recognition have prominent features in many areas such as identity verification in smart devices, Face Indexing, criminal investigations, diagnosing diseases, smart card applications, identifying people on a social platform, security camera, video surveillance, Face ID, Multimedia Environment, and many more. In the face recognition process, firstly input the image for preprocessing then recognition of the face is done by training the recognizer [19,21,22].

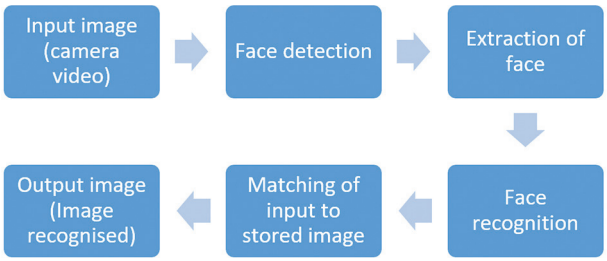

Fig. 1. Face Recognition Block Diagram

After teaching, testing, and the recognizer on the dataset(s) to achieve the results, there will be a positive outcome if the faces are correctly matched, else it will be negative. Retrain the face recognizer and test with the dataset again if a negative result is obtained. Face recognition may be done using a variety of algorithms. Any change in algorithm and dataset influences the accuracy of the face recognition system. The three steps of the Face Recognition process are:

Face Detection: faces are detected from the image or video. Apply preprocessing to know the exact location/coordinates of the face and extract that face for further processing then

Feature Extraction: by cropping the face from the image and extracting features from it. Here may use face embeddings to extract the features from the face.

Face Recognition: compare faces for embeddings of every face in the data saved in a file and classify whether the face of a person is matched or not.

In a neural network, a person's image begins as an input, and output in form of the vector is known as face embedding in the case of machine learning. To recognize a new image that is not in the dataset, the first step is to compute the face embedding for the image using the same network and then compare this embedding with the rest of the embeddings. To recognize the face; if the generated embedding is closer or similar to any other embedding were passed two images, as image1 did not save the embeddings but saved the embeddings of image2. Thus, when we compared the two new embeddings with the existing ones, the vector for image2 is closer to the other face embeddings of image2, whereas the face embeddings of image1 are not closer to any other embedding and thus the program cannot recognize the image1.

4. LITERATURE SURVEY

After the analysis of many papers, and research surveyed in the FR field, the face recognition surveys include face recognition, facial expressions, and estimation of age. This paper includes the latest papers. The study shows gaps for researchers. For the development of the face recognition technique; 23 datasets were used and have provided the essence of scholars' papers including methods, performance, and limitations. The performance might vary on different datasets [1]. The research focused on facial expressions and presented a systematic review. There was a study of techniques and algorithms of face detection that was proposed and abbreviated such as PCA, LBP, OF, Gabor filters, and many more for a better understanding. CK+ databases were used to detect difficulty with correctness during cognition of facial expressions with the environment. When poses were changed then system accuracy was suffered [2].

The research proposed a statistical model that detected measures of smiling faces. When a person smiles then the model measured different aspects of the face such as the mouth region, & geometric variations around facial parts, and also count active features during a smile. The proposed framework used 210 different parameters for smiling faces. For classification, SVM and the K-NN methods with CK+ and the MUG databases were used to classify gender. When measuring the smile of a person they assumed that; some discussions represent that females always have significant nature in expressing facial features than men and one of them is a smiling face. With the K-NN algorithm, the rate of classification was 86%, and to predict gender it was 85% achieved an overall rate of gender classification was 75% attained in this research [3]. The analysis of recent research in aging was also included. The estimate of age calculated by techniques such as MAE or CS and existing modeling techniques such as Linear Binary Pattern, Gabor Filter, Linear Discriminant Analysis, Principal Component Analysis, and Local Directional Pattern has been used. Then the performance of various systems was compared and evaluated to estimate the age of people who were challenged with the number of datasets such as FGNet, Morph, and Gallagher Collection Person datasets that are public databases. Morph, NIS, YGA, LHI image database, and Gallagher Collection Person databases are large databases and more compatible to evaluate the gender and age of a person with the regression technique [4].

After that; a comparative study of OpenCV and "dlib" were performed and further observed time complexity. Therefore; combine phases to make the system better performance rather than a single one because OpenCV was more effective and performed better results than the "dlib" library in face identification and recognition applications for the IoT platform as well. When combined LBPH with HOG then the results of facial recognition are better than the above algorithms such as Eigenface, and Fisher Face [5-7]. Unfiltered photos of faces, as well as age and gender groups, may all be predicted with reasonable accuracy using a convolution neural network. Two layers are employed to determine an individual's age or gender, a feature extraction layer, and a classification layer. The convolution network was already trained with the IMDB-wiki dataset and was on Morph_II images and at last with the OUI-adience dataset. The model results better with 16.6 classifications of age and achieves 3.0% more accuracy for the classification of gender [8].

Other techniques include such as Eigenfaces, SVM, and FaceNet neural networks on Facial Embedding. The facial embeddings have been set up by passing through a Pre-trained Network. Viola-Jones algorithm is used for face detection. The maximum accuracy obtained to classify gender is 97% and KNN has a better result than Logistic Regression, SVM, Naïve-Bayes, and Decision Trees [9]. With the addition of two normalization processes on two levels, CNN's modified architecture was further developed. The proposed algorithm applied batch normalization for the first as well as final convolution layers and achieved higher accuracy rates. Distinct facial traits were extracted & the Softmax classifier was employed in CNN's fully connected layer to categorize faces. It observed that the proposed approach on the Face dataset gave better results which improved the performance of face recognition [10]. A CNN system for recognition & identification of expression of a student's face was presented. The network has 4 levels in which 2 layers were fully connected and 2 were max-pooling layers finally created a model of facial emotion recognition that identifies the emotion of students from faces. The model has three methods: Haar Cascade detector to detect faces, normalization, and emotion recognition in Convolution network with FER dataset. The proposed system achieved a 70% rate of accuracy at 106 epochs. is helpful in education that helps teachers to recognize the interest of students by their expressions of faces during their studies. Used ResNet for facial emotion recognition, solve many problems like gradient points, and gave visual perceived results and better performance with the network system. The system obtained high accuracy i.e., 85.76 and 64.40 on training and testing datasets during convolution neural network and also do better with the FER database [11-14].

Face detection, recognition, and emotion classification of the face were classified as three phases: face detection, recognition, and emotion classification of the face. OpenCV and python were suggested for the CV technique. The expressions are categorized into seven states, each of which expresses a particular facial scenario. The Viola-Jones method was utilized for emotion recognition on the FER2013 dataset and an accuracy of 88% was achieved with happiness in images and the lowest accuracy with sadness was 57% detected. Hence the designed system performs better than existing ones and is helpful to analyze the emotions of

students' E-learning techniques [15]. The optimization was performed for seven expressions on the faces of persons. To identify the emotions convolution neural network, an approach with Keras and theano libraries was implemented for facial expressions. The Viola-Jones method was utilized for emotion recognition on the FER 2013 dataset [16].

A state-of-art model designed using python and supervised learning that might be helpful to detect emotions of the face that was captured with a web camera with 96% prominent accuracy. In addition, end-to-end CNN architecture was introduced. CNN model was trained for supervised face bounding boxes and personal identities using Wider_FACE and CasiaWeb FACE databases and tested with face detector and "fddb" and "lfw" data sets. The feature map was created using a spatial transformer network (STN) without the need for face alignment. The results come with 89% accuracy in the detection phase and 98% in the recognition phase. Therefore, it is better to conclude that rather than two models, combining them as a single one has better performance. After that, a system was used that might detect a person directly from a group of persons. For this, they used a deep convolution network that trained the model and gave good results by applying a filter to detect the face of a person from multiple gestures [17-18]. Stochastic gradient descent (SGD) was used to train the network using the Celeb Faces attribute dataset (Celeb A) and achieved 99.7% accuracy on the Labeled wild_ Faces and 94% on YTF databases [19-21].

4.1 RESEARCH GAPS, FUTURE SCOPES

Research always explores a path for further research. Therefore firstly, consider a deep study of these papers and then find out the limitations/gaps in the papers and also find out the future scope for further research. Research gaps and future scopes along with techniques and limitations are discussed in table 1.

Table 1. Research Gaps and Future Scopes

Citation	Publication, year	Title of Paper	Techniques used	Research Gaps/ Limitations	Future Scope
[1]	IEEE, 2018	Changing Facial Features in Face Recognition and Age Estimation: A Critical Review Study	SVM, LBP, GAP	The system face problem with the evaluation of age effects.	The system can be implemented with newborn child's faces.
[22]	ACM, 2018	Face recognition: Sparse Representation vs. DeepLearning	SRC, CNN, Multi-PIE and YTC databases	Noted that SRC has small databases. Errors occurred during recognition of gestures &, expression of the face was challenged.	Face recognition might be further rectified with the merging of CNN locality & SRC linearity to enhanced variants.
[15]	IEEE, 2019	An investigation of the effectiveness of facial recognition systems on humans	Eigenfaces, Fisherfaces, and LBPH algorithm	Many faces were identified with a single data when using the LHBP database.	In the future, can elaborate with ambient analysis & implementation for the recognition of faces with distinct angles & poses.
[8]	Elsevier, 2019	Facial Embeddings for Gender Classification: A New Approach	KNN, Facenet NetworkViola-Jones algorithm, python	In the UTK Face dataset, only 203 images for training and testing; work with a small database.	This work can be explored to obtain better results with the estimation of age by including race value, and place of the center of a person.
[18]	IEEE, 2019	Student Emotion Detection with CNN's Facial Emotion Recognition	Haar Cascades, CNN on FER 2013 dataset and OpenCV library.	The system got confused in fear & sad faces with feared expression results were comparatively poor.	In the future, can try to apply the CNN framework with 3D face images of students with facial expressions.
[12]	Science Direct, 2019	Imperfect facial data can be used to train deep face recognition systems.	CNN, VGGF, and SVMs as well as CS models for facial feature extraction.	the dataset utilized was far excluded from the practical session and work was on data which incorrect in the past.	Extend this work with Cctvcameraimages for face detection.
[6]	Hindawi, 2020	For Age and Gender Predictions of Unfiltered Faces, Deeply Applied Classifiers	two-level CNN Model, robust image preprocessing algorithm	Challenging conditions with resolution, lightning effects, and deep makeup on OUI_ imagesdataset.	A deep CNN model with a lasting algorithm will be considered. Research can investigate the apparent age estimation approach.
[4]	Hindawi, 2020	Improved Mask R-CNN-Based Face Detection and Segmentation	FCN, faster R-CNN, Mask R-CNN, G-Mask model add Segmentation branch	Due to G- mask segmentation, complexity increased.	Try to improve the speed of the G-Mask method.
[5]	Elsevier, 2020	Facial emotion identification using a deep self-attention network	Deep learning framework with CNN, ResNet. FER dataset.	Work was restricted to only Y-channel. X-channel not covered inYcbcr for resized images	The system can be enhanced with other techniques of computer_vision using deep learning.

Citation	Publication, year	Title of Paper	Techniques used	Research Gaps/ Limitations	Future Scope
[32]	IEEE, 2020	Prediction of Emotions Using Facial Expression Recognition	CNN classifier and Csv image format were used.	The model suffered from fitting when emotions were detected in between 70 and 80 passes and then the model seems to overtrain.	This model extended to identify mood swings of the person due to situations that come in the environment which was a reason for varying behavior.
[38]	Springer, 2020	Face-recognition technology and gender bias in criminality detection	Deep network with SNN & CNN designed.	The only small size of dataset used, a problem arises when enlarging the dataset, occurred difficulty in measuring the impact of racial bias and subjectivity of identifying race	CNN may use to train and test enlarging datasets and also work in measuring the effect of race and gender bias to detect and express individuality signs.
[11]	Hindawi, 2020	FaceFilter: DL and Filter Algorithms for Face Recognition	Deep convolutional network. FaceNet, SGD algorithm.	The problem comes with many faces while the model detected faces correctly. This restriction shows poor results.	This work tries to make an adequate system that overcomes the limit of detection of faces.
[25]	IJERT, 2021	Real-Time Face Mask Detection & Recognition using Python	Face Recognition System, Python	There is a need to improve the accuracy	Research would be useful to find the face mask while entering a public location
[33]	Hindawi, 2021	Analysis & Implementation of Optimization Techniques for Facial Recognition	Face Recognition System	Need to do more work on performance enhancement	Research might be extended to improve scalability
[35]	ASTROS, 2021	Performance Evaluation of CNN And VGG on Real-Time Face Recognition	CNN, VGG, Face Recognition System	There is a need to integrate a compression mechanism to improve performance	Such research would play a significant role in image processing
[41]	Hindawi, 2021	CVS-based algorithm for digital image face detection and recognition	Face Detection	Research has limited scope and flexibility	Face detection and recognition enhancement could play a significant role in security systems.
[42]	Springer, 2022	Novel Face Detection Algorithm Based on Fuzzy Distance-Based Minimum Spanning Tree Clustering	Face Detection	Fuzzy logic and clustering mechanism implementation are found complicated	Research would lay a strong foundation of decision making in future research works
[43]	Springer, 2022	ML techniques for facial detection and recognition: a survey	Face Detection, Machine Learning	There is a lack of technical work	Such research would play a significant role in decision-making using a machine learning technique

5. PROBLEM STATEMENT

There have been several types of research in the area of face recognition. These techniques are considered image processing and machine learning approach to perform face recognition operations. But the issue with previous research is performance and accuracy. There is a need to do more work in the area of the face recognition system.

6. PROPOSED RESEARCH METHODOLOGY

In the proposed work research related to face recognition has been considered and the methodologies used in those researches are considered. The face recognition surveys also include facial expressions and estimation of age. This paper includes the latest papers for the year 2018-2022. The research layout certain difficulties faced in the face recognition area with facial features and prediction of age. Hence, the paper enlightens them with future scopes.

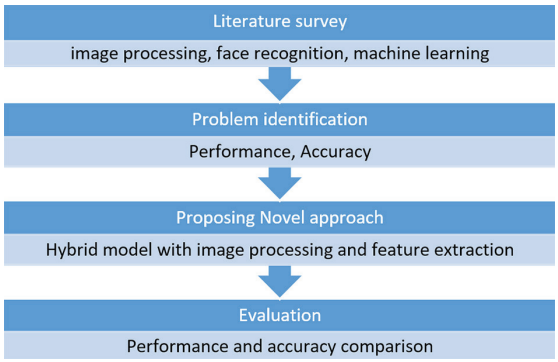

Fig. 2. Process flow of work

7. RESULT AND DISCUSSION

The performance of face recognition shown in table 2 is in terms of accuracy and demonstrates with a comparative study of algorithms for face detection. The model designed for face detection as well as recognition is summarized with different datasets.

7.1 ACCURACY OF FACE RECOGNITION SYSTEM

The results of the study show that higher the accuracy rate for KNN has 97% on a self-small dataset, for SVM has 95%, and LBPH at 80% on a self dataset. The CNN model has an accuracy rate was detected 83%, and with deep CNN of 99.7% on the LFW dataset.

Table 2. Performance of ML models with datasets

Citation	Author	Year	Algorithm	Machine Learning Model(s)	Dataset(s)	Accuracy(%)
[16]	Hassan et al.	2018	-	KNN, SVM	CK+, MUG	86
[17]	Lu et al.	2018	-	Deep coupled ResNet	LFW, face	99
[29]	G. P. Nam et al.	2018	-	PSI-CNN	LFW, CCTV	88.7
[8]	Avinash et al.	2019	Viola John	KNN	SELF	97
[12]	Ali et al.	2019	-	VGG (face)	FEI	70-90
[13]	Khan et al.	2019	-	Deep CNN	-	98.5
[15]	Sharmila et al.	2019	Haar Cascade	LBPH	SELF	80
[18]	Imane et al.	2019	Haar Cascade	CNN	FER 2013	70
[31]	Chen Qin et al.	2019	-	Deep CNN	-	94.6
[40]	Ishan et al.	2019	-	MatConv Net	SELF	94.8
[5]	Arpita et al.	2020	-	YCbCr	FER	64
[6]	Olatunbosun et al.	2020	-	CNN	IMDb-WIKI, MORPH-II	83
[7]	Shaik et al.	2020	Viola John	CNN	FER 2013	70
[9]	Hongxin et al.	2020	-	CNN + STN	FDDB, LFW	86.3
[10]	Ekaterina et al.	2020	Viola John	CNN	FER 2013	69
[11]	Mohammed et al.	2020	-	deep CNN	LFW	99.7
[32]	Kaustav et al.	2020		CNN	CSV	69
[33]	Justice et al.	2021	YouTu, PSO	SVM	AT&T	82.05
[41]	Di Lu et al.	2021	Seetaface	SVM	Yale-B	66
			BscGc	SVM, OpenCV	ORL	95

7.2 PERFORMANCE GRAPH OF DATASETS

The below graph provides information on recognition rate with measures of accuracy in the percentage of recent years with different datasets. The accuracy of a model varies with datasets, as shown in Fig. 3. The performance graph is taken in between various datasets used in the number of years.

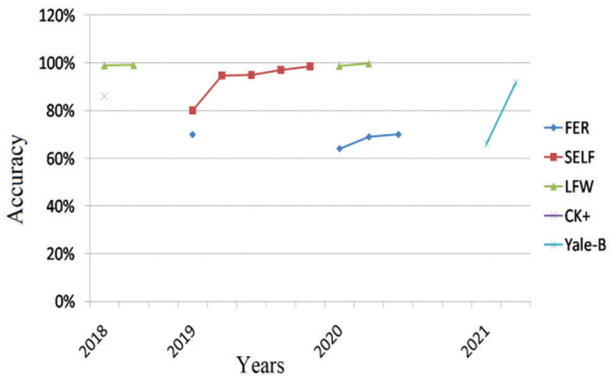

Fig. 3. Performance Graph of Datasets

8. CONCLUSION

Face recognition is a very promising field in today's era. The results of the study show that the deep CNN model has high accuracy with the LFW dataset compared to other datasets for FR. The accuracy rate for age estimation is 92% in the deep CNN model. This paper finds that the facial technique's performance was distinct for different data sets i.e. varied from one data set to another. The paper survey concludes that sometimes the system confuses with angry/sad and fear/surprise facial expressions, and challenges have come in age estimation also. Despite this, the paper focuses on future perspectives. Hence, a machine learning model can be designed to identify a person and predict the emotions of a face by using supervised learning more effectively to solve the real scenario challenges to enhance the performance of the system. After that work can be enhanced for age estimation as well.

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