Literature Review of Face Recognition for Degraded Images

Muthanna Qahtan Ismael [*], Nada Jasim Habeeb [**], Alla Hussein Ansaf [**]

[*] Information Technology, Technical College of Management, Middle Technical University, Iraq
Email: dac2010@mtu.edu.iq.
https://orcid.org/ 0009-0009-3092-6094

[**] Information Technology, Technical College of Management, Middle Technical University, Iraq
Email: nadaj2013@mtu.edu.iq.
https://orcid.org/0000-0003-0337-5767

[**] Kut Technical Institute, Middle Technical University, Iraq
Email: alaa.ansaf@mtu.edu.iq.
https://orcid.org/0000-0003-1241-3673

Abstract

Face recognition technology is a biometric method used to identify or verify individuals by their facial characteristics. It is widely used in commercial and law enforcement applications, such as surveillance systems, passport verification, security systems, and human-machine interaction. However, face recognition challenges such as noise, image deterioration, corruption, and external elements. To improve face recognition accuracy in noisy environments, noise reduction techniques, and robust representation learning methods are needed. This study attempts to clarify on Active Appearance Models, Viola-Jones, and Convolutional Neural Networks algorithms which have been used in literature studies, as well, provide the issues by organizing the abundance of articles and information in this field to highlight current research trends, and provides an outline of their advantages and disadvantages.

Keywords- Active Appearance Models (AAMs), Convolutional Neural Networks (CNNs), Face recognition, Noise, Viola-Jones algorithm.

I. INTRODUCTION

Face recognition technology recognizes or verifies people by their facial characteristics. It does more than just find a face in an image; it examines certain features and compares them to a dataset of recognized faces [1]. It works by using a dataset of known faces by comparing them with the facial features of an unfamiliar person. The system consists of five main functional blocks, with the following responsibilities:
A. Image input unit: This is the point at which face recognition begins. An image was captured from a camera not entered by the user into the face recognition system of this module. B. Face detection is a technique that can manage high variability parameters like position, scale, and illumination is needed for the face detection stage, which finds face images in unrestricted contexts. C. The unit for Pre-Processing: to enhance the system's recognition, the photos in this module are normalized. The following are the pre-processing steps that were used: 1) Normalization of image size. 2) Removal of the background. 3) Translation and rotational normalizations. 4) Normalization of illumination. D. The Feature Extraction unit: The important features that will be used for classification are determined after entering natural facial images into this unit, as this unit depicts the facial image by creating an accurate feature vector. E. The Classification unit: The features that are identified in the face image are subjected to comparison with the ones kept in the face database by the use of a pattern classifier. Then, a categorization of the face image is made as either known or unknown. F. Face dataset: the purpose here is to hold a comparison between train images found in the dataset and the test images. Subsequently, images may be sent to a database for further comparison, especially when the face is categorized as unknown [2,3]. Face recognition is a crucial tool in technology with numerous applications, especially in commerce and law enforcement. It is widely used in surveillance, passport verification, security protocols, and human-machine interaction. Face identification is an essential procedure in the whole face recognition process, where it is used in biometric recognition systems, search, and security systems. Face recognition technology is considered a reliable and precise method for individual identification, as it enhances security systems without any major issues. Its practical applications can be found in residential, business, and commercial complexes. As well, its practical applications are available in residential complexes, along with business and trade complexes. Face recognition has become a widely accepted method for analyzing surveillance videos, particularly for detecting anomalies in public settings. [4,5]. Nowadays, face recognition technology is in high demand in the government and private sectors as security concerns grow in different aspects of

life and work. The development of facial recognition has increased significantly. One of the best systems has the following main features:1. High accuracy: The facial recognition system must have a high ability to recognize faces in all types of conditions, which may include, for example, when images of faces are exposed to differences in lighting or are exposed to conditions that cause them to be distorted, such as fog or noise. 2. Real-time facial recognition: The system must have real-time facial recognition features instead of images or video. These features are very important, especially from a security standpoint, to prevent unauthorized access. 3. Expansion capability: The system should be able to expand as required by the organization. Security: The facial recognition system must have a strong security layer by encrypting the data of administrators and users. 4. Ease of use: The system must be easy to use for administrators and users. 5. Real-time processing and analysis: it must have a high ability to distinguish faces in real time and also have a high ability to analyze these faces. Figure 1 shows a schematic diagram of a typical face recognition system.

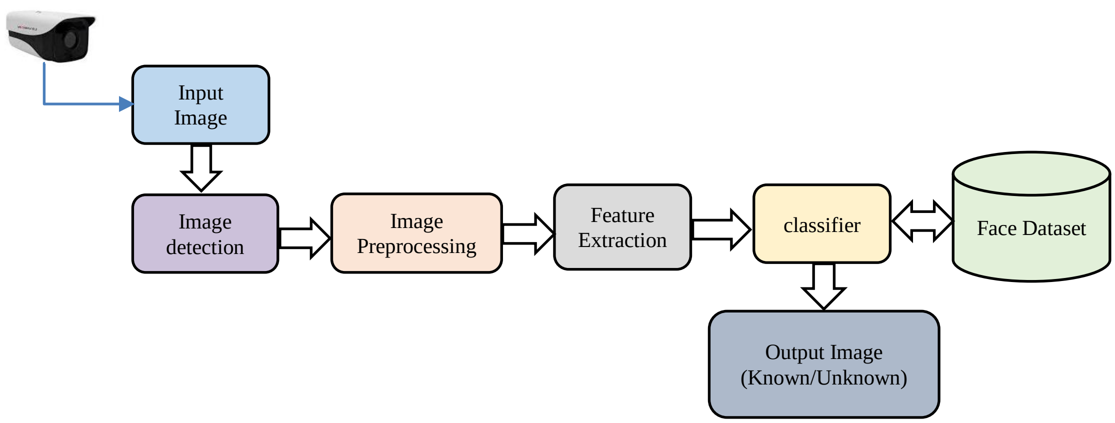


Figure 1. Schematic Diagram of Face Recognition System

As shown in the figure 1, The system comprises functional blocks that process input images, determine face recognition, normalize images, identify key features for classification, and compare these features with the dataset, resulting in a final determination of the face's identity.

Face recognition under degraded faces has several challenges. One major challenge is the presence of feature- and label-noise, which is caused by the ambiguity of facial expressions and low-quality images. Another challenge is the noise in the images and illumination changes, which can affect the accuracy of emotion recognition from facial expressions [7,8]. Additionally, the unrestrained noise type in each engagement, such as inter-class conflict, makes it difficult for algorithms to perform well at face recognition [9]. Noise and blur in face recognition can be caused by various factors, such as image deterioration, corruption, and external factors that impact the treatment and functionality of biometric authentication systems [10]. The existence of noise or blur can significantly impact the face recognition process, leading to degraded performance and compromised security [11]. These challenges necessitate developing the system through noise reduction techniques and robust representation learning methods to enhance face recognition accuracy in noisy environments. Below is shown the size of the global market for face recognition technology in figure 2.

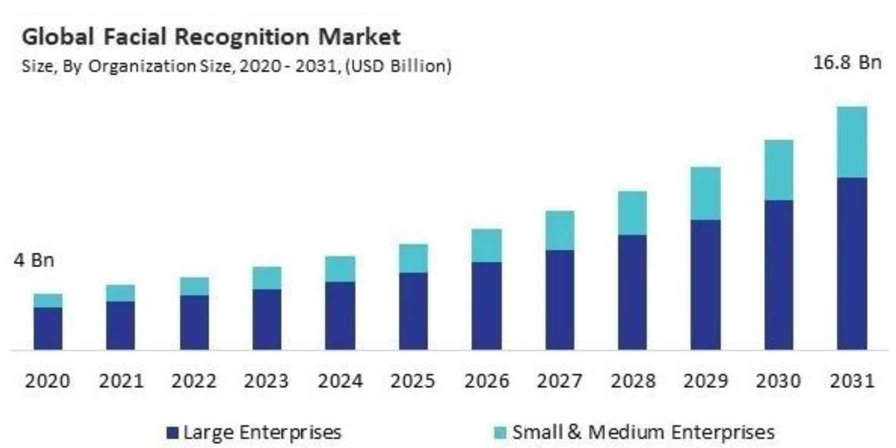


Figure 2. Global Facial Recognition Market [6].

In the figure 2, illustrates the projected market size for global facial recognition is expected to reach $16.8 billion by 2031, with a compound annual growth rate (CAGR) of 14.5% during the forecast period. One of the main drivers propelling the market is the increasing use of effective surveillance systems to improve safety and security. Other factors include the increasing installation of these systems in different businesses and shopping centers, and the broad availability of high-tech facial recognition systems.

II. PROPLEM AND CHALLENGES

Facial recognition algorithms have significantly improved in the last decade due to the collaboration between commercial product developers and university computer vision researchers. The impact of using algorithms on security is uncertain, as many real-world security situations still depend on human performance for tasks such as facial recognition. The real challenge with face detection and identification technology lies in effectively handling various situations with uncooperative subjects and unrestricted data acquisition. The following are common challenges and obstacles that a face recognition system may encounter when attempting to identify and detect faces:

1. Illumination

Variations in light are called illumination. Changes in illumination can affect how much light is reflected from an item and how an image's shading and shadows are apparent. In fact, changing the lighting can produce more noticeable alterations in a photograph than changing a face's identity or perspective. Under various lighting circumstances, a person is photographed several times with the same camera and the exact facial expression may appear different, yet the face is seen in an almost identical pose. Face recognition is often considered difficult by both humans and computers when there are changes in lighting conditions. Thus, changing lighting conditions continue to be a major source of difficulty for automatic face recognition systems. [12,13].

Figure 3: Differences in illumination in face imageries [14].

As shown in the figure 3, it demonstrates how changes in lighting can significantly alter the appearance of a face, making challenging for recognition systems to maintain accuracy. This highlights the need for advanced techniques to handle varying illumination conditions.

2. Low Resolution

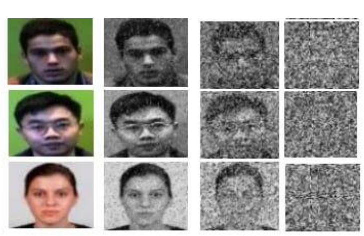
When the resolution of the selected face image becomes less than 16×16, a face recognition system has a low-resolution difficulty. Numerous surveillance applications encounter this issue; a facial image with such low quality has very little information since the majority of the features are lost. This may significantly lower the recognition level [15].

Figure 4: Comparison of a high- resolution face image (1) with low- resolution face images (a–h) [16].

In the figure 4, the comparison shows how low- resolution images lose critical details, which can hinder the performance of recognition systems. Enhancing image resolution is crucial for maintaining recognition accuracy in such scenarios.

3. Noise

Face recognition is essential for consumer technology, law enforcement, and security. However, a variety of noise sources, including occlusions, posture fluctuations, intra-class variations, ambient noise, sensor noise, and image noise, might affect its accuracy. Noise can result in restricted application in a variety of real-world circumstances, higher processing costs, and decreased accuracy. The look of a face can be distorted by elements like weather and camera noise, making it challenging to precisely identify important characteristics [17,18,19]. The following figure shows face images with different noise intensities.



a b c d

Figure 5. (a) represents the source images, (b) represents the noisy images with 10%, (c) represents the noisy images with 50%, and (d) represents the noisy images with 90%. [17]

In the figure 5, it shows how varying levels of noise can lead to image quality degradation, making it difficult for facial recognition systems. Noise reduction techniques are essential to mitigate these effects and improve system reliability.

III. FACE DETECTION AND RECOGNITION TECHNIQUES UNDER DIFFERENT IMAGE DEGRADATIONS

In the present paper, we conducted an extensive review of literature to identify some of the best and most recent noise reduction techniques in face recognition. These techniques help face recognition systems to identify face features in the input image by improving the accuracy and reducing noise in the image, and then classify the image and match it with the images stored in the database to identify the person's identity.

1. Active Appearance Models (AAMs)

Active Appearance Models (AAMs) are statistical models used to detect and recognize facial features in both static and dynamic images. They involve a combination of a shape model and an appearance model. The former model helps to track the continuous change in the facial shape, while the latter tracks the change in the facial texture [20,21]. AAMs provide a higher level of accuracy in facial recognition techniques, specifically in tracking the alternation in pose, and expressive features. Thus, they offer a model of easy interpretation which has its role in helping to enhance and debug face recognition tasks. AAMs enjoy computational efficiency, and so they are reliable in applications of limited resource devices.
Face recognition AAMs have their limitations in terms of scalability, noise sensitivity, and pose. As such, they are practically limited and much less effective in far-reaching postures and profiles. Table (1) below gives an exposition of previous studies employing AAMs in face recognition.

TABLE 1. Previous studies using AAM for face recognition

	Author's name	Year	Research Problem	The proposed method and research steps	The results	References
1	Zeng, Nanyang, et al.	2018	In the discipline of pattern recognition, facial expression recognition is a crucial area of study.	The facial expression identification system used a high-dimensional feature combining face geometry and appearance elements, and deep sparse auto encoders (DSAE) are designed to learn robust and discriminative features from data for high accuracy.	The proposed approach achieved a high accuracy rate of 95.79% in identifying seven facial expressions, outperforming three state-of-the-art methods by up to 3.17%, 4.09% and 7.41%, respectively.	[22]
2	Peng, Yao, and Hujun Yin.	2018	A vision for understanding and modeling expression variations in face recognition and expression classification over the past decades	The study introduced a method for expression classification and face recognition using photorealistic expression manifolds, generating shape and expression details for new subjects and performing these tasks on an extended training set.	The proposed strategy for robustly identifying faces with different expression levels and ranges on various datasets yields the best results when compared to existing methods and historical database synthesis.	[23]
3	Rao, Yongming, et al.	2019	The challenge is developing a technique that, in contrast to existing video aggregation approaches, integrates information from video frames to represent features effectively and efficiently.	The technique used metric and adversarial learning to gather unprocessed video frames, reducing processing time and producing more discriminative images, accelerating recognition and minimizing analysis.	The technique enhances face recognition performance by producing discriminative images from video clips, improving speed and accuracy for person re-identification and video-based face recognition.	[24]
4	Choudhury, Ziaul Haque.	2020	The face recognition system confronts difficulties due to several problems with heavily makeup-covered features and poor-quality photos.	Two novel techniques have been proposed for detecting facial marks and recognizing faces with makeup and low-quality images, using active appearance models, Canny edge detectors, and SURF algorithms.	The study achieved a 93% accuracy rate in a second experiment using a database of 1000 Indian face photos, indicating a 95% accuracy rate.	[25]

5	To, Xiaoguang, et al.	2021	Large poses, poor illumination, low resolution, occlusion, and noise can degrade face image quality, making facial recognition systems challenging to accurately identify.	The Multi-Degradation Face Restoration model is a novel method for transforming low-quality facial images into high-quality ones, utilizing feature representation, pose residual learning, and 3D-based PNM to maintain face identity.	A demonstration is made by both qualitative and quantity experiments of the superiority of the MDFR method over those of both face formalization and face restoration.	[26]
6	Shanthi, P., and S. Nickolas.	2021	The impact of neighboring pixels' relationships on texture-based feature extraction methods for distinguishing facial expression differences.	The method proposed combines Local Binary Pattern and Local Neighbourhood Encoded Pattern, focusing on adjacent pixels' relationship with the central pixel, using Chi-square statistical analysis for feature identification and multiclass Support Vector Machine for classification.	The hybrid feature demonstrated superior performance, achieving an average recognition accuracy of 97.11% on the MMI dataset and 97.86% on the CK+ dataset, especially in noisy environments.	[27]
7	Kommineni, Jenni, et al.	2021	Researchers are grappling with the challenge of developing efficient techniques for feature extraction from photos due to the ambiguity and complexity of human faces.	Their study introduces a high-performance computing technique for facial expression identification, utilizing a dual-tree m-band wavelet transform algorithm and a Gaussian mixture model for efficient classification.	The trials' findings indicate that the suggested technique's maximum precision, which is observed at the fourth decomposition level of DTMBWT, is 99.53%.	[28]
8	Mi, Yuxi, et al.	2022	The increasing prevalence of concerns over the misuse of original face photos for malicious purposes is leading to privacy violations in face recognition systems.	They introduced DuetFace, which is a privacy-preserving facial recognition technology that divides frequency channels based on visual display importance, enabling client-side facial feature transfer through an interactive block.	The proposed method achieved good results in improving performance and protecting facial images against unwanted inspection, achieving good recognition accuracy.	[29]
9	Shreekumar, T., et al.	2022	Identifying faces from low-quality photos or video frames, influenced by noise, blur, or lighting, is challenging and requires more effective techniques.	Their study introduced a deep recurrent neural network method for removing noise and minimizing light-related difficulties in reconstructing super-resolution images of blurred images.	The experiments' outcome demonstrates that the suggested algorithms performed well.	[30]

2. Viola-Jones algorithm

The Viola-Jones algorithm is a widely used framework for object detection, particularly for identifying faces in images. Developed by Paul Viola and Michael Jones in 2001, this method is effective in recognizing low-quality face images with issues like noise, blur, and poor lighting [31,32]. By utilizing Haar-like features and a series of classifiers, it focuses on capturing facial features like eyes, nose, and mouth. Each classifier addresses a specific aspect within an image, and successful features progress through subsequent classifiers until a face is identified [33]. The algorithm excels in detecting faces in high-quality images with proper lighting and processes quickly, making it suitable for applications requiring rapid analysis, such as security systems. It can be adapted and trained to recognize unconventional faces like those wearing glasses or hats [34]. Moreover, it extends its functionality to identify various entities like cars and pedestrians, benefiting from image processing tasks such as surveillance, security, and human-machine interaction. While the Viola-Jones method offers simplicity, speed, and accuracy in face recognition, it may have limitations in scenarios demanding higher precision or dealing with diverse face orientations [35]. Studies implementing this approach for face recognition are detailed in Table 2.

TABLE 2. Studies implementing the Viola-Jones algorithm in face detection

	Author's name	Year	Research Problem	The proposed method and research steps	The results	References
1	Barnouti, N. H., et al.	2018	The problem is related to devising a dependable and professional system for face recognition and tracking along with the various current approaches for face recognition.	The proposed system employs 2DPCA and KLT trackers to identify faces in video streams, employing the Viola-Jones technique for face identification and 2DPCA for face feature extraction.	The Viola-Jones face detection algorithm and KLT demonstrated effectiveness in tracking multiple faces even when the identified face shifts to the left or right.	[36]

2	Nasir, Ahmad Fakhri Ab, et al.	2019	The main question of the study is how to improve the accuracy and robustness of face detection using a method with the Viola Jones algorithm, especially for images with diverse lighting, skin tone, and ethnic differences.	Hybridization with skin colour segmentation enhances face detection accuracy in challenging images using YCbCr colour space, tested through comparison of varying lighting, orientations, and ethnicities.	The YCbCr and Viola-Jones approach achieved high accuracy (~88%) in various situations, while the original algorithm and HSV colour model showed slightly lower accuracy due to skin colour distribution differences.	[37]
3	Bendjillali, Ridha Ilyas, et al.	2020	The challenge is improving the accuracy and robustness of facial recognition systems, particularly with challenging factors like illumination variations and pose changes.	The study presents a three-step Face Recognition system, which includes feature learning for classification, facial image enhancement using M-CLAHE, and the Viola-Jones technique, using VGG16, ResNet50, and Inception-v3 CNN architectures for feature learning and classification.	The Inception-v3 architecture achieved the highest recognition accuracy, reaching 99.44% on Extended Yale B and 99.89% on CMU PIE, with image enhancement and advanced CNNs significantly improving recognition accuracy.	[38]
4	Xiao, Yihan, Dalu Cao, and Lipeng Gao.	2020	The study question is how to accurately detect faces in images when parts of the face are occluded.	The POOA algorithm uses an average gray value of a face image, multiplied by a suitable coefficient, and by a Haar feature to retrieve the face's occlusion region. This quick algorithm is proposed.	The technique has produced good results in terms of size, shape, and occlusion area, with a notable enhancement in detection precision.	[39]
5	Hari, M. Fakhrul,et al.	2021	The face, a unique part of the human expression, comprises all facial features that require identification and discovery.	The Viola-Jones algorithm was proposed, which is a face recognition method that uses Adaboost, Integral Image, Haar-like Filter, and Cascade algorithms to detect human faces.	The first study showed high accuracy in face detection, with an accuracy of between 85% and 95%. The second study improved accuracy and completion times and identified emotions from facial expressions. The third study achieved 94.5% accuracy.	[40]
6	Yadav, Laxmi,et al.	2021	The challenge is to improve the accuracy and robustness of facial recognition for user authentication, especially under noisy and difficult conditions.	The study introduced a method for recognizing facial features for system authentication using deep learning and K-nearest neighbors, overcoming issues like erroneous approval and incorrect rejection rates.	The model achieved an average recognition accuracy of 96.40%, demonstrating resilience against various noise sources like uneven lighting, motion blur, and posture changes.	[41]
7	Yallamandaiah, S., & Purnachand, N.	2021	The challenge is to improve the accuracy and robustness of facial recognition for user authentication, especially under noisy and difficult conditions.	The study introduced a method for recognizing facial features for system authentication using deep learning and K-nearest neighbors, overcoming issues like erroneous approval and incorrect rejection rates.	The model achieved an average recognition accuracy of 96.40%, demonstrating resilience against various noise sources like uneven lighting, motion blur, and posture changes.	[42]
8	Ashor, S., & Ahmed, H. M.	2022	The challenge is to improve the accuracy and robustness of facial recognition systems, especially in difficult conditions such as inadequate lighting.	The system enhances photos using Histogram Equalization and gamma, then uses Viola-Jones face detection and convolutional neural networks to identify individuals and extract facial traits.	The suggested system achieved 100% accuracy during training with a low error rate.	[43]
9	Sunardi, S., et al	2022	The challenge is reducing noise in digital photos to increase the accuracy of face detection using a Viola-Jones algorithm.	The median filtering technique was employed to reduce noise in digital images while maintaining key facial features, evaluated using MSE, PNSR, and Viola-Jones face detection techniques.	The method with confusion achieved a 90% accuracy rate in face detection in digital photographs, with the highest PNSR of 14.37 and lowest MSE of 9.33.	[44]
10	Kristanto, Verry Noval, et al.	2023	Poor quality digital images in criminal investigations can complicate and time-consuming facial recognition processes due to their inability to be viewed by the human eye.	The Viola-Jones approach is utilized for face recognition of low-quality images, employing techniques like cascade classifier, integral image, adaboost, Haar feature, principal component analysis and Fisher's linear discriminant.	The study found that the LBP method outperforms other recognition techniques in blur and brightness problems, while the PCA method excels in face recognition in noise challenges.	[45]
11	Hutagalung, Sandy ST, et al.	2023	The challenge is to determine the effectiveness of face detection using the Viola-Jons	The OpenCV and Viola-Jones algorithm systems are face detection systems used at three light intensity	The study reveals that the system's efficiency is highest at light intensities up to 50	[46]

			algorithm in low-intensity brightness environments based on OpenCv. .	levels, evaluating accuracy, precision, recall, and F-score using standard metrics.	Lux, with 99.2% accuracy, an f-score of 0.996, and recall of 0.993, even in brightly lit areas.	

3. *Convolutional Neural Networks (CNNs)*

Convolutional Neural Networks (CNNs) are a powerful type of deep learning architecture particularly adept at image recognition and classification tasks. They are superior at extracting subtle features and patterns from images, making them highly effective for a wide range of applications, such as facial recognition, object detection, medical image analysis, self-driving cars, and natural language processing [47,48]. CNNs have the primary benefit of learning from raw pixel input; no human feature engineering or preprocessing is needed. However, CNNs also possess certain limitations that constrain their effectiveness and their potential widespread application. The main limitation of CNNs is that they require a large amount of labeled data for efficient training, which can be costly and time-consuming to gather and annotate. Table (3) displays past research that utilized CNN for face recognition.

TABLE 3. Previous studies using CNN for face recognition

	Author's name	**Year**	**Research Problem**	**The proposed method and research steps**	**The results**	**References**
1	Yang, Yu-Xin, et al.	2018	In certain scenarios, the complex image background and unknown noise levels can pose challenges in extracting robust information from CNNs.	The researchers have introduced a stable face recognition technique called SR-CNN, which integrates CNN, SIFT, and RTF, and utilizes a GPU for optimal computational speed.	The experiments utilized a self-assembled face database and the Labelled Faces Wild (LFW) database. Results showed LFW had a 5-6 times acceleration ratio and a 10.97-13.24% increase in true positive rate, while self-assembly had a 12.65-15.31% increase.	[49]
2	Li, Jing, et al.	2018	Facial features, which contain diverse identifying information, often lead to poor face recognition performance, due to significant variation between the training and test sets.	A method called C2D-CNN, a color 2D Principal Component Analysis (2DPCA)-Convolutional Neural Network method has been proposed, enhances face recognition performance by combining original pixels' features with CNN image representation.	The experimental results showed that the proposed method outperformed the modern method in addressing the problem of low recognition accuracy due to differences between the training and experimental data sets.	[50]
3	Dian, Renwei, et al.	2020	The combination of Hyperspectral Imagery (HSI) and Multispectral Imagery (MSI) creates a high-resolution HSI image with a low frying ratio.	CNN-Fus is a method for combining High-Score Image (HSI) and Multi-Score Image (MSI) datasets. It used sparse representation and convolutional neural network (CNN) demising to deny grayscale images.	Grayscale noise was reduced when the trained CNN network was used, outperforming advanced fusion techniques in tests to improve parameter estimation.	[51]
4	Silwal, Raj, et al.	2020	Face identification in unrestricted settings is challenging due to illumination, stances, noise, and occlusion, making it difficult to identify specific people.	The study utilized a convolutional neural network (CNN) and multi-block local binary pattern (MB-LBP) units to extract high-level discriminative features and handmade features, and combined them using a SoftMax classifier.	The improved algorithm significantly improved facial recognition processing speed and accuracy, achieving a 94.37% increase in accuracy and a reduction in processing time from 357 to 307 milliseconds.	[52]
5	Zhang, Yaobin, et al.	2020	Large web-based face recognition datasets are plagued by noise in identity classification, including label flips and outliers.	FaceGraph is a proposed method for cleaning label noise in face recognition datasets, using global-to-local discrimination and two consecutive graph convolutional networks.	The technology, using Arcface, improves facial recognition by cleaning a massive celebrity dataset, A Million Celebs, from 18.8 million images. It outperformed the latest methods, and also achieved 95.62% of the temporary protection rate.	[53]

6	Mishra, N. K., et al .	2021	Recognizing faces in surveillance data is a challenge due to the low resolution of the combined image. Effective recognition of high- and low-resolution images also represents a challenge.	They proposed a deep learning-based architecture called mpdCNN to address the problem of face recognition with high accuracy and robustness in low- and high-resolution images.	The mpdCNN architecture achieved 88.6% accuracy on the SCface dataset and a 99% accuracy rate on face recognition datasets, outperforming other recent techniques.	[54]
7	Sun, Hezhi, et al.	2021	Due to various types of noise, hyperspectral images (HSIs) are often corrupted during the imaging process.	A plug-and-play CNN-based denoising model for hyperspectral images, combining low-rank representation and pre-trained CNN prior, is user-friendly and doesn't require retraining.	The proposed model outperforms other methods in denoising Gaussian and Poisson noise in various quantitative evaluation metrics, demonstrating superior performance.	[55]
8	Quan, Yuhui, et al.	2021	Evaluation of the capabilities of real-valued CNNs for image denoising despite the widespread use of complex-valued transforms in image processing	A CNN is developed to reduce image noise, utilizing complex-valued operations, noise resilience, nonlinear activation, and compact convolution provided by 1D complex-valued filters.	Experimental results show complex-valued denoising CNN outperforms advanced real-valued CNNs and is more resilient to noise model discrepancies, promising for picture denoising and image recovery tasks.	[56]
9	Xie, Shaodong, et al.	2023	CNN can sometimes struggle to provide accurate information due to complex image backgrounds and unknown noise levels.	The study proposes a multi-level information fusion convolutional neural network (MLIFCNN) for image demonizing, consisting of four blocks: a reconstruction block, a coarse-grained information refinement block, a fine-grained information extraction block, and a multi-level information interaction block.	Experimental results showed that this method outperformed many other excellent methods in quantitative and qualitative aspects. .	[57]
10	Jabbooree, Abbas Issa, et al.	2023	Facial expression recognition (FER) techniques often suffer from low accuracy or unpredictable results due to factors such as facial occlusion or lighting variations.	Fusion-CNN is a method that works by extracting hybrid features from an undirected skeleton graph with a one-dimensional ellipse trained to improve accuracy and combining them with a CNN for classification.	The results showed that Fusion-CNN outperformed other algorithms, achieving recognition accuracy of 98.22%, 93.07%, 90.30%, and 90.13%, respectively, for the CK+, JAFFE, KDEF, and Oulu-CASIA datasets.	[58]
11	Kumar, C. Ranjeeth, et al.	2023	Facial recognition systems' accuracy can be influenced by factors like image quality, background, and race definitions, posing potential problems.	The study utilized a CNN-based method for face detection, utilizing the KNN algorithm for data collection and training, and a Siamese network for image classification.	The study found 99% prediction accuracy when using a prediction-based approach on 25 training individuals, and 98% accuracy when using a KNN-based model on 25 individuals.	[59]
12	Xu, Ruizhuo, et al.	2024	Consumer depth sensors used for 3D face recognition often produce noisy and coarse data, making them impractical for direct use.	DMDNet enhances face depth image quality in low-quality 3D FR using DIIF, while LDNFNet integrates unique features between depth and ordinary images.	The proposed methods demonstrated effectiveness and robustness in experiments on four low-quality datasets, with state-of-the-art results on the Lock 3D Face dataset when combined with DMDNet and LDNFNet.	[60]

Generally, Generally, the number of research studies and articles published using these techniques in recent years can be observed, as shown in Figure 6.

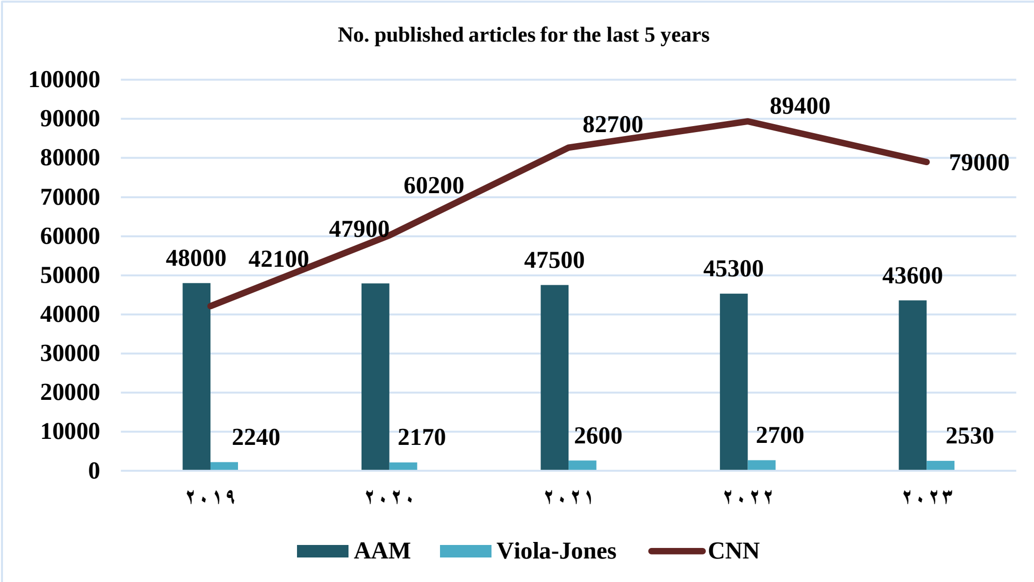


Figure 6. Number of articles that applied different techniques in a face recognition system and that were monitored from a Google Scholar.

In the Figure 6, it shows the number of research and articles published between 2019 and 2023 in international scientific journals that used AAM, Voila-Jones, and CNN technologies in the face recognition system mainly. Where the CNN based face recognition reached the highest percentage of published research compared to the research published for the other methods for the years specified in the figure.

The most important challenges faced by these methods, especially when the images are exposed to conditions that may cause distortion of the data in the images. One of these conditions is high noise, which causes severe damage to the contents of face images and thus blurring of images. Another challenge is changes in lighting, which leads to poor contrast and accuracy of images. Such matters lead to difficulty in extracting the information necessary to recognize faces, which exceeds the results of the false positive.

IV. CONCLUSION

Facial recognition technology is an advanced technology with significant importance in various fields, providing security, identity verification, video analytics, and human-computer interaction benefits. However, facial damage can impede recognition due to challenges such as deformation, image degradation, low accuracy, and poor lighting, making it difficult to recognize key facial features and visible changes on the face, hindering the system from matching the face with its stored image. The main techniques that were discussed in this paper are Active Appearance Models (AAMs), the Viola-Jones algorithm, and Convolutional Neural Networks (CNNs). AAMs are statistical models used to detect and track facial features, and effectively deal with different types of noise such as makeup and low-quality images. The Viola-Jones algorithm, a popular object detection framework, uses Haar-like features and a cascading classifier to efficiently detect faces in images. CNNs, powerful deep learning architectures, are effective in handling noise and complex backgrounds, achieving high accuracy rates. The review emphasizes the importance of combining different techniques to enhance accuracy and robustness in noisy environments. By addressing these challenges, face recognition systems can be improved, leading to broader and more beneficial applications.

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