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The current situation and potential development of face recognition

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Abstract. Face recognition has received more attention in the recent past. It refers to using biometric technology to identify individuals from a captured image by comparing it to the images in the database. There are three face recognition techniques: 2D, 2D-3D and 3D. Face recognition occurs in three processes. Firstly, face recognition begins with face detection, where an image is identified as having a face. That is followed by face extraction, which involves identifying the various faces within an image. The final stage is face classification which entails face verification or face identification. Depending on the type of system, face recognition can either occur in verification or identification mode. Additionally, face recognition has various applications in the current global environment. Face recognition can be used in security systems, hospitals, schools, and retail industries. It allows easier verification and identification of individuals. However, despite the development of the technology, there are still some challenges, such as plastic surgery, illumination, aging, occlusion and pose variation.

Keywords: Face Recognition, Technique, Face Identification, Occultation, Illumination.

1. Introduction

Face recognition is a biometric technology that allows individuals identification using their face structure and features. Face recognition technology is similar to human vision recognition, which allows one to differentiate a person from another using their physical and structural features. Humans use their eyes to recognize visual patterns, which the brain recognizes as meaningful concepts. For computers, when it is a video or picture, it is recognized in terms of pixels [1]. The computer should thus determine what concept a part of the data represents. Therefore, face recognition technology should determine the face's owner from the available data. When speaking of face recognition, it entails all the related technologies which are used to build the system. These are face positioning, face detection, image processing, and identity recognition technologies [1]. Creating biometric technologies such as face recognition has become vital in the upcoming smart cities. Consequently, engineers and scientists have employed accurate and robust algorithms to ensure that the new security systems achieve their goals while protecting personal data and preventing breaches. Initially, a common type of recognition was the password. However, with the advancement of technology, better security systems have been developed incorporating biometrics. Biometric technology allows individuals to recognize their physical and behavioral characteristics [2]. In addition, they are also

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advantageous since a person only needs to present themselves in front of the sensor instead of remembering long and complicated passwords.

The face is a vital part of the human body with the various features and expressions that separate one's face from another. As such, a technology that provides security using facial recognition has become valuable worldwide due to its increased ease of use and reliability. Face recognition has many applications in business organizations, residential buildings, airports, railway terminus, and security organizations. The face recognition technology works by recognizing a human face and comparing it to the faces which have been inputted into the database. The face has between 80 to 90 nodal points, which face recognition technology uses to identify individuals. From the face nodal points, a face recognition system measures unique aspects such as the length of the jawline, the distance between the eyes, the depth of the eyes, and the shape of the cheekbones [3]. Face recognition is in the field of biometrics. Biometrics are automated mechanisms of identifying a living person's identity using physiological characteristics such as facial features, fingernails, or behavioral characteristics, such as handwriting [4]. Because biometric systems identify individuals using their biological characteristics, they are challenging to forge. In addition, the physiological biometric identities are more stable over time compared to the behavioral. The face recognition system is among the biometric recognition technologies with the least intrusiveness and greater accuracy.

This paper summaries face recognition, including its development, the technique, and the current state of face recognition technology. The paper will also provide the analysis for applications of face technology, its advantages, and its disadvantages. Consequently, the paper will describe the future of face recognition. Finally, the work will highlight promising research directions in the line of face recognition.

2. Face Recognition meaning and techniques

Face Recognition forms part of computer vision. It is a biometric technology that identifies individuals based on their facial features. Face technology captures an individual's face and compares it with the existing data of faces in the system to identify the person. A person can quickly identify others through their eyes. However, human eyes are limited because of the limited concentration span. This makes it necessary to use computers for face recognition. The face recognition process entails recognizing an individual's face, followed by verification from either a video or a picture [4]. Even though face recognition has been researched extensively, various challenges still prevent it from functioning effectively. These include pose variation, misalignment, expression variation, and illumination variation. Face recognition incorporates all the related technologies. These include face position, detection, image processing, and identity recognition. Face detection is the algorithm used to combine all faces' components into a single image. It entails scanning the captured image to determine if it represents an actual face [1].

There are currently three types of face recognition,2D face recognition,2D-3D face recognition, and 3D face recognition. 2D face recognition follows four steps. Firstly, the system detects the face; this is followed by face alignment; after this step is feature extraction, and finally, the features extracted from the face are matched with the images from the existing database to recognize the face's owner. Consequently, the matric for 2D face recognition is computed on the foundation of pixel values at the different corners of the face illuminated under various conditions. Face matching is done by matching the face imputed with those available in the database. However,2D face recognition has various limitations which have necessitated improvement. The performance and system recognition rate of 2D face recognition depends on the conditions under which the image was captured, like facial expressions, lighting conditions, partial occlusion, image quality, and head orientation [5]. The other technique is the 2D-3D face recognition which combines aspects of 2D and 3D. Andrea Abate proposed the technique for collective 2D visuals used with 3D model face recognition using different aspects such as recognition rate, input size, and the number of tasks addressed. The 2D face recognition was improved by adding different features and aspects such as stereovision techniques and

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principal component analysis. The figure below represents the face identification process of the 2D-3D face recognition technique.

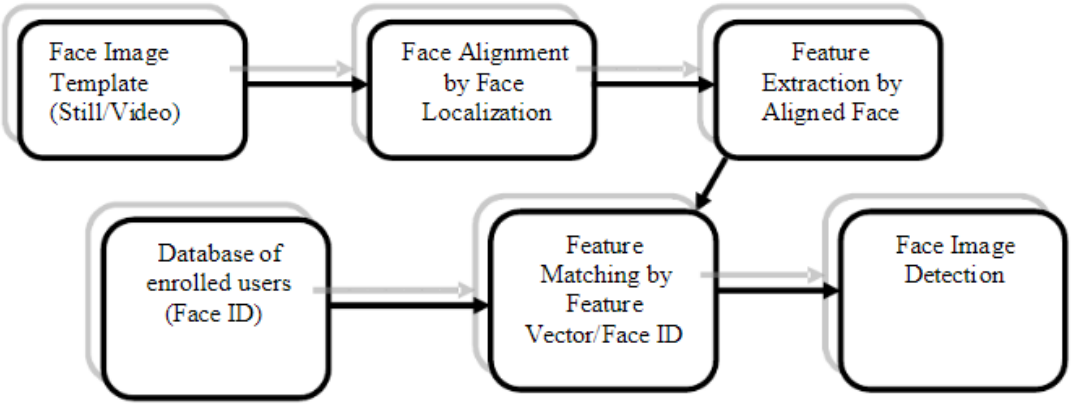

Figure 1. 2D-3D Face Recognition Technique identification process [5].

The final and most current face recognition technique is 3D recognition. Faces from real images have different forms and textures, which loop in three dimensional.3D face recognition technique solves various problems in the other techniques by recognizing the face image precisely and minimizing the issues of occlusions, pose variations, and different conditions of illumination [5]. The motivation behind creating and using the 3D face recognition technique is to overcome the challenges the 2D technique has. The 3D face images were identified using various augmentation techniques and tested using various databases. Consequently, the 3D technique can be improved by using a high-quality sensor camera to capture better images. Thus, of all the face recognition techniques,3D currently performs the best, having solved the problem of the 2D technique.

3. History of face recognition

Face recognition's long history and artificial intelligence development bring hope for a greater future for the technology. The first reported attempt at comparing a part of a photograph to identify an individual was in 1871 in a British court. Face recognition has been revolutionized by artificial intelligence, allowing individuals to be recognized from videos and photographs. There have been significant historical developments that have shaped and contributed to the advancement of face recognition. The figure below shows the important stages in the history of facial recognition.

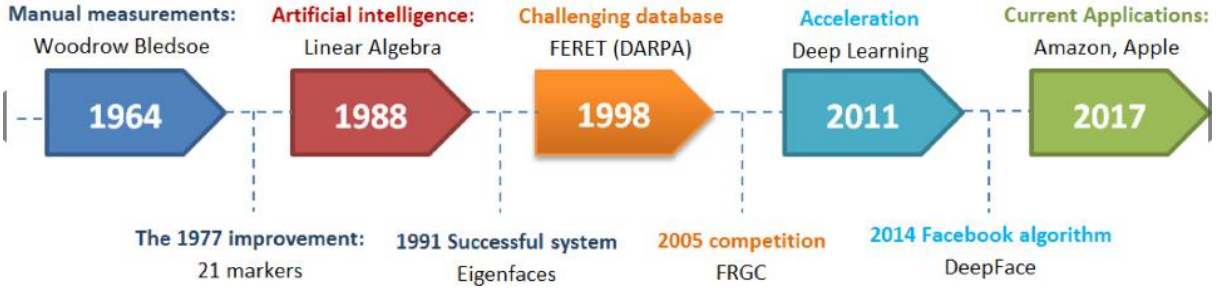

Figure 2. Significant historical developments in Face Recognition [6].

In 1964, Bledsoe et al. studied computer programming to develop facial recognition. The study created possibilities for the creation and application of the technology. The researchers imagined a semi-automatic face recognition method in which the operators were asked to key in twenty different facial computer measures like the size of the mouth or eyes [6]. This system was further improved in 1977 by adding21 markers, such as hair color and lip width [6]. Face recognition experienced greater advancements in 1988 with the introduction of artificial intelligence [6]. The use of AI showed various

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weaknesses in the system. Consequently, algebra was applied to interpret images differently, thereby manipulating and simplifying them to independent human markers. The actions of DARPA in 1998further encourage research in the field of face recognition technology. DARPA came up with the face recognition technology program that provided a broad challenging database of 850 people and 2500 images that researchers could use to research further the subject [6]. Consequently, advances and development of face recognition were encouraged in 2005 when the face recognition grand challenge was launched. Various engineers and scientists competing in the challenge developed better face recognition technology. The advances continued and were accelerated by the incorporation f deep learning in 2011. Deep learning allows machines to learn using artificial intelligence. The computer can therefore choose the points to be compared, improving this learning as it compares more images. Facebook's use of deep face in 2014 has further revolutionized what face recognition can achieve. The algorithm allows the network to determine the performance of the eye to over 97% and can also be used to imitate it [6]. Currently, face recognition is used in various industries, government, legal and commercial enterprises.

4. Steps in face recognition

The face recognition process is divided into three steps, face detection, extraction of features, and classification. The figure below shows the steps in face recognition

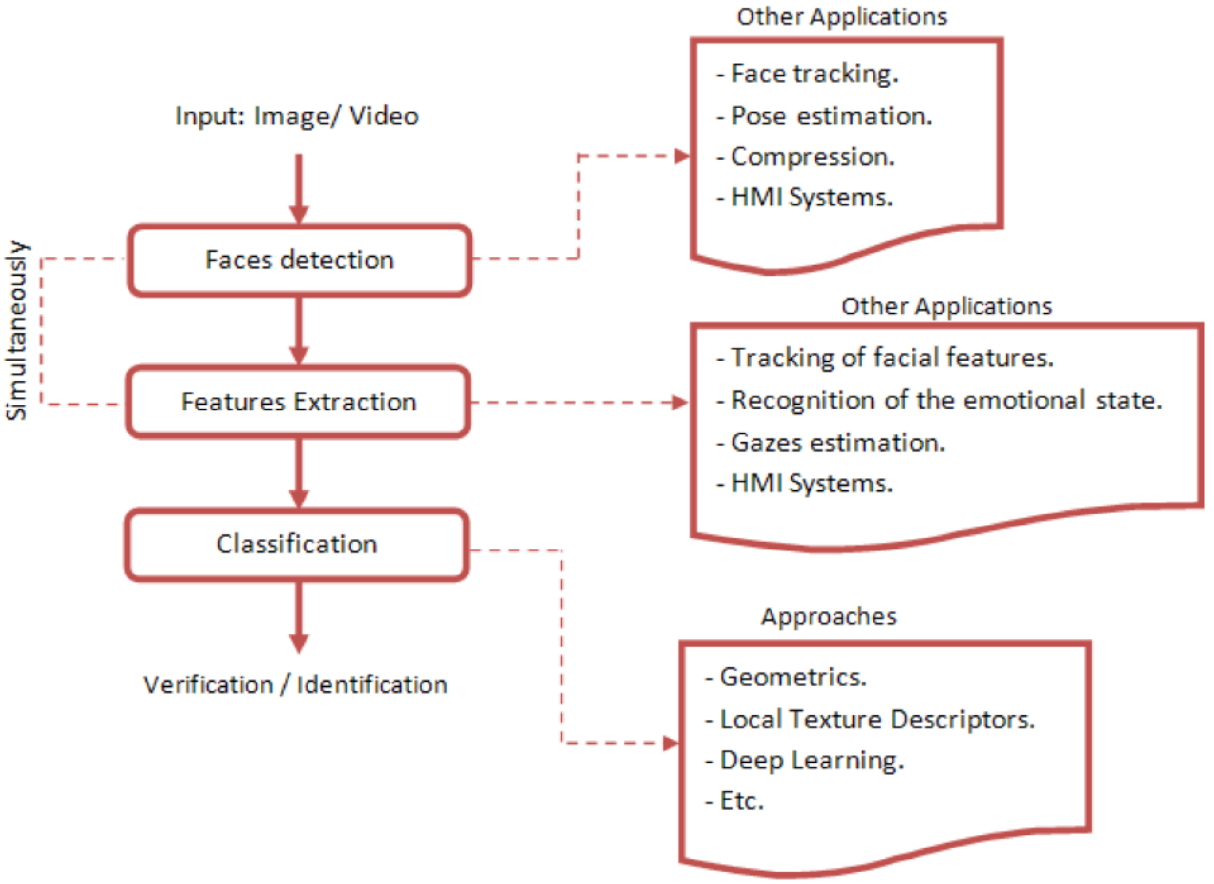

Figure 3. Steps of face recognition. Source [6].

Any biometric system's effectiveness, especially face recognition, largely depends on the means of locating a face on an image [7]. Face detection is, therefore, the first stage in face recognition. It is used to decide whether an image contains a face or not [6]. If an image contains a face, the function of face detection is to determine the location of one or several of the faces within the image. One of the

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algorithms that Can be used for face detection is the viola jones algorithm. The algorithm effectively detects various components of the face, such as the nose, eyes, lips, eyebrows, mouth, etc. [7]. The next step in face recognition is face extraction. That is the extraction from the detected face, a signature vector deemed enough to represent a face [6]. Here, a face's individuality and the distinction between two different faces are made. This process can similarly be accomplished during the face detection phase. The final step of face recognition is classification. This step involves verifying the face's details and identifying the person to who the face belongs from the database. Verification is matching the face in an image with another in a database to give access to a given room, premise, or material. On the other hand, identification entails comparing the face image to many faces in a database to identify who it belongs. The steps can vary depending on the face recognition technology being used. They can either be separated or have two steps carried out at once. Mostly, this occurs at the face detection and extraction stage, which can be done at the same time.

A face recognition system operates in either a verification or identification mode, depending on the use of the system. When operating in the verification mode, the face recognition system identifies whether the image of the face is similar to that of the captured face in the database, thereby allowing entry. The system performs a one-on-one comparison of whether the said identity is true or false. Therefore, the verification mode is used to confirm the identification of the individual to avoid a case of different people using the same identity. The effectiveness of the verification mode is determined by the estimated mean accuracy or the receiver operating characteristic. The ACC determines the percentage of the correct classifications [6].

On the other hand, ROC analysis determines the true and false accept rates [6]. Consequently, when the face recognition system is in the identification mode, it identifies who an individual is by comparing the captured face image with the face images in the database. Thus, the system compares a single face against all faces to determine the individual without the identity being provided beforehand. Identification is important for harmful face recognition applications. It is especially used to prevent a single individual from using multiple identities, mostly to commit crimes or harm people.

5. Application of face recognition

Face recognition has multiple applications in various areas. In smart campuses, face recognition can build a safer educational environment [8]. Previously, the management of campus entry and exit management relied on physical gate registration. New students and employees who had forgotten their registration forms would be sent back or prevented from entering an institution because of their lack of identification. In addition, with the larger number of people entering campuses daily, manual registration is slow and tiresome and can lead to traceability issues impacting the educational environment. In addition, during examinations, invigilators have to compare the identities of the individuals with those on their student cards. This process is stressful and requires a lot of staffing. It is also time-consuming and not as accurate. Therefore, with the implementation of face recognition, it is easier to identify people at the gate hence easing movement; also, invigilators can confirm the students' identities before sitting for exams, promoting honesty in academics [8]. Also, campuses have expanded, meaning more people to manage and greater insecurity. Due to many crimes and uncertainties, it is challenging for the management and security officers in the school to manage it. Although cameras capture many security footages in school, manual identification is challenging. If face recognition is used, it is easy to identify people on campus and identify those who commit crimes. Furthermore, face recognition on campuses improves the attendance of students and personnel. Logging in using face recognition instead of manual signing makes it difficult to fake attendance. Finally, face recognition on campuses can prevent unauthorized people from entering a specific place. That includes harmful laboratories, computer labs, and even administration offices.

Furthermore, face recognition also has uses in the law enforcement industry. Face recognition can be used to prevent crimes. That includes where face recognition is used to preemptively identify and manage a person who had previously been identified as a perpetrator of a crime [9]. It can also be used for repressive purposes to identify an individual who has committed a crime [9]. Also, face

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recognition is used in traffic surveillance. For instance, to scan individuals crossing streets with face recognition surveillance or target specific individuals. In many cases, face recognition in policing is under identification mode. It is when cameras have taken the face image of an individual doing a crime, and the police have to compare it to various images in their databases o identify the offender. Face recognition makes it easier and faster for the police to solve crimes. Instead of relying on manual identification and asking around for the person whose face is caught in cameras, the police can look for the person in their databases and issue an arrest warrant before they have the time to escape or commit other crimes. Also, face recognition is used in policing to identify victims. In some cases, bodies of unidentified people may lie in mortuaries and hospital beds. Before, it was difficult to identify such people, especially when they did not carry their identification documents or were without their families coming forward. However, with face recognition, law enforcement can run their faces through the police database to identify the individual. Therefore, face recognition makes policing more efficient.

Face recognition also has multiple uses in various industries. For instance, in the transport sector, face recognition is used in ride apps where the driver can confirm their clients, and the customers, too, can confirm their driver. In addition, it also has an application in border and airport security. Face recognition ensures more stringent border measures to prevent criminals from attempting to cross the border or arrest them on site. Furthermore, face recognition can be applied in retail [6]. Japan has already adopted face recognition in their retail stores, whereby they use it to determine the age and gender of customers to suggest drinks. Face recognition is also used in the healthcare industry. The technology protects private health information and prevents unauthorized personnel from logging into devices with health information. Also, face recognition is important in assisted living. Such an environment requires constant monitoring of the movement of staff and people living there. If an older person with a disease such as dementia gets lost and cannot remember their names or contact their families, face recognition can be used to trace their families or homes.

6. Face recognition challenges

Like any other kind of technology, face recognition also has its set of challenges preventing it from operating effectively. A major challenge of face recognition is occlusion. The face can be captured in a pose where some features may not be seen properly. An example is when the person is wearing glasses, a hat, or a mask, or their faces are occluded by a shadow [6].In policy, victims are sometimes asked to identify suspects with partly occluded faces based on recorded images. This can be challenging as the occluded faces prevent the victims from identifying important facial features which differentiate one person from another. For face recognition technology, occlusion distorts the image making it difficult to identify the important facial characteristics. In addition, it changes the distance between two images of the same item. These variations result in low recognition results. In addition, alignment errors take place when a face is occluded, resulting in a significant reduction in recognition rates.

In addition, heterogeneous face recognition is also a challenge for face recognition. That is when the face image is collected at a different time or in a different environment and has to be compared with one in a varying environment. Consequently, two facial recognitions from two different imaging methods create a challenge. For instance, if one is collected at night with infrared technology while the files collected by the police are a visible image [6].In this case, identifying or validating such faces is challenging, especially in criminal proceedings.

Illumination is also another issue affecting face recognition. Illumination refers to lighting differences where face images can appear differently because of the different environments they were captured in. Illumination can result in greater differences between individuals, thereby causing face recognition to fail by wrongly classifying the images when comparing the face images [10]. Humans can easily recognize images despite the changes in lighting. However, for biometric systems, this task is still challenging. Existing research where different images were shown under different filters determined that the changes in the lighting conditions resulted in greater changes in image differences compared to face differences. Because of this challenge, engineers have been called forward to

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develop algorithms that would prevent the differences in images from arising due to changes in lighting. One of the techniques brought forward is image processing techniques that normalize the different images captured under different lighting. Also, the 3D face model can be used to solve the illumination issue. The figure below shows the changes in illumination when images are captured in different environments.

Figure 5. Illumination changes [10].

Another major challenge of face recognition is pose variation. A large discrepancy between two face images can prevent proper identification [11]. Face recognition often fails when there is a variation in poses between the input image and the one in the database. In situations such as passport photos, the face is always facing the front; this also occurs when confirming identity as people are asked to face the front. However, the passport case is a controlled environment; most places where face recognition is used are not controlled. Pose variation identifies images or people under different poses [10]. It is a simple task for humans as they can look at other features to determine who the person is. However, it is challenging for biometric systems, especially for surveillance applications. Without the proper pose, making an image from a surveillance video or photo is difficult. In the current world, security threats are increasing, especially from terrorists. Face images of criminals are terrorists are usually collected in a certain pose, mostly frontal, and these images are stored in a database. Therefore, when surveillance cameras catch and compare them with the images, it is easy to identify and stop them. However, that is not the case in real life since the camera may catch them in different poses, making it challenging to identify them by comparing them with the images in the database.

Plastic surgery also impacts the ability of face recognition to identify individuals. The process of plastic surgery changes a person's facial structure, making them, in some cases, appear as completely different people. Plastic surgery changes the texture of the skin between the face images of a single individual [10]. Certain procedures change the structure of a face completely, making it entirely unrecognizable. In addition, aging also changes the face structure, making it challenging for face recognition. The problem with aging is that it can alter face variation. The variation resulting from aging can lead to a change in the overall face structure of an individual. Furthermore, the unique facial characteristics can also change as a person ages making it difficult to identify them using face recognition.

7. Ethical issues of face recognition

Despite the many applications and advantages of face recognition, various ethical issues have arisen regarding its implementation and use. For instance, in policing, there is an issue regarding the face recognition algorithm used to identify people likely to commit crimes. Face recognition is designed in a manner in which they scrutinize certain individuals over others in security. That can lead to too much scrutiny of innocent people and promote racial biases. Furthermore, algorithms are sometimes biased regardless of the technology [12]. Unlike traditional means for surveillance, the face recognition algorithm sorts people into different characteristics, which can result in presumptive business. In addition, there is also the issue of privacy of data in the use of face recognition. This technology is deemed as one of the silent technologies. That means that its implementation is hidden, and operation is passive [12]. The hidden nature of face recognition technology means it can be

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embedded into existing technology, thereby capturing a person's data without their consent. Generally, it is unclear how the police use face recognition, the kind of data they collect, and what they do with it. The sheer amount of information one can accesses using a person's face recognition data is worrying. The security of the data is also in question as to whether someone can hack into databases.

Therefore, the rapid developments and applications of face recognition have led to the ethical choice of maintaining the privacy of individuals while at the same time securing society. Therefore, it is vital to balance the rights and responsibilities of face recognition. In the United States, for instance, law enforcement heavily relies on face recognition, collecting data from over 17 million of its citizens [13]. Despite the rollout of face recognition broadening by the day, the average citizen lacks control and ways of holding the government accountable. In the era of technology and information sharing, the nature of exchanges occurring among individuals and even on social media are the sharing of personal information [14]. It is, therefore, easy for privacy violations to occur during the acquisition, storage, and use of personal information from face recognition systems. Users are likely to fear adopting and using such technologies if they fear privacy violations and how such data will be used. A good way to encourage the acceptance of face recognition is through educating the users and making them part of the implementation. When the users know what the technology will be doing, the benefits, and the upholding of their privacy, they will be more accepting.

8. Conclusion

This paper provides information regarding face technology, its challenges, applications, and ethical issues. This work's outcome shows the broad adaption of face recognition in various industries. With the advancements in technology, especially artificial intelligence, face recognition has likewise advanced to become more accurate and effective in validating and identifying individuals from face images. Face recognition technology has moved from human-controlled computer vision, and currently, deep learning is being incorporated to improve the efficiency of face recognition. Furthermore, there is numerous research n face recognition with large databases available for improving and creating better face recognition technology. The recent improvements in 3D technology sensors provide a new direction for face recognition. 3D sensors can solve some of the challenges experienced by the current face recognition systems. 3D databases considerably improve the accuracy of face recognition using data collected in adverse conditions.

This work is useful as it presents the current face recognition technology and its application. In addition, this paper identifies the challenges of existing face recognition, paving the way for future research into solutions for these challenges. Some challenges of face recognition, such as illumination and occlusion, are less researched. That is due to the lack of enough datasets that show these conditions as they occur in real life. Future research should therefore pay more attention to the pre-processing approaches, deep neural networks, and face datasets.

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