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2D Face Recognition Methodologies and Applications: A Review

Mokhtar M. Hasan [1], Noor A. Ibraheem [2, *], and Noor M. Abdulhadi [3]

[1,2,3] Department of computer Science, College of Science for Women, University of Baghdad, Baghdad, Iraq:
[1]mokhtarmh@csw.uobaghdad.edu.iq
[2]nooraibraheem@csw.uobaghdad.edu.iq*
[3]noorma_comp@csw.uobaghdad.edu.iq

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Abstract: Face recognition is one of the most dynamic exploration fields of pattern recognition, with numerous uses and applications including distinguishing proof, forensics, access control, legal sciences, and human-computer interactions. Although, distinguishing a face in a group brings up difficult issues about individual opportunities and stances moral issues. 2D methodologies arrived at some level of development and revealed exceptionally high paces of recognition. This presentation is accomplished in controlled conditions where the securing boundaries are controlled, like lighting, point of view, and distance between the camera–subject, occlusions, and masked faces. This work presents an overview of the present status of-the-art methodologies used to improve the classification performance of face recognition process, feature extraction, and face identification limitations and applications.

Keywords: 2D face recognition, face identification applications, face analytics, feature extraction.

1. INTRODUCTION

The human face is a complex multidimensional construction that can pass on a ton of data about the individual, including appearance, facial components. Successfully and productively examining the provisions identified with facial data is a difficult errand that requires a ton of time and exertion [1]. Face recognition framework is utilized for the ID and check of a face from a video or advanced digital picture [2]. Face recognition is one of the most dynamic exploration fields of computers and example recognition, with numerous reasonable and business applications including distinguishing proof, access control, legal sciences, and human-PC associations [3].

Huge strategies, calculations, approaches, and data sets have been proposed over late years to concentrate on compelled and unconstrained face recognition. 2D methodologies arrived at some level of development and revealed extremely high paces of recognition. This presentation is accomplished in controlled conditions where the securing boundaries are controlled, like lighting, point of view, and distance between the camera–subject. Be that as it may, if the surrounding conditions (e.g., lighting) or the facial appearance (for example posture or look) change, this presentation will debase significantly [3].

Biometric recognition programming assumes an undeniably critical part in current security, organization and business frameworks. Biometrics incorporate unique marks, retinal checking, voice distinguishing proof and facial recognition. Facial recognition has drawn specific interest, as it gives an attentive, non-nosy method for discovery, ID and confirmation, without the requirement for the subject's information or assent [4].

The last decade has given critical advancement in this space inferable from propels in face demonstrating and investigation strategies. Despite the fact that frameworks have been created for face discovery and following, dependable face recognition actually offers an incredible test to PC vision and example recognition analysts. There are a few purposes behind ongoing expanded interest in face recognition, including rising public worry for security, the requirement for character check in the computerized digital world, face investigation and demonstrating methods in sight and sound information the executives and computer diversion. [5].

Despite the fact that there is a wide scope of conceivable looks, clinicians have distinguished six central ones (joy, pity, shock, outrage, dread and revulsion) that are generally perceived. Clearly a framework equipped for performing programmed recognition of human feelings is a helpful errand for a bunch of uses like human-PC collaboration, security, emotional registering [6]. Face recognition keeps on improving, profiting from propels in a scope of various examination fields, for example, picture handling, design recognition, computer illustrations, and physiology. Frameworks in view of noticeable range pictures, the most explored face recognition methodology has arrived at a huge degree of development with some reasonable achievement. In any case, they keep on confronting difficulties within the sight of enlightenment, posture and expression changes, just as facial camouflages, all of which can fundamentally diminish recognition exactness. Among different methodologies which have been proposed trying to defeat these restrictions, the utilization of infrared (IR) imaging has arisen as an especially encouraging exploration course [7].

The principal downside of the facial element-based strategies is that they need to complete complex preparation process which consumes a ton of computational time, and these methodologies are not helpful for processing an enormous number of preparing face pictures in viable applications. Albeit the down sampled based strategies don't have to execute complex preparation process, down sampled pictures might lose some discriminative data for face ID, and the coefficient vector of a straight blend is challenging to get particularly the preparation test size is huge [41]. The objective of this work is to provide a thorough and critical review of the current 2D face recognition methods. The following are the primary objectives

- Summarize Existing Methodologies
- Highlight the strengths, limitations, and applicability of these methods.
- Explore the developments in applying facial recognition systems in reality.
- Provide available databases designed for face recognition.

2. RELATED WORKS

Facial recognition and identification is a space of high exploration interest because of its wide range of uses, the accessible extension for development inexactness and computational speed because of advancement in equipment, and progressively enormous and available information bases [4].

First efforts to recognize a facial subject by looking at a piece of a facial photo were announced at an English court in 1871 [8]. In circumstances when video or photographs of a crime scene are available, face recognition is likely to be the most common law enforcement tool. To compare a suspect's face to that of a legal expert, a human facial image analysis is used. Advances in robotic facial recognition have improved the efficiency of legal professionals and streamlined the examination process [9].

Serign Modou Bah, and Fang Ming, in [1] divided the system into two key segments: the first segment focused on further refining the face recognition computation, while the second segment focused on the executive's framework's participation in light of recognized human faces. The following are the main commitments: (1) a synopsis of the inherent properties of infrared imaging that make this methodology promising for face recognition, (2) a systematical study of the most powerful techniques, with an emphasis on arising normal wanders as well as crucial contrasts among elective methods [7]. Abd_Almuhsen, F, et al., in [6], researchers concentrated on which chipped away at utilizing a mix of either includes extraction or the recognition of expressions. FERS is utilized in numerous applications like amusement, clinical, security, mental issues furthermore numerous different fields. Salama AbdELminaam D, et al., in [10] developed a face recognition system by applying transfer learning method in fog computing and cloud computing and implemented by deep convolutional neural networks (DCNN) [10]. Liton Chandra Paul, and Abdulla Al Sumam, in [11] constructed a face recognition system using Principal Component Analysis (PCA) method, applied the training set database on 36 face images of 18 persons of students of Electronics and Telecommunication Engineering department, Batch-2007. They represented the feature vector by a combination of weighted eigenvectors; classification was implemented minimum Euclidean distance.

In [12], Peng P, et al, constructed a framework of face recognition software using PCA method also, they presented two pre-processing methods, 1) face selection or separation, which deals with exaggerated face appearances, and 2) Local binary pattern LBP method that works with non-uniform illuminations. In [13], Shah, Parin M. have suggested a system that detects face with less false detection rate, using skin color, edges detection and features extraction and utilized Support Vector Machine (SVM) for classification of images into face/ non-face class. The system applied various factors on input images such as luminance, chrominance, saturation, elliptical and nose, eye, mouth [13].

In [14], Medapati, P.K. et al, developed a system that derives features using convolution network system and recognize the face using adaboost large memory storage and retrieval neural network. Rajath Kumar M. P., et al, proposed system can be used to take out the safety risk in smart cities [14], while another combination of artificial neural networks using PCA and BPNN for face recognition system [15]. Genetic Algorithm (GA) has been used for this purpose as explained by Pratibha Sukhija , et al, [16], Saifuddin Md. Tareeq, et al, [17], Khan, R. Z., et al, [26]. Also Mokhtar M Hasan, et al, constructed and recognized face using neural networks [39]. Changhui Hu, et al, in [41] proposed a new vector projection grouping (VPC) approach for the issue of face distinguishing proof. Face pictures of a solitary item class are more comparable than those of various article classes, and the vector projection length can assess the closeness between two picture vectors in the face picture vector space. In the suggested VPC approach, the most comparable preparation picture and it’s relating class mean picture are utilized to conclude the last characterization, which is decided for the greatest blend projection length. To address the halfway impediment issue in face acknowledgment.

F. Xiong and Z. You, [31] produced a model for face recognition using Gabor low - order restoration method, results showed that the proposed method strong against variable light and protect the overall facial articulation, it further developed the splendor differentiation of the image, yet in addition sift through the light part of the face actually, with accuracy 98.56%. While authors Shugang Li, et al, [32] addressed some applications of image processing including Face recognition application. In [33] Yan Sun, et al, applied a zero-space based Fisher discriminant analysis method for face recognition. Other data structure methods can be used for various applications, for example Ibraheem, N.A., et al, [27] applied circular queue data structure for Substitution Cipher Algorithms, and Muna Khalaf, and Ban N. Dhannoon, et al, [35] applied residual dilated u-net for medical image segmentation.

A combination of GA and Back Propagation Neural Networks (BPNN) algorithms are applied for face recognition process by Mahendra P. Panigrahy, et al, [18]. In [19], Yanbang Zhang, et al, connected PCA and SVM algorithms for face recognition as well. Kopaczka M., et al, [20] suggested a robust facial detection and face tracking using active appearance models in thermal infrared images. A general overview and survey classification of face recognition techniques introduced in [6][7][21-24][38][45]. A summary of the discussed techniques is presented in Table 1.

TABLE I. SUMMARY OF DIFFERENT FACE RECOGNITION METHODS, WITH THE DATASET USED.

Author name, Reference No.	***Method name***	***Description***	***Result***	***Dataset used***
Serign Modou Bah, and Fang Ming, [1]	Local Binary Pattern (LBP) algorithm	Used Local Binary Pattern (LBP) algorithm combined with some image processing techniques like Contrast Adjustment, Bilateral Filter, Histogram Equalization and Image Blending.	99.0%	N/A
Liton Chandra Paul, and Abdulla Al Suma, [11]	Principal Component Analysis (PCA)	Features extraction is represented as a linear combination of weighted eigenvectors. minimum Euclidean distance is performed for recognition	N/A	36 face images of 18 persons of ETE-07 series
Peng P, et al, [12]	principal component analysis	Constructed a model for face recognition using PCA with multiple variations for different requirements.	93.85%	total number of variations exceeds 150
Shah, Parin M., [13]	Support Vector Machine	Combined features such as recognizing skin color, and detecting edges as a statistics parameters and implemented by SVM.	90%	Own images, and some images from Internet
Salama AbdELminaam D, et al., [10]	deep convolutional neural networks (DCNN),	Tested in tested with different three standard machine learning algorithms (Decision Tree (DT), K Nearest Neighbor(KNN), Support Vector Machine (SVM)).	99.06%	three face images datasets (SDUMLAHMT, 113, and CASIA)
Pratibha Sukhija, et al, [16]	Genetic Algorithm (GA)	Applied Genetic Algorithm GA based approach for face recognition. GA recognized unknown face images from three different databases; ORL database, UMIST database, Indbase database.	98.57 %	ORL database
			100%	UMIST database
			98.33%	Indbase database
Saifuddin Md. Tareeq, et al, [17]	Genetic Algorithm (GA)	Make benefits from facial estimated features like eyes, mouth, nose, and eyebrow, for template information, which will be localized for face geometry skeleton.	150 images	98.71%
Mahendra Pratap, et al, [18]	Genetic Algorithm (GA), and Neural Networks (NN)	Extracted face features from face image edge's that is converted into a binary. These extracted features of the face images are fed into the GA & BPNN for recognition alternatively.	80% GA	30 face images
			93.33% NN	30 face images
Yanbang Zhang, et al, [19]	PCA and SVM Algorithms	PCA is used to transform the input face image into a new feature space by reducing feature 's dimension	N/A	N/A

		and eliminate the correlation and noise between image features, and recognized using SVM		
Kopaczka M., et al, [20]	Active appearance model (AAM)	face image tracked in the thermal infrared domain. Using a suitable database and a well-performing combination of algorithms comprising DSIFT for modelling and SIC	N/A	created their own face database with LWIR video sequences of currently 31 (25 male, 6 female) subjects.in total 1390 images
Rajath Kumar M. P., et al, [15]	PCA and BPNN	Recognize frontal views of faces, using multi-variate data of face image set reduced using PCA. BPNN is used for training and learning, testing conducted over	N/A	Olivetti Research Laboratory (ORL) Face database
Medapati, P.K. et al, [14]	convolution network, and adaboost	Artificial intelligence internet of things–based facial expression detection system is used for matching and predicting human faces.	N/A	N/A
F. Xiong and Z. You, [31]	Gabor low - order restoration	Applied Gabor low - order restoration transformation, on each training image sample and their error images are transformed into feature vector of Gabor that combined into a dictionary of Gabor characteristics.	98.56%.	N/A
V. C. R, V. Asha , et al, [44]	Convolutional neural networks	extractes various features from images using CNN, and generates a set of digits representing a face (called a face code)	N/A	N/A
Salar J. Rashid, et al, [46]	Gabor wavelets transform, PCA is used in dimensionality reduction. At last, SVM	Gabor wavelets transform extracted the facial characterized features then methodology (PCA) used to reduce the dimensionality, and, SVM to classify the features according to image classes.	98.7%	Yale database of 165 images from 15 individuals
[47]	Support Vector Machines Optimisation	the Sparrow Search Algorithm (SSA) applied for SVM parameter optimisation	95.1%	ORL standard face database, in 400 images

3. FACE RECOGNITION METHODOLOGY

A systematic procedure for face recognition methodology used to guarantee precise and effective identification or verification of facial characteristics [45][48][49]. As shown in the following steps:

A. Problem Definition

This step defines the purpose of the proposed system, for example for surveillance, video tracking, security, with the available resources such as the environment, required tools and processing speed.

B. Database Preparation

In this step, it is important to determine the dataset used, first, collect a dataset of facial images or videos, or use an available dataset properly for the required application. Taking into considerations various factors that might have effects on image quality such as pose, orientation, varying lighting conditions, races, rotations and noise in the images.

C. Preprocessing

For Preprocessing facial images, some methods are required for example, Image Normalization by Resizing images, also removing some unwanted background, noise, and adjust orientations, other data images may need to apply transformations such as flipping, rotation, changing colors, or scaling.

Then to detect the face, determine an appropriate algorithm or technique to detect the face from input video frame/ image like Haar Cascades, YOLO, etc.

D. Feature Extraction

For extracting features from the detected facial images, two methods can be considered; traditional-Based methods such as Local Binary Patterns, Eigenfaces, Fisherfaces, etc. and Artificial intelligence methods like Deep Learning-Based Methods.

E. System Training

By using some classification methods to recognize the face object such as neural network NN, support vector machine SVM, etc. the model is trained with a suitable loss function to reduce errors. So the system is trained on the labeled dataset.

F. Face Recognition Methods

Keep a database of known facial embeddings and calculate resemblance between the input images and stored image using metrics such as Euclidean Distance, Cosine Similarity.

G. Evaluating and Testing

Test the suggested model under real-world conditions to verify its dependability, robustness, and evaluate the system using some measurements metrics such as accuracy, F1-score, precision, recall, and ROC curve. Figure 1 presents the general main issues for face recognition system which are: problem definition, database preparation, preprocessing, feature extraction, system training, face recognition methods, evaluating and testing.

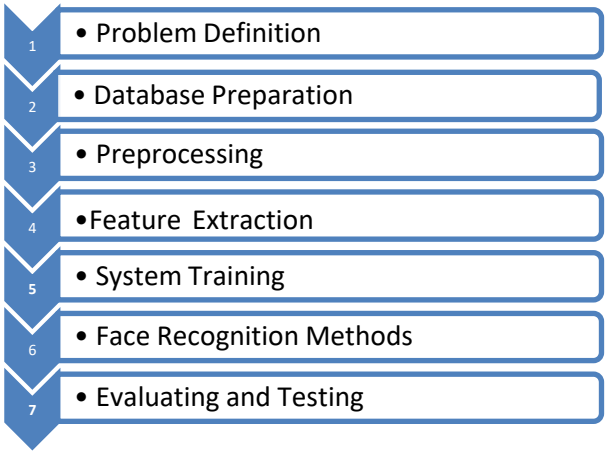

Figure 1. General steps of face recognition system.

General standard design of face recognition system is explained in Figure 2.

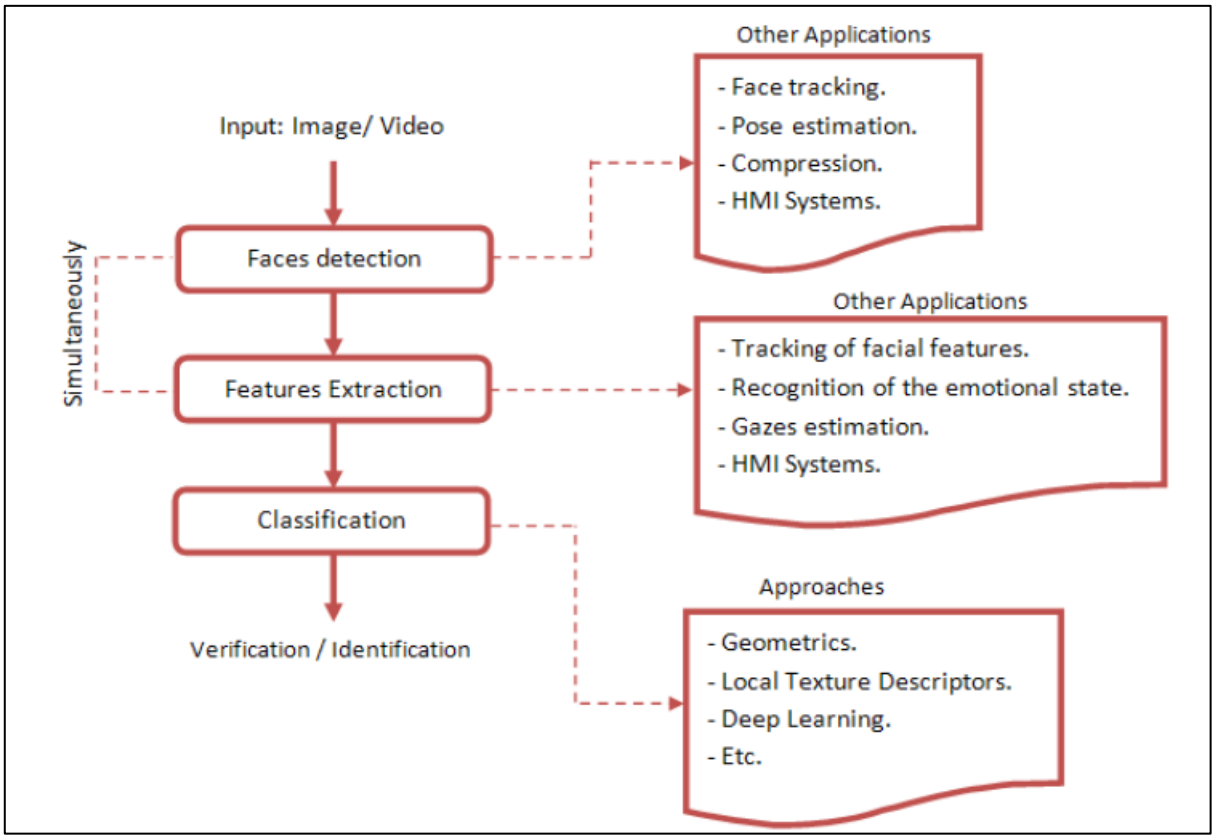

Figure 2. The standard design of an automated face-recognition system [3].

4. METHODS LIMITATIONS

Although face recognition techniques have evolved considerably, each strategy has limitations. Here is an outline of typical problems with certain well-used methods: PCA is sensitive to factors like changes in illumination, occlusions, or face obstructions that can greatly affect PCA performance. It also assumes linearity and is unable to capture non-linear facial fluctuations, such as those brought on by changes in posture or emotion. If the dataset is limited or lacks diversity, PCA cannot be generalized [50]. Researchers in [12] applied PCA-based face recognition system for smart phones, and presented the role limitations of this work, lighting and expression on the face, occlusion, shooting angle. Consequently, the model's modifications aim to mitigate the effects of these two variables [12], besides the method is time-consuming which a main problem in smart mobile application. The model of quantitative analysis Even while AAM can accurately recognize landmarks in unseen photos due to its capacity to model untrained faces, it has demonstrated a discernible difference in fitting performance on viewed and unknown images. The technique could recover rapid head movement or excessive out-of-plane rotating and was accurate enough to follow an invisible face during a succession of difficult head pose changes in a video clip [20].

The problem with facial recognition 3D data is that, in order to obtain precise 3D data by (texture and depth maps), all system components must be properly calibrated and compatible. Current 3D face recognition methods depend on feature surface descriptor extraction and coincide methods [1]. Hence, they are computationally costly and impractical for real-

world uses. Furthermore, because they need the subject's cooperation, they are useless in uncontrolled or semi-controlled situations when the input is a 2D luminance image taken with a single camera [1].

5. GENERAL FACE RECOGNITION DATABASES

Numerous facial recognition databases are generally available and were created for various purposes, including benchmarking, testing, and training. The general facial recognition databases are listed below [34][56]:

A. General-Purpose Face Recognition Databases

These databases are frequently used in training and testing Face recognition models.

- *Labeled Faces in the Wild (LFW):* includes more than 13,000 photos of faces taken "in the wild" in a variety of settings, with different expressions, lighting, and poses.
- *CelebFaces Attributes Dataset (CelebA)*: More than 200,000 pictures of famous faces with 40 facial characteristics (such as spectacles or beards) included.
- *CASIA-WebFace:* For the purpose of training deep facial recognition models, a sizable dataset comprising 500,000 images and 10,000 was gathered.
- *MS-Celeb-1M:* a massive dataset with 10 million images of 100,000 celebrities.
- *VGGFace and VGGFace2:* 2.6 million facial photos from 2,622 identities are available on VGGFace. With more than 3.3 million images of more than 9,000 identities, VGGFace2 is a modified version.

B. Specialized Face Recognition Databases

These datasets concentrate on particular face recognition concerns or conditions.

- *AR Face Database:* contains 4,000 images of 126 individuals with various settings, including different lighting, occlusions, and facial expressions.
- *Yale Face Database:* A small collection of 15 pictures of individuals taken in 11 distinct lighting scenarios with various emotions.
- *Bosphorus Database:* contains 4,666 excellent 3D facial scans of 105 individuals with different positions, occlusions, and expressions.
- *AffectNet:* extensive collection of over a million human faces with traits, sentiments, and facial expressions identified.

C. Surveillance and Video-Based Databases

These datasets concentrate on surveillance or video situations.

- *IJB-A/IJB-B/IJB-C:* NIST datasets include photos and videos of people in uncontrolled settings.
- *YouTube Faces Dataset:* More than 3,000 videos featuring 1,595 individuals were gathered from YouTube.
- *UCCS Dataset:* images of actual individuals taken for surveillance purposes at different ranges.

D. Real-Time and Large-Scale Datasets

These datasets reflect the limitations encountered in the real world.

- *MegaFace:* More than 1 million photos featuring 690,000 distinct identities

- *WIDER Face:* 32,000 photos and 400,000 faces with labels in different situations make up the dataset.

6. PERFORMANCE EVALUATION

The assessment conventions empower scientists to contrast techniques for distinguishing current faces and high-level strategies without the need to rehash past encounters. Frequently, certain trial parts can't be rehashed, for example, calculation subtleties, and setting boundaries can't be saved. The significant test presented by face acknowledgment innovation is that the utilization of disconnected test bunches neglects to take care of the issue of contrariness between the calculations utilized and the calculation boundaries executed for the test information [42]. The most regularly involved presentation assessment standards for face evaluation, ID and following factual measures that support correlation of the face acknowledgment model. There are two fundamental errors the framework can make in its assessment execution [42]:

A. False Acknowledgment (FA)

Once in a while it is called a bogus match, a positive mistake or a first blunder. At the point when the quest information for an individual didn't take recently found in the display is related with at least one individual in the display, FA is the proportion of the quantity of looks for non-existing competitors, where at least one of the up-and-comers in the show are returned or more prominent than the edge, to the quantity of irrelevant ventures.

B. False Rejection (FR)

Here and there it is known as a misleading non-match, a negative mistake. This happens when a quest for an individual's biometric character doesn't return to the right character; misleading dismissal is valuable concerning proportion and limit, where it very well may be characterized as the quantity of looks for a coordinate with an enrolled individual beyond R or higher.

C. Evaluation Protocol

Frequently, certain test parts can't be rehashed, for example, calculation subtleties, and setting boundaries can't be saved. The significant test presented by face acknowledgment innovation is that the utilization of separated test bunches neglects to take care of the issue of contrariness between the calculations utilized and the calculation boundaries executed for the test information.

7. FACE RECOGNITION APPLICATIONS

For face recognition applications, unconstrained situations, like most biometric applications, produce appearance variances that pose open face recognition issues. Face recognition techniques performed well on the images that are gathered with participation of the subjects. While the difficulties of progress in illumination, occlusion/ articulation, rotation, pose make this issue complicated, age changes the facial surface and shape while blocked images left halfway facial elements for handling, along these lines making the issue of face recognition a lot harder [21][27][43]. In the following subsections, a discussion of some difficulties that need to be addressed in the near future [3].

5.1 Face recognition and obstruction

Because the face can be taken in any attitude in any environment without any user assistance, the image may only contain a portion of the face [25].

5.2 Heterogeneous face recognition

The correlation of two facial representations from distinct imaging technologies is required for recognition of heterogeneous faces; this is highly beneficial in legal contexts [30].

5.3 Face Recognition from a Single Sample

The single sample per person (SSPP), or simply single sample face recognition, is one of the most exclusive and accurate applications of face recognition (SSFR) [3].

5.4 Soft Bio-metrics and Face Recognition

Soft bio-metrics is a human feature that provides precise information that can be used to establish a person's age, gender, eye and hair color, length, weight, skin color, or ethnicity from facial photographs, for example [28].

5.5 Smartphones and Face Recognition

Face recognition of mobile devices has numerous advantages. Users do not need to recall either the PIN or the password, and it can be easily accomplished on smartphones and tablets because only the forehead camera is necessary [36][37].

5.6 Video Surveillance/ face tracking

Face recognition framework performance in video observation is heavily dependent on picture securing conditions. On account of camera center issues, this can bring about picture obscuring, low-resolution, and block impacts. For this situation, the challenge of face recognition tracking systems is to recognize people from photos caught utilizing video surveillance cameras or poses with shifting stances. This challenge stays inexplicable and requires additional research [20].

5.7 Internet of things with face recognition

The internet of things (IoT) technology is currently booming, as is the method of connecting national or urban devices to the Internet for intelligent communication. Various life-simplifications will be available as a result of incorporating facial recognition into the IoT. A door in an apartment, for example, could recognize the resident and open automatically, a smartphone via its front camera using facial recognition [14].

5.8 Face Aging and recognition

The classic way to identify the presence of a particular individual in a previously registered database is to discover the presence of a particular individual in a previously registered database. For example, locating and identifying lost children as like the age difference between a query image and lost children [29].

5.9 Forensic Applications

Provide law enforcement with methods for recognizing faces in damaged photos or films [8][30].

5.10 Other Face recognition applications

It has become one of the most dynamic research regions particularly lately as it has an assortment of wide applications in the fields [16][28]:

- Public security
- Regulation implementation and trade
- Visa confirmation
- Criminal distinguishing proof
- Access control
- Artificial Human-Computer Interaction
- Computerized libraries and data security

8. DISCUSSION

One search method that draws inspiration from Darwinist theory is the Genetic Algorithm GA. For large heap spaces, the Genetic Algorithm is effective in cutting down on computation time. A genetic algorithm-based method is utilized to quickly identify the unknown image because face identification from a vast heap space is a time-consuming process [18].

BPNN is considered as a computer model that draw inspiration from the architecture and operation of biological neural networks. Principal component analysis PCA which can lower the feature space's scale and get rid of noise and correlation between image features by transforming input image into a feature space. It is appropriate for systems with low resources because it is simple to implement and computationally efficient. The support vector machine algorithm SVM is used to generate a classification algorithm. A review that goes further and models the distinction of element vectors and afterward creates and learns them, [10] can't resist the urge to show tremendous contrasts between the produced vectors and unforeseen impediments truly. Endeavors to make models hearty to impediment are continuous, however such investigations require a ton of assets because of image increase. A review that investigated viable expansion techniques and the planning of applying increase [1] figured out that the preparation opportunity expanded fundamentally because of how much learning expected because of the utilization of expansion.

Multiscale Twofold Management Convolutional Neural Organization (MDSCNN) is proposed to have numerous organizations prepared with facial patches of various scales for including extraction. Multiscale patches are trimmed from the entire face and adjusted in view of their eye-corners [40]. Generative Adversarial Networks (GANs) One type of machine learning framework innovative application. Their development has become a crucial component of facial recognition technology, by improving facial recognition performance while also addressing popular obstacles like occlusion, position variability, and limited data access [51]. GANs still suffer from certain restrictions, such as the difficulty of convergence instability for training samples, which in turn required significant computational resources. Additionally, in case of poorly trained data used, GANs generate unrealistic images, which could degrade recognition accuracy.

Emerging technologies such as transformers, generative adversarial networks (GANs), and other multi-modal systems are transforming a number of domains, such as face recognition, computer vision, and natural language processing. Transformers are deep learning architectures that are being used in a variety of fields [52]. For efficient face embedding generation, transformers are employed, which increases accuracy in difficult situations such posture variations and

occlusion. To enhance performance, multi-modal systems combine information from several modalities, including text, graphics, and audio, one of these systems is face recognition, and Speech-Driven Face Generation [53]. Other Emerging Technologies are Diffusion Models [54] which is a class of generative models gaining popularity for producing high-quality images and videos, and Neural Radiance Fields (NeRFs) [55] mostly used for 3D rendering and reconstruction from 2D images, which makes realistic facial modeling possible.

9. CONCLUSIONS

Face recognition is an essential part for approval and security fields. It got significant consideration from analysts in different areas of science like biometrics and computer vision. Face recognition is as yet a difficult issue in the field of computer vision.

Face recognition systems were first developed using conventional methods, but their accuracy and robustness have significantly increased with the development of deep convolutional neural networks (CNNs) and other contemporary approaches like transformers and generative adversarial networks (GANs). These techniques have made it possible for face recognition systems to function well in a variety of difficult real-world situations, such as changing lighting, postures, and occlusions. Even with these developments, a number of issues still exist. Research is still needed concerning problems including biases in algorithms and privacy concerns. This paper introduced a concise review of issues strategies, challenges limitations and applications in the area of face recognition. Available facial databases are presented as well. Face recognition software has the potential to develop into a reliable and effective tool for a variety of applications.

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DATA AVAILABILITY STATEMENT

The data used is included in the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest in influencing the work in this paper.

REFERENCES

[1] S. M. Bah, F. Ming, “An improved face recognition algorithm and its application in attendance management system”, *Array 5*. 2020. Doi: https://doi.org/10.1016/j.array.2019.100014

[2] S. Nasr and K. Bouallegue and M. Shoaib and H. Mekki, “Face recognition system using bag of features and multi-class SVM for robot applications”, *International Conference on Control, Automation and Diagnosis (ICCAD)*, pp. 263-268, 2017.

[3] I. Adjabi, A. Ouahabi , A. Benzaoui and A. Taleb-Ahme, “Past, Present, and Future of Face Recognition: A Review”, *Electronics*, Vol. 9, No. 1188. 2020. doi:10.3390/electronics9081188.

[4] A. J. Shepley, Deep “Learning for Face Recognition: A Critical Analysis”, *ARXIVLABS IV*, VI, Jul. 12, 2019, https://arxiv.org/pdf/1907.12739.

[5] W. Wójcik, K. Gromaszek, and M. Junisbekov, "Face Recognition: Issues, Methods and Alternative Applications, in Face Recognition - Semisupervised Classification", *Subspace Projection and Evaluation Methods*. London, United Kingdom: IntechOpen, 2016. Available: https://www.intechopen.com/chapters/51031 doi: 10.5772/62950

[6] Abd_Almuhsen, F. Almudhafer, Zainab A. Khalaf, "Review of Different Combinations of Facial Expression Recognition System", *Journal of Physics: Conference Series* 1591, 012020. 2020. doi:10.1088/1742-6596/1591/1/012020

[7] R. S. Ghiass, O. Arandjelovic, A Bendada., and X. Maldague, "Infrared face recognition: A comprehensive review of methodologies and databases". *Pattern Recognition*, Vol. 47(9), pp. 2807-2824. 2014.

[8] G. Porter, G. Doran, "An anatomical and photographic technique for forensic facial identification". *Forensic Sci Int.* Vol. 114(2), pp. 97-105. 2000. doi: 10.1016/s0379-0738(00)00290-5.

[9] S.Z. Li, A.K. Jain, "Handbook of Face Recognition", 2nd ed.; S*pringer Publishing Company:* New York, NY, USA, 2011.

[10] S. Abdel minaam D, AM Almansori, M. Taha, E. Badr "A deep facial recognition system using computational intelligent algorithms". *PLoS ONE*, Vol. 15(12), e0242269, 2020. https://doi.org/10.1371/journal.pone.0242269

[11] L. C. Paul , A. Al Sumam, "Face Recognition Using Principal Component Analysis Method", *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*, Vol. 1, No. 9. 2012.

[12] P. Peng, I. Portugal, P. Alencar, D. Cowan, "A face recognition software framework based on principal component analysis". *PLoS ONE*, Vol. 16. No. 7. 2021, https://doi.org/10.1371/journal.

[13] P. M Shah, "Face Detection from Images Using Support Vector Machine". *Master's Projects*. 321. 2012. DOI: https://doi.org/10.31979/etd.wg5s-gyqn

[14] P.K. Medapati, P.H.S.T. Murthy, K.P. Sridhar, "LAMSTAR: For IoT-based face recognition system to manage the safety factor in smart cities". *Trans. Emerg. Telecommun. Technol.* pp. 1–15. 2019. online:https://onlinelibrary.wiley.com/doi/abs/10.1002/ett.3843?af=R

[15] M. P. Rajath Kumar, R. K. Sravan and K. M. Aishwarya, "Artificial neural networks for face recognition using PCA and BPNN", *TENCON 2015 - 2015 IEEE Region 10 Conference*, pp. 1-6, 2015. doi: 10.1109/TENCON.2015.7373165.

[16] P. Sukhija, S. Behal, P. Singh, "Face Recognition System Using Genetic Algorithm", *Procedia Computer Science*, Vol. 85, pp. 410-417, 2016. https://doi.org/10.1016/j.procs.2016.05.183.

[17] S. Md. Tareeq, R. Parveen, L. J. Rozario and Md. Al-Amin Bhuiyan, "Robust Face Detection using Genetic Algorithm", I*nformation Technology Journal*, Vol. 6, pp. 142-147. 2007. Doi: 10.3923/itj.2007.142.147

[18] M. P. Panigrahy, N. Kumar, "Face Recognition using Genetic Algorithm and Neural Networks", *International Journal of Computer Applications*, Vol. 55, No.4, pp. 0975 – 8887, 2012.

[19] Y. Zhang; F. Zhang; L. Guo, "Face Recognition Based on Principal Component Analysis and Support Vector Machine Algorithms", *IEEE 40th Chinese Control Conference (CCC)*, 2021. Doi: 10.23919/CCC52363.2021.9550727

[20] M. Kopaczka, K. Acar and D. Merhof. "Robust Facial Landmark Detection and Face Tracking in Thermal Infrared Images using Active Appearance Models". *In Proceedings of the 11th Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications VISAPP, (VISIGRAPP 2016)*, Vol. 4, pp. 150-158. 2016. DOI: 10.5220/0005716801500158

[21] A. K. Agrawal, Y. N. Singh," Evaluation of Face Recognition Methods in Unconstrained Environments", *International Conference on Intelligent Computing, Communication & Convergence (ICCC-2015), Procedia Computer Science 48*, PP. 644 – 651. 2015.

[22] A. B. Rubin, "A Facial Challenge: Facial Recognition Technology and the Carpenter Doctrine", *27 RICH. J.L. & TECH.*, No. 2, 2021.

[23] C. Mejda, A. Elkefi, W. Bellil, and C. B. Amar. "A Survey of 2D Face Recognition Techniques", *Computers*, Vol. 5, No. 4: 21, 2016. https://doi.org/10.3390/computers5040021

[24] P. Jain, S. Gupta, K.R. Ramkumar, "Review on Face Recognition by Machine Learning and Deep Learning Approaches". *6th International Conference on Computing for Sustainable Global Development (INDIAC*om), pp. 528-534. 2019.

[25] H. Deng, Z. Feng, G. Qian, X. Lv, H. Li, , G. Li, ,"MFCosface: A Masked-Face Recognition Algorithm Based on Large Margin Cosine Loss". *Appl. Sci.*, 11, 7310. 2021. https://doi.org/10.3390/app11167310

[26] R. Z. Khan, , N. A. Ibraheem, "Genetic Shape Fitting for Hand Gesture Modeling and Feature Extraction using Variable Length Chromosome". *British Journal of Science*, Vol. 10, No. 1, pp. 1-11. 2013.

[27] N. A. Ibraheem, M. M. Hasan, "Combining Several Substitution Cipher Algorithms using Circular Queue Data Structure". *Baghdad Science Journal*, Vol. 17, No. 4, pp. 1320-1327, 2020. doi:10.21123/bsj.2020.17.4.1320.

[28] A. Br¨omme, C. Busch, A. Dantcheva, K. Raja, C. Rathgeb and A. "Uhl (Eds.): BIOSIG", *Lecture Notes in Informatics (LNI), Gesellschaft f¨ur Informati*k, Bonn 2020.

[29] D. Deb, L. Best-Rowden and A. K. Jain, "Face Recognition Performance under Aging", *2017 IEEE Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*, pp. 548-556, 2017, doi: 10.1109/CVPRW.2017.82

[30] M. Cho, T. Kim, I. -J. Kim, K. Lee and S. Lee, "Relational Deep Feature Learning for Heterogeneous Face Recognition", *IEEE Transactions on Information Forensics and Security*, Vol. 16, pp. 376-388, 2021. doi: 10.1109/TIFS.2020.3013186

[31] F. Xiong and Z. You, "Research on Face Image Recognition System Based on Computer Artificial Intelligence Technology", *IEEE 3rd International Conference on Electronic Technology, Communication and Information (ICETCI)*, Changchun, China, pp. 1158-1161, 2023, doi: 10.1109/ICETCI57876.2023.10176850.

[32] S. Liu, L. Zhao, C. Qu, "Research on Image Recognition Technology Based on Artificial Intelligence", *Computer Life* Vol. 11, No. 1. 2023.

[33] Y. Sun, Z. Ren, W. Zheng, "Research on Face Recognition Algorithm Based on Image Processing", *Computational Intelligence and Neuroscience*, 2-4, 2022, doi: 10.1155/2022/9224203

[34] M. Wang, W. Deng, "Deep Face Recognition: A Survey". *ArXiv*. 2018. https://doi.org/10.1016/j.neucom.2020.10.081

[35] M. Khalaf, B. N. Dhannoon, "MSRD-Unet: Multiscale Residual Dilated U-Net for Medical Image Segmentation", *Baghdad Science Journal*, Vol. 19(6), pp. 1603-1611, 2022, doi: https://dx.doi.org/10.21123/bsj.2022.7559

[36] H. Soliman, A. Saleh, E.n Fathi, "Face Recognition in Mobile Devices", *International Journal of Computer Applications*, Vol. 73, No.2. 2013.

[37] E. Ozen, F. Alim, S. B. Okcu, E. Kavakli, C. Cigla, "Real-Time Face Recognition System at the Edge", *Conference SPIE Defence and commercial Sensing, Proceedings*, Vol. 13057, 2024, Signal Processing, Sensor/Information Fusion, and Target Recognition XXXIII; 130570N, https://doi.org/10.1117/12.3013671

[38] M.O. Oloyede, G.P. Hancke, H.C. Myburgh, "A review on face recognition systems: recent approaches and challenges". *Multimed Tools Appl 79*, pp. 27891–27922. 2020. https://doi.org/10.1007/s11042-020-09261-2

[39] M. M Hasan, N. A. Ibraheem, "Face Construction and Recognition using Neural Networks", *International Journal of Computer Systems*, Vol. 04, No. 06, 2017, Available at http://www.ijcsonline.com

[40] D. Zeng, R. Veldhuis, and L. Spreeuwers, "A survey of face recognition techniques under occlusion", *IET biometrics*, Vol. 10, No. 6, pp. 581-606. 2021.

[41] C. Hu, M. Ye, Y. Du, X. Lu, "Vector projection for face recognition", *Computers & Electrical Engineering*, Vol. 40 No. 8, pp. 51-65, 2014, https://doi.org/10.1016/j.compeleceng.2014.08.010.

[42] A. T. Hussein Alrawi, A. Mosslah, M. G. Alwan, "Performance Evaluation For Face Database", *Journal of Southwest Jiao tong University*, Vol. 55, No. 1. 2020. Doi: 10.35741/issn.0258-2724.55.1.39

[43] C. Mingtsung, Q. Wei, H. Jiaqi, Z. zhuomin, "Research on the application of face recognition system", *Journal of Physics: Conference Series*, 1684, 2020. doi:10.1088/1742-6596/1684/1/012126

[44] V. C. R, V. Asha, B. Saju, S. N, T. R. Mrudhula Reddy and S. K. M, "Face Recognition and Identification Using Deep Learning", 2*023 Third International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT)*, Bhilai, India, pp. 1-5, 2023. doi: 10.1109/ICAECT57570.2023.10118154.

[45] Md. T. H. Fuad, A. A. Fime, D. Sikder, Md. A. R.Iftee, J. Rabbi, M. S. Al-Rakhami, A. Gumaei, O.Sen, M. Fuad, Md. N. Islam, , "Recent Advances in Deep Learning Techniques for Face Recognition", *IEEE Access*, Vol. 9, pp. 99112-99142, 2021. doi: 10.1109/ACCESS.2021.3096136.

[46] S. J. Rashid, A. I. Abdullah, M. A. Shihab, "Face Recognition System Based on Gabor Wavelets Transform, Principal Component Analysis and Support Vector Machine". *International Journal on Advanced Science, Engineering and Information Technology*, Vol. 10(3), pp. 959–963, 2020. https://doi.org/10.18517/ijaseit.10.3.8247

[47] W. Lei, Y. Lei, B. Li, and K. Jia, "Support Vector Machines Optimisation for Face Recognition Using Sparrow Search Algorithm", *journal Traitement du Signal*, 2023.

[48] T. Matsukawa, T. Uemura, T. Yamaguchi, "A survey of face recognition technology and its application to security systems". *Journal of Electrical Engineering & Technology*, Vol. 12(1), pp. 72-84. 2017.

[49] V. Arora, T. Afnas, "A short survey on face recognition". *Journal of applied research on industrial engineering*, Vol. 8(2), pp. 169-175. 2021.

[50] L. Aofan., et al. "An Improved Principal Component Analysis (PCA) Face Recognition Technique using Modular Approach". *PriMera Scientific Engineering*, Vol. 2(4), pp. 23-35. 2023.

[51] T. Karras, T. Aila, S. Laine, J. Lehtinen, "A Style-Based Generator Architecture for Generative Adversarial Networks". *IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI).* 2019. https://doi.org/10.48550/arXiv.1812.04948

[52] A. Dosovitskiy, L. Beyer, A. Kolesnikov, D. Weissenborn, X. Zhai, T. Unterthiner, M. Dehghani, , M. Minderer, G. Heigold, S. Gelly, J. Uszkoreit, N. Houlsby, "An Image is Worth 16x16 Words: Transformers for Image Recognition at Scale". *ArXiv*. 2020. https://arxiv.org/abs/2010.11929

[53] K. Vougioukas, S. Petridis, M. Pantic, "Realistic Speech-Driven Facial Animation with GANs". *ArXiv.* 2019. https://arxiv.org/abs/1906.06337

[54] J. Ho, A. Jain, P. Abbeel, "Denoising Diffusion Probabilistic Models". *ArXiv,* 2020. https://arxiv.org/abs/2006.11239

[55] B. Mildenhall, P. P. Srinivasan, M. Tancik, J. T. Barron, R. Ramamoorthi, R. Ng, "NeRF: Representing Scenes as Neural Radiance Fields for View Synthesis". *ArXiv*. 2020. https://arxiv.org/abs/2003.08934

[56] G. B. Huang, M. Mattar, T. Berg, E. Learned-Miller, "Labeled Faces in the Wild: A Database for Studying Face Recognition in Unconstrained Environments", 2008.