ISSN 2278-3091
Volume 9, No.1.2, 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse1691.22020.pdf
https://doi.org/10.30534/ijatcse/2020/1691.22020

Face Recognition State-of-the-art, Enablers, Challenges and Solutions: A Review

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ABSTRACT

In the past decade, face recognition has gained an important role among the most frequently used image processing applications and the availability of viable technologies in this field has also contributed significantly to this. Face recognition has become an enabler in healthcare, surveillance, photo cataloging, attendance, and much more, which will be discussed in this review paper. Despite rapid progress in face-recognition technology, various challenges such as variations, occlusion, facial expressions, aging and many more that affect the performance of the system still need to be addressed. This paper presents a review on the state-of-the-art, enablers, challenges and solutions for face recognition. Face recognition can be categorized into three groups; namely global approach, local feature approach, and hybrid approach. The global approach uses the whole face as input for the face recognition system. The local approach uses measurements between important landmarks of a face and certain face region selection for training. The hybrid approach blends global and local approaches in which the hybrid approach uses the best global and local approach methods. The challenges of face recognition are; (i) automated face detection where difficulties lies on detecting a person's face, (ii) pose variations cause by rotation of people's head, (iii) face occlusion, (iv) facial expression changes, (v) ageing of the face, (vi) varying illumination conditions, (vii) low image resolution, (viii) identity look-alike or twin, and (ix) other technical difficulties. Finally, the solutions to each of the highlighted challenges were described. The survey found that all the images considered for training and testing were made up of RGB images. With the rapid growth of computer technology in terms of computing speed and the increasingly sophisticated functions of smartphones, multispectral or even hyperspectral imagery could be considered for face-recognition research.

Key words: face recognition, enablers, challenges, solutions.

1. INTRODUCTION

Computer technology has been a big part of our lives today. There are currently a number of ways to identify and verify methods. A biometric system is a pattern recognition system that identifies a person based on a feature vector derived from a specific biological characteristic or behavioral features that a person has. Among the popular biometric technologies, Face features scored the highest degree of consistency in a machine-readable travel document system based on multiple assessment factors and are the most effective method of human surveillance [1]. Face detection and face recognition have a promising potential for many uses, including security monitoring and human computer interaction. Facial recognition technology has reached an incredibly high standard in the last few years. Face recognition can be applied to both still images and videos. Face-recognition approaches for still images can be divided into three groups: global approach, local feature approach and hybrid approach [2]. The hybrid approach combines global and local face recognition approaches in an either serial or parallel to overcome the shortcomings of individual methods [3].

1.1 Face Recognition as an Enablers

In an article published in [4], Face recognition is steadily gaining popularity in healthcare partly due to improvements in artificial intelligence that allowed the technology to be used in various ways. Face recognition technology has many potential applications in healthcare such as (i) securing hospital premises, (ii) emotion detection and sentiment analysis, (iii) patient fraud monitoring, and (iv) analyzing traffic patterns in hospitals. Haspari et al. [5] have proposed an approach to address the visually impaired problem by developing a portable smart cane by integrating the face recognition feature on the cane using Haar-Like features and Eigenfaces.Developmental prosopagnosia (DP) is a neuro developmental disorder characterized by a significant deficiency in facial identity recognition, which is assumed to result from the failure to develop the required visuo-cognitive mechanisms [6].Bate et al. [7] suggest that the field of face recognition research to continue developing new and accurate face perception tests, and multiple tests of familiar and unfamiliar face memory that aim to unpick the challenging face learning process. Real-time human face detection and recognition is being carried out by analyzing video sequences captured by closed-circuit television (CCTV). Nowadays, airport security is very important for airline staff office and passengers and airport security systems that are based on face recognition technology have been implemented at many airports around the world [8] to detect a wanted suspect. In China, face recognition systems are used in factories, business centres with biometric access control and stadiums [9]. Li et al.[10] presented a cloud-based, omnipresent monitoring system through face recognition which consists of a face detection and recognition monitoring client module and a data visualization cloud storage module. Nowadays, it is very easy to take a photo by using smartphones. This then produces a significant number of electronic images. Managing a large number of digital images is very important for photography enthusiasts as well as for educational institutions. Huang and Huang [11] has introduced a Photo Automatic Face Recognition Classification System that is easy for users to locate their images. The program initially performs self-deep learning to obtain the face's feature value from a provided photograph of an individual. A And instead, after reading the sample photo, the program will find all of the photos in the specified folder and copy the photos found including the sample face to the corresponding person name folder. A conventional approach to record student attendance is performed by asking every student to sign on an attendance list that passes through all students during the beginning of lectures. With the growing number of Android smartphone, Sunaryono et al. [12], Khan et al. [13], Elias et al. [14], and Shen et al. [15] have developed a mobile-based attendance system using face recognition based approach. Face recognition can also be applied for computer security purpose by using an available face databases. The face image database can be used for forensic purposes, such as checking a face picture for the identification general identification card to check for missing people, refugees to government agencies, banking, online purchases, newborn identification, employee or passport identification [16].Face recognition can be used to spot individuals that registered more than once under different names or identifying look-alike's faces. Rustam and Faradina [17] have developed a face recognition system for identifying look-alike faces using Fuzzy Kernel C-Means which achieves a 74% accuracy rate tested on Look-Alike Face database (LAF).Face Recognition may also be used to provide details about each person's gender [18]. One of the methods used to show advertisements that are applicable to the person watching the billboard is the gender classification. In addition, the gender classification is useful for restricting the area to only one subject, e.g. when in a dormitory or train. According to [19], an adequate amount of work has also been done to detect facial emotions. Chokkadi et al. [20] presented a survey of the Deep Learning Face Recognition System, and a number of studies have already established time-invariant, multi-expression, illumination-variation, and image-to-image weight-variation. The author in [21] presented a survey on linear and nonlinear PCA-based face recognition techniques where it was reported that Kernel-PCA (KPCA) and 2D-KPCA performed well in uncontrolled situations of varying illumination and slight change in expression and pose.Soltanpour et al. [22] presented a review of local feature methods for 3D face recognition and indicates the potential research may involve a comparative analysis of the different local 3D face recognition function extractors. Sharif et al. [23] also presented a face-recognition survey where it was suggested that there is still a need for a face-recognition system that can deliver accurate results in an unrestricted environment. Kas et al. [24] provided a review on Local Binary Pattern (LBP) Face Recognition Descriptors, illustrating the shortcomings and strengths of each LBP texture descriptor for each test dataset, promoting a deeper understanding of current texture descriptors and providing researchers with guidance on which type of classification to be used according to the databases. Arsalane and Aicha [25] presented a survey on approach-based geometric information for detection of 3D face landmarks, and it was stated that there is still some flaw with regard to face occlusions and handling some lost data in the 3D face, and this will be a huge advantage to create a more robust geometric information-based algorithms to address these challenges.

From the reviewed articles, it can be seen that the advantage of for face recognition is that it is known as a passive and non-intrusive method for verifying and recognizing individuals. Face recognition interests are also motivated by the availability and low cost of video equipment, the ever-increasing number of video cameras installed in the workplace and the non-invasive nature of facial recognition systems [2].Face recognition is designed to identify people on the basis of their facial traits. But automated face recognition systems need to address specific issues that will be addressed in this paper.

2. FACE RECOGNITION: STATE-OF-THE-ART

Although extensive work has been carried out in this field for over 40 years, there are still unresolved work issues and the current algorithm performance is still far from that of human perception [2] and it was one of the fields of pattern recognition and computer vision that was most researched. The global approach is also known as the holistic approach. This method makes use of the entire face region as the raw input to the system. The Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), and Independent Component Analysis (ICA) are examples of global approach techniques. The local approach is also known as the feature-based approach where simple measurements of important facial landmarks and selection of face region of interest. Some examples of geometric approach techniques are the Scale Invariant Feature Transform (SIFT), Hidden Markov model (HMM), Elastic Bunch Graph, Neural network-based approach, and FaceIt®. Hybrid face recognition has gained much interest in recent years due to its similarity to the human’s capability to recognize a person [2].

2.1 Global Approach

Yangfeng Zheng [26] proposed a method called the Average-Half-Face (AHF) which divides a full face into two halves and then averages them together. Ke et al. [27] presented a group representation-based classification approach by integrating all the training samples of a test sample's nearest neighboring groups into the first group. Next a process for creating a virtual sample is performed on the first group. The virtual samples are joined together to form the second group. Finally, on those two sets, the suggested method performs SRC to obtain two residuals for the classes. Liu et al. [28] proposed method called transfer learning-based sparse representation and weighted fusion (TLSRWF) for automatic face recognition system. Allagwail et al. [29] presented a Local Binary Pattern-based two-dimensional discrete wavelet transform for face recognition using face-symmetry. Tuncer et al.[30] suggested to use Fuzzy-based Discrete Wavelet Transform (DWT) and Fuzzy with two novel Local Cross Pattern (LCP) graph descriptors for face recognition. Shi et al. [31] presented a collaborative-representation-based classification-algorithm (CRC) approach using statistical histogram measurement (H-CRC) in conjunction with a 3D morphable model (3DMM) for pose-invariant face classification. Chen et al. [32] proposed an algorithm for addressing the illumination invariant face recognition. Dual-tree complex wavelet transform was used to generate face images that are approximately invariant to illumination changes. Chen et al. [33] proposed a hierarchical clustering-based spectrum band selection method which mitigates the influence of noise and extracts features from each spectra band by using the Gabor filter and the histograms of oriented gradients algorithm Ling et al.[34] proposed a self-residual attention-based convolutionary neural network (SRANet) for discriminative face embedding feature, which aims to learn the long-range dependencies of face images by reducing the redundancy of information between channels and concentrating on the most informative components of space function maps. Vinay et al. [35] proposed a robust method for real-time face recognition. Li et al. [10] propose a cloud-based ubiquitous monitoring system via face recognition. The framework consists of a facial detection and recognition tracking application module, and a data analysis cloud storage module. Biswas and Sil [36] proposed a method for face recognition using contourlet transform (CNT) and curvelet transform (CLT) which improves the rate of face recognition under different challenges. Cheng et al. [37] proposed an effective illumination estimation model based on Lambertian reflectance to extract illumination invariants for face recognition under complex illumination conditions. Shekar et al.[38] investigated the efficiency of a rule-based method derived from edges for face representation and recognition when class numbers are fixed and established. Edge characteristics, including straightness and crookedness, are used for rules derivation. It was stated that the proposed system does not require comprehensive techniques for extracting and classifying features. Their experimental research on the standard CALTECH face databases reveals an recognition rate of approximately 89.1%.Table1 summarizes the global approach face recognition system.

Table 1: Summary of global approach reviews

Ref. no.	Method	Database	Performance
[10]	multi-scale Gabor and center-symmetric local binary pattern (CSLBP)	ORL, Yale-B, and Yale databases	ORL (100% rank-1), Yale-B (97.5% rank-1), Yale databases (93.3% rank-1)
[26]	AHF based on Eigenface and CNN	ORL database	99.3%
[27]	group representation-based classification method	ORL, Georgia-Tech, FERET, CM-PIE and Libor face databases	92.5% (ORL), 60.55% (Georgia-Tech), 77.37% (CM-PIE), 83.35% (Libor)
[28]	TLSRWF	ORL, FERET, LFW	95% (ORL), 95% (FERET), 83.33% (LFW)
[29]	2D Discrete Wavelet Transform with Single-Level and Gaussian Low-Pass Filter, The Local Binary Pattern, Gray Level Co-Occurrence Matrix, and the Gabor filter were used for feature extraction	ORL and Yale	100% for both databases
[30]	Local Cross Pattern (LCP)	AT&T, CIE, Face94, and FERET	AT&T (97.3%), CIE (100%), Face94 (100%), and FERET (96.3%)
[31]	H-CRC	ORL, Georgia Tech, FERET, FRGC, PIE and LFW	ORL (99.17%), Georgia Tech (79.88%), FERET (88.77%), FRGC (95.47%), PIE (93.82%) and LFW (52.53%)
[32]	LOG-DTCWT 1	Extended Yale Face Database B and the CMU-PIE face database	Extended Yale Face Database B (87.32%) and the CMU-PIE 100%)
[33]	KL-HC-HOG	CMU database and Ploy-U database	CMU (99.4%), Ploy-U (97.45%)
[34]	self-residual attention-based convolutional neural network (SRANet)	LFW, AgeDB, CFP	LFW (99.83%), AgeDB (98.47%), CFP (95.6%)
[35]	The Gaussian Filter, Local Binary Patterns	FACES94, FACES95, FACES96, Grimace	93.6%, 90.6%, 91.6%, and 96.6%
[36]	contourlet transform (CNT) and curvelet transform (CLT)	JAFFE, ORL and FERET	JAFFE (97.19%), ORL (98.79%), FERET (98.1%)
[37]	Lambertian reflectance model	A database combined from Yale B and extended Yale B	95.06%
[38]	the rule-based method derived from Canny Edge features	CALTECH face databases	Approximately 89.1%

2.2 Local feature Approach

Yu et al. [39] proposed a framework for local representation-based face recognition. An aligned down sampling local binary pattern features of the frontal face images are used for classification. The recognition is then carried out using an improved robust sparse coding algorithm. An et al. [40] introduced a face alignment framework, called Adaptive Pose Alignment (APA), which they used to improve performance in face recognition or face analysis tasks for data processing. It has been stated that the APA approach can not only reduce the intra-class variation but also remove the noise generated by the aligning procedure. They also suggest a method of standardization of features that combined with the APA approach to establish more discriminative representation of a face or image. Al-Waisy et al. [41] presented a multimodal local feature extraction method focused on combining the benefits of anisotropy and multidirectional transforms such as the Curvelet transform with Fractal dimension. It has been stated that the Curvelet transformation is a quick and efficient technique to depict the edges and curves of the facial structure. They also suggested a method called the Multimodal Deep Face Recognition (MDFR) system, which adds feature representations by training a deep belief network (DBN) in place of pixel intensity representations on top of the local feature representations. Surakhi et al. [42] proposed a meta-heuristic algorithm based face recognition system. Genetic algorithm and Chemical Reaction Optimization (CRO) Algorithm is used to search for the best point in the image which will be used as a pivot and their performances are compared. The generated vector of excludes features that are not necessary for the recognition or may reduce accuracy. Rajasekhar et al. [43] proposed a method which is iterative based image matching approach that uses affine transforms to identify the descriptors and classified according to Bayes theorem. Yale facial data set is used in the validation and the results are compared with SIFT (Scale In-variant Feature Transform) based face recognition approach. Table 2 summarizes the local feature approach face recognition system.

2.3 Hybrid Approach

Abbas et al. [44] present a recognition analysis that is based on defining a set of coherent parts from 3D face recognition system. Those coherent parts can be considered as latent factors in the face shape space. Non-negative matrix Factorisation technique was proposed to segment the 3D faces to coherent regions. Li and Xie[45] proposed a cascading BGP face recognition method based on heuristic information for the deficiency of binary gradient mode (BGP). The experiment was conducted on Yale and ORL face database. Li and Huang [46]presented a cross-pose face recognition method based on regression-iterative method and interactive-subspace method (RIM-ISM) to address the pose change problem in face recognition system. The desired function converges quickly through the regression replication, and forty-fivesets of significant feature locations such as nose, mouth, and eyes were derived from the desired face study. The pose-adjustment was achieved by settling the cross-pose face image pose deflection angle, while the cross-pose face image similarity was determined using the interactive subspace process. Elmahmudi and Ugail[47] presented a method that utilized both controlled and uncontrolled public facial datasets through deep learning. It was reported that for a given partial facial data, the feature extraction method was based on convolutional neural network-based architecture along with the pre-trained VGG-Face model. Two classifiers namely the cosine similarity and the linear support vector machines are used to test the recognition rates. The experiments were carried out on the controlled Brazilian FEI and the uncontrolled LFW dataset. Ratyal and Taj[48] proposed an approach to 3D face recognition called Pose Learning-based Coarse to Fine (PCF) algorithm based on a Deep-learning-based analysis of pose-invariant image. The following steps were taken with the PCF algorithm: (i) Pose-learning-approach using heuristic nose tips to approximate the location of face acquisition; (ii) A coarse to fine nose alignment approach based on L2-standard-minimization, and (iii) a transformation method to match the entire face picture using the information obtained from the alignment of the nose tips. The face recognition algorithm has been implemented in both verification and identification settings. The face recognition algorithm based on dCNNhas been applied d-MVAHF images, while the verification algorithm was used using d-MVAHF-SVM-based methodology. Chen and Haoyu [49] proposed an SVM-based face-recognition algorithm combined with a VGG network model that extracts facial features, which can also minimize feature measurements and eliminate irrelevant features in the computation. The VGG-16 model is obtained by training a training dataset which is used for extraction of the features. In addition, PCA is used for reduction of the dimensionality of features. Finally, face recognition is implemented with a linear kernel function via the SVM classifier. Lv and Zhao[50] suggested a 3D face recognition approach based on the study of local conformal parameterisation and iso-geodesic stripes. They used the local conformal parameterization to obtain a 2D representation of the face that removes the effect of head poses. They derive the facial characteristics from the 2D facial image based on the iso-geodesic lines, and use the Chain 2D Weighted Walkthroughs (C2DWW) to obtain facial match results. The system is stated to be resilient to different head positions, facial expressions, and occlusions of any sort. The main drawback of their system, however, is the susceptibility to nasal area occlusions. Table 3 summarizes the hybrid approach face recognition system.

Table 2: Summary of local feature approach reviews

Ref. No.	Method	Database	Performance
[39]	Robust sparse coding	faces in the wild data sets	95% recognition rate with a recall rate of 80%
[40]	Adaptive Pose Alignment	LFW and CPLFW datasets	99.8% (LFW) 92.92% (CPLFW)
[41]	multimodal deep face recognition (MDFR) framework	FERET, SDUMLA-HMT, LFW dataset,and CAS-PEAL-R1	FERET (100%), SDUMLA-HMT (98% approx.), LFW (98.83%), CAS-PEAL-R1 (100%),
[42]	Genetic algorithm and Chemical	XM2VTSDB multi-modal	91.4% for CRO, 93.7% for Genetic

	Reaction Optimization (CRO) Algorithm	face database project	Algorithm
[43]	iterative based image matching approach	Yale face dataset	90%

Table 3: Summary of hybrid approach reviews

Ref. No.	Method	Database	Performance
[44]	3D face recognition approach based on face Factorisation	FRGCv2 dataset	96.4%
[45]	cascading BGP face recognition method	Yale and ORL	approximately 86% (Yale) and 74.17% (ORL)
[46]	RIM-ISM	FERET MIT-CBCL	75% (45 degree face pose) and 80% (90 degree face pose) on FERET, 97.52% on MIT-CBCL database
[3]	VGG, deep learning	Brazilian FEI and LFW	For a ¾ portion of the face image, Brazilian FEI database is 100% SVM-Wo, 76% to 99% for SVM-Wo
[48]	Pose learning-based Coarse to Fine (PCF)	GavabDB, FRGC v2.0, Bosphorus, and UMB-DB	GavabDB (99.82%), FRGC v2.0 (99.95%), Bosphorus (100%), and UMB-DB (100%)
[49]	SVM combined with VGG network model	CelebA dataset and LFW dataset	CelebA (93%) and LFW (97.47%)
[50]	3D based local conformal parameterization and iso-geodesic stripes analysis	BosphorusDB database	90%

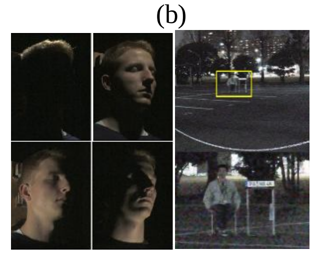
2.4 Depth and Analysis

From Table 1, Table 2, and Table 3, it can be seen that the global based face recognition approaches is the most popular, followed by the hybrid approach which gaining popularity in the recent years due to its edge in overcome the shortcomings of global and local approaches [39]. One of the reason on the low number of local approach papers is because local approach computational is much more complex than global. Also from all the papers reviewed, no benchmark test is available to compare facial recognition systems, which makes it difficult to compare the different results reported. Although some researchers use similar database for their experiment, the criteria of their training data selection such as the distance between the person and the camera was not properly stated and justified. In addition, some of the testing procedure was unclear. Furthermore, there are no comparisons of all the face recognition studies reported for the resources used in the reported system. It can also be seen that there’s a lack of investigation on the effect of colourspaces of images on face recognition. Since the computing speed of a computer or smartphone has improve so much compared to decades ago, it may be a good time to consider imaging data that has more than three bands (RGB) for face recognition such as multispectral or even hyperspectral imaging. An image processing called the exposure bracketing can also be considered.

3. CHALLENGES IN FACE RECOGNITION

The main challenge of the face recognition system is the ability to perform in situations where subjects are non-cooperative and the acquisition process is unconstrained. The causes of variability in the appearance of the face can be grouped into two categories [51], [52]; (i) Intrinsic factorsand (ii) Extrinsic factors. Intrinsic factors are solely related to the face's physical existence and are independent of the observer, whereas extrinsic factors change the face's appearance by the interaction of light with the face and the observer. Figure 1 shows some common challenges faced in face recognition. It is a challenging task to detect a face in a surveillance footage in a busy location with complex background as shown in Figure 1 (a) especially when there is often some motion made by the subjects. The face pose varies with the observer's viewing angle and rotation in heading position which often lead to substantial changes in face appearance or shape and generate intra□subject face's variations, thereby creating an issue for the recognition of the input image and making automatic face recognition across a challenging task [51], [53].Face occlusion is one of the important challenges of face recognition due to the presence of various occluding objects such as glasses, beard, or moustache on the face [51]. Some examples of face occlusion is shown in Figure 1 (b).Human emotions vary from time to time thus resulting in many different facial expressions as shown in Figure 1 (c). Also, make-up and hairstyle change facial expressions. These differences in facial expressions change the appearance of the face and it becomes difficult for a face recognition system to match the accurate face stored in the database [51].Ageing of the human face can affect the face recognition system process if the time gap between each image capture is significant. As shown in Figure 1 (d), the overall intensity of the light reflected from an object and shadows visible in an image as well as the shading pattern can differ.

(a) (b) (c)



(d) (e)

Figure 1: Example of challenges in face recognition. (a) Group photo [57], (b) Partial occlusion in face images [59], (c) Variations in expressions [60], (d) Variations in illumination [58], (e) A common low-resolution image sample of a security camera

The problem of face recognition due to dramatic changes in lighting is the most challenging for both humans and algorithms [51], [53]. In a facial recognition device, the low-resolution problem arises when the facial picture to be recognized is less than 16 pixels by 16 pixels. As the individual's face is further away from the camera, the area around the face would be smaller, thus containing limited pixel information as shown in Figure 1 (e). Different persons may have a similar appearance (commonly seen between twins or siblings). Thus, sometimes it is hard for a human to identify them and a face recognition system would face the same difficulties. The problem such as camera distortion, the background noise of an image can also affect the recognition performance.

4. PROPOSED SOLUTIONS FOR FACE RECOGNITION CHALLENGES

The following sub-sections will discuss the proposed solutions to the challenges discussed in section 4.

4.1 Solution for Automated face detection challenge

The most important aspect of face recognition is face detection since a face needs to be extracted from video or image before proceeding into the face recognition process. In [54], the researchers described three of the popular face detection algorithms, classified as: (i) Face detection by skin colour, (ii) Face detection by Haar classifier, (iii) Face detection by face characteristics. Reshmi and Grace [55] proposed a face recognition approach for surveillance system based on the open-source Processing 2.2.1 for face detection and PCA for face recognition. Chowdhry et al. [56] designed and implemented a smart security system for a restricted area where access is limited to people whose faces are available in the training database. The face detection is based on skin colour (local feature) analysis and YCbCrcolour space was chosen for its property that separates the luminance and chrominance components of real-time Closed-Circuit Television (CCTV) surveillance.

4.3 Occlusion

Lahasan and Lutfi [65] wrote a survey on handling occlusion problem in face recognition. The approaches are summarized in Table 3. Another method of solving the occlusion problem in face recognition is by using a 3D face model-based face recognition system. Harguess et al. [66] proposed a face recognition system that tackles the problem of self-occlusion by observing a person from multiple cameras with different views of the person’s face and fusing the recognition results. Kokila and Yogameena [67] present a face detection and recognition algorithm that identify a wanted person in a surveillance video based on the Viola-Jones algorithm. A Histogram of Oriented Gradients (HOG) and LBP features are extracted from the segmented face. SVM is used for the matching.

4.4 Facial Expression Changes

A variety of a person’s emotion or mood can be collected and stored as a training database. Hadid [68] proposed a face recognition that is based on Local Binary Patterns (LBP) method where the LBP description is computed over the whole face image and encodes only the occurrences of the micro-patterns without any indication about their locations. The LBP based method is reported to achieve a recognition rate of 97% in the case of recognizing faces under different facial expressions. Leo and Suchitra[69] presented an expression-invariant approach based on SVM that uses an effective blend of 3D Principal Component Analysis (PCA) and Support Vector Machine (SVM) to concentrate on the face recognition system. In the process, each face is initially registered using the Mean Landmark Points (MLPs), which allows the exact extraction of distinct features from the facial region using 3D PCA.

4.5 Ageing of the Face

Since there is a substantial distinctionof two photos of the same person taken at significant differences in time, it is recommended that the training database be updated periodically (for example within 6 months or a year).Sawant and Bhurchandi [70] provide an extensive review of the cross-age face recognition. According to them, for a practical face recognition system, the ultimate aim is to build a framework that provides consistent and reliable performance across age groups, all other differences in demographic and appearance factors. In their report, they have reported three clear guidelines for future research and development in age invariant face recognition; (i) A collaborative approach to global and local features could lead to improved results. (ii) It is claimed that the 3D facial image technologies are more accurate for age identification. (iii) Deep generative models can be used to recognize a whole sequence of ageing.

4.6 Varying Illumination Conditions

A common approach to overcoming image with illumination variations is to use image representations that are relatively insensitive to illumination such as edge maps representation, image intensity derivatives, and images convolved with 2D Gabor-like filters [71]. Another method addressing the illumination variations on the faces are as follows; (i) Use the grey-level information to extract the 3D shape of the object, namely, shape from shading approach. (ii)Use a training face database that consists of several images of the same face taken under different illumination conditions. Shah et al. [72] address the varying illumination issues by proposing a robust algorithm that transforms pixels from the non-illumination side to the illuminated side. The basic subspaces method used for face recognition is PCA and LDA. To overcome the illumination problem, an Original Pixel Preservation Model (OPPM) framework was presented which transforms pixels from the non-illumination side to the illuminated side. Ekenel and Sankur[73]proposed multi resolution techniques for face recognition system. These techniques were applied to mitigate the loss of classification performance due to changes in facial appearance. Mokhayeri et al. [74] proposed an approach that generates multiple synthetic face images per person on camera to address the low-quality image problem caused by illumination variations. Weyrauch et al.[75] presented a face recognition approach invariant to illumination and pose by incorporating component-based recognition and 3D morphable models. They used their own 3D face database, which was designed by themselves. To create a broad collection of digital images, the 3D models are rendered under varying pose and lighting conditions. Then, these images are used to train facial recognition based on components.

4.7 Low Image Resolution

The captured low-resolution video images can be improved by using a Super-Resolution (SR) based technique or by implementing an algorithm that can disregard video frames that are considered useless. SR method is commonly used to solve the low-resolution face image problem commonly exists in a face recognition system that uses surveillance or video images as data input. Hao et al. [76] presented an SR face reconstruction technique based on Nonlocal Similarity and Multi-Scale Linear Combination Consistency (NLS-MLC) and Resolution Scale Invariant Feature (RSIF). Lanchi et al. [77] proposed an image enhancement method based on Unsharp mask for the preprocessing module in a face recognition system. Using images from the World Wide Web to evaluate their system, their results was compared with Polesel et al. [78] results and Lanchi et al. [77] claimed that their enhancement method is much more efficient in term of processing time with a run-time of 21miliseconds per frame compared to Polesel et al. [78] run-time of 31miliseconds per frame. Their method also has lesser interference of noise and artefact.

4.8 Identity Look-Alike or Twin

A combination of face recognition system and other biometrics such as a fingerprint is proposed for authentication of such condition. Rustam and Faradina[79] proposed a face recognition system to identify look-alike faces using Support Vector Machine. Two types of kernel function have been implemented, which are the Radial Basis Function (RBF) kernels and the polynomial kernels. Their look-alike system can be narrow down the potential look-alike or twins for manual verification.

4.9 Other Technical Difficulties

Any sudden decrease in performance can probably cause by hardware failure. It is advisable to check on the hardware component of the system before investigating the software component of the face recognition system.

5. CONCLUSION

This paper presented a survey on the state-of-the-art, enablers, challenges and solutions for face recognition. The role of face recognition as an enabler in healthcare, surveillance application, photo cataloguing, attendance system, access control, and security, has been described. The challenges, as well as the proposed solutions of face recognition, has been described. They are; (i) automated face detection where difficulties lies on detecting a person's face, (ii) pose variations cause by rotation of people's head, (iii) face occlusion caused by sunglasses or beard, (iii) facial expression changes, (iv) aging of the face where there is a considerable gap between the two photos of the same person, (v) varying illumination conditions on the person's face, low image resolution captured, identity look-alike, and other technical difficulties. The face detection problem can be solved by applying a skin colour detection followed by a face detection algorithm. Pose variations, facial expression changes, and varying illumination condition problems can be solved by training multiple images with different image condition. Occlusion problem can be solved by using a combination of global and local approaches. 3D face model-based face recognition can be used to solve occlusion and ageing of the face problems. Low image resolution can be solved by implementing the Super-Resolution method. A combination of face recognition with another biometric method can be used to solve identity look-alike problem. From the survey, it was found that the global based face recognition approaches is the most popular, followed by the hybrid approach. Computer with high specifications are getting cheaper and faster and researchers may start to feel that the differences in computational time between algorithms are becoming very small and negligible. Thus, research on a hybrid approach to increase recognition performance has a higher priority. It can also be seen that there is a lack of investigation into the effect of color-space images on facial recognition. Since the computing speed of a computer or smartphone has improved so much compared to decades ago, it may be a good time to consider imaging data with more than three bands (RGB) such as multispectral or hyper spectral imaging for facial recognition. A technique called the exposure bracketing retained the details of the shadow and highlight of an image thereby providing further data for face recognition analysis.

REFERENCES

1. X.Lu. **Image analysis for face recognition**.2003.http://www.cse.msu.edu/lvxiaogu/publications/ImAna4FacRcgJu.pdf. Accessed 16 August 2011.
2. W.Zhao, Chellappa,R. ,Phillips,P.J. and Rosenfeld,A. **Face recognition: A literature survey**. *ACM Computing Surveys(CSUR)*, Volume 35, issue 4, pp.399-458, 2003. https://doi.org/10.1145/954339.954342
3. T. M. Kodinariya. **Hybrid Approach to Face Recognition System using Principle component and Independent component with score based fusion process**. *arXiv preprint arXiv:1401.0395*, 2014.
4. Sightcorp. https://sightcorp.com/blog/how-facial-recognition-is-used-in-healthcare/.AccessedonNovember2019.
5. G. I. Hapsari, G. A. Mutiara, and H. Tarigan. **Face recognition smart cane using haar-like features and eigenfaces**. *Telkomnika*, *17*(2), 2019. https://doi.org/10.12928/telkomnika.v17i2.11772

6. Susilo, T. and Duchaine, B. **Advances in developmental prosopagnosia research**. *Current opinion in neurobiology*, 23(3), pp. 423-429, 2013.
7. S. Bate, R. J. Bennetts, N. Gregory, J. J. Tree, E. Murray, A. Adams, A. K. Bobak, T. Penton, T. Yang, and M. J. Banissy. **Objective patterns of face recognition deficits in 165 adults with self-reported developmental prosopagnosia**. *Brain sciences*, *9*(6), p.133, 2019. https://doi.org/10.3390/brainsci9060133
8. D. N. Parmar and B. B. Mehta. **Face recognition methods & applications**. *arXiv preprint arXiv:1403.0485*, 2014.
9. N. U. Bagrov, A. S. Konushin, and V. S. Konushin. **Face Recognition with Low False Positive Error Rate**. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*(2/W12), 2019.
10. C. Li, W. Wei, J. Li, and W. Song. **A cloud-based monitoring system via face recognition using Gabor and CS-LBP features**. *The Journal of Supercomputing*, *73*(4), pp.1532-1546, 2017.
11. H. Huang and Y. Huang, February. **Photo Automatic Classification System Based on Face Recognition**. In *Journal of Physics: Conference Series*, Vol. 1168, No. 4, p. 042007, 2019.
12. D. Sunaryono, J. Siswantoro, and R. Anggoro. **An android based course attendance system using face recognition**. *Journal of King Saud University-Computer and Information Sciences*, 2019.
13. M. Z. Khan, S. Harous, S. U. Hassan, M. U. G. Khan, R. Iqbal, and S. Mumtaz. **Deep Unified Model For Face Recognition based on Convolution Neural Network and Edge Computing**. *IEEE Access*, *7*, pp.72622-72633, 2019.
14. S. J. Elias, S. M. Hatim, N. A. Hassan, L. M. Abd Latif, R. B. Ahmad, M. Y. Darus, and A. Z. Shahuddin. **Face recognition attendance system using Local Binary Pattern (LBP)**. *Bulletin of Electrical Engineering and Informatics*, *8*(1), pp.239-245, 2019. https://doi.org/10.11591/eei.v8i1.1439
15. H. Shen, X. Wang, and X. Zhang. **Batch Attendance System Based on Face Recognition**. In *IOP Conference Series: Earth and Environmental Science*, Vol. 252, No. 3, p. 032145, 2019.
16. M. Sharif, F. Naz, M. Yasmin, M. A. Shahid, and A. Rehman. **Face Recognition: A Survey**. *Journal of Engineering Science & Technology Review*, *10*(2), 2017.
17. Z. Rustam and R. Faradina, May. **Application of Fuzzy Kernel C-Means in face recognition to identify look-alike faces**. In *Journal of Physics: Conference Series*, Vol. 1218, No. 1, p. 012045, 2019.
18. Z. Rustam and A. A. Ruvita, November. **Application Support Vector Machine on Face Recognition for Gender Classification**. *Journal of Physics: Conference Series*, Vol. 1108, No. 1, p. 012067, 2018.
19. P. Thakur and D.R. Shrivastava. **A review on text based emotion recognition system**. *International Journal of Advanced Trends in Computer Science and Engineering*, 7(5), 2018. https://doi.org/10.30534/ijatcse/2018/01752018
20. S. Chokkadi, M. S. Sannidhan, K. B. Sudeepa, and A. Bhandary. **A Study on various state of the art of the Art Face Recognition System using Deep Learning Techniques**. *International Journal of Advanced Trends in Computer Science and Engineering*, vol. 8(4), pp. 1590-1600, 2019. https://doi.org/10.30534/ijatcse/2019/84842019
21. J.H.Shah, M.Sharif, M. Raza, and A. Azeem.**A Survey: Linear and Nonlinear PCA Based Face Recognition Techniques**. *Int. Arab J. Inf. Technol.*, 10(6), pp.536-545, 2013.
22. S.Soltanpour, B. Boufama,and Q.J.Wu.**A survey of local feature methods for 3D face recognition**. *Pattern Recognition*, 72, pp.391-406, 2017.
23. M.Sharif, F.Naz, M.Yasmin, M.A.Shahid, and A.Rehman.**Face Recognition: A Survey**. *Journal of Engineering Science & Technology Review*, 10(2), 2017. https://doi.org/10.25103/jestr.102.20
24. M.Kas, MerabetEl, Y., Y. Ruichek,and R.Messoussi.**Survey on Local Binary Pattern Descriptors for Face Recognition**. *In Proceedings of the New Challenges n Data Sciences: Acts of the Second Conference of the Moroccan Classification Society*, pp. 1-6, 2019.
25. Z. Arsalaneand M.Aicha.**Survey on the approaches based geometric nformation for 3D face landmarks detection**. *IET Image Processing*, 13(8), pp.1225-1231, 2019.
26. Y.Zheng,February. **2DFaceRecognitiononCNNwithHalf-Average-Face**. *JournalofPhysics:ConferenceSeries*,Vol.1169,No.1, pp.012043,2019.
27. J. Ke, Y. Peng, S. Liu, Z. Sun, and X. Wang. **A novel grouped sparse representation for face recognition**. *Multimedia Tools and Applications*, *78*(6), pp.7667-7689, 2019. https://doi.org/10.1007/s11042-018-6277-x
28. Z. Liu, D. Jiang, Y. Li, Y. Cao, M. Wang, and Y. Xu. **Automatic face recognition based on sparse representation and extended transfer learning**. *IEEE Access*, *7*, pp.2387-2395, 2018.
29. S. Allagwail, O. S. Gedik, and J. Rahebi. **Face recognition with symmetrical face training samples based on local binary patterns and the Gabor filter**. *Symmetry*, *11*(2), p.157, 2019.
30. T. Tuncer, S. Dogan, M. Abdar, M. Ehsan Basiri, and P. Pławiak. **Face Recognition with Triangular Fuzzy Set-Based Local Cross Patterns in Wavelet Domain**. *Symmetry*, *11*(6), p.787, 2019. https://doi.org/10.3390/sym11060787
31. L. Shi, X. Song, T. Zhang, and Y. Zhu. **Histogram-based CRC for 3D-aided pose-invariant face recognition**. *Sensors*, *19*(4), p.759, 2019.
32. G. Y. Chen, T. D. Bui, and A. Krzyzak. **Illumination invariant face recognition using dual-tree complex wavelet transform in logarithm domain**. *Journal of Electrical Engineering*, *70*(2), pp.113-121, 2019.
33. Q. Chen, J. Sun, V. Palade, X. Shi, and L. Liu. **Hierarchical Clustering Based Band Selection**

Algorithm for Hyperspectral Face Recognition. *IEEE Access*, *7*, pp.24333-24342, 2019.

34. H. Ling, J. Wu, L. Wu, J. Huang, J. Chen, and P. Li. **Self residual attention network for deep face recognition**. *IEEE Access*, *7*, pp.55159-55168, 2019.
35. A. Vinay, A. Gupta, A. Bharadwaj, A. Srinivasan, K. B. Murthy, and S. Natarajan. **Deep learning on binary patterns for face recognition**. *Procedia computer science*, *132*, pp.76-83, 2018. https://doi.org/10.1016/j.procs.2018.05.164
36. S. Biswas and J. Sil. **An efficient face recognition method using contourlet and curvelet transform**. *Journal of King Saud University-Computer and Information Sciences*, 2017.
37. Y. Cheng, Z. Li, and Y. Han. **A novel illumination estimation for face recognition under complex illumination conditions**. *IEICE Transactions on Information and Systems*, *100*(4), pp.923-926, 2017.
38. B.H.Shekar, G.Thippeswamy, P.Shivakumara.**A rule based model for efficient representation and accurate recognition of human faces**. ACE 2010 - 2010 *International Conference on Advances in Computer Engineering*, art. no. 5532812, pp. 326-329, 2010.
39. A. Yu, G. Li, B. Hou, H. Wang, and G. Zhou. **A novel framework for face recognition using robust local representation–based classification**. *International Journal of Distributed Sensor Networks*, *15*(3), p.1550147719836082, 2019.
40. Z. An, W. Deng, J. Hu, Y. Zhong, and Y. Zhao. **APA: Adaptive Pose Alignment for Pose-Invariant Face Recognition**. *IEEE Access*, *7*, pp.14653-14670, 2019.
41. A. S. Al-Waisy, R. Qahwaji, S. Ipson, and S. Al-Fahdawi. **A multimodal deep learning framework using local feature representations for face recognition**. *Machine Vision and Applications*, *29*(1), pp.35-54, 2018. https://doi.org/10.1007/s00138-017-0870-2
42. O. Surakhi, M. Khanafseh, and Y. Jaffal. **An enhanced Biometric-based Face Recognition System using Genetic and CRO Algorithms**, 2018.
43. D. Rajasekhar, T. J. Prasad, and K. Soundararajan. **An affine view and illumination invariant iterative image matching approach for face recognition**. *International Journal of Engineering & Technology*, *7*(2.8), pp.42-46, 2018.
44. H.H.Abbas,B.Z.Ahmed,andA.K.Abbas. **3DFaceFactorisationforFaceRecognitionUsingPattern Recognition Algorithms**. *Cybernetics and Information Technologies*, *19*(2), pp.28-37, 2019.
45. Li, L. and Xie, H. **Cascading BGP face recognition method based on heuristic information**. *In Journal of Physics: Conference Series,* Vol. 1168, No. 4, p. 042006, 2019.
46. K. Li and Q. Huang. **Cross-pose face recognition by integrating regression iteration and interactive subspace**. *EURASIP Journal on Wireless Communications and Networking*, *2019*(1), p.105, 2019. https://doi.org/10.1186/s13638-019-1429-x
47. A. Elmahmudiand H.Ugail. **Deep face recognition using imperfect facial data**. *Future Generation Computer Systems*, *99*, pp.213-225, 2019.
48. N. Ratyal, I. A. Taj, M. Sajid, A. Mahmood, S. Razzaq, S. H. Dar, N. Ali, M. Usman, M. J. A. Baig, and U. Mussadiq. **Deeply learned pose invariant image analysis with applications in 3D face recognition**. *Mathematical Problems in Engineering*, 2019.
49. H. Chen and C. Haoyu, May. **Face Recognition Algorithm Based on VGG Network Model and SVM**. In *Journal of Physics: Conference Series* Vol. 1229, No. 1, p. 012015, 2019.
50. C. Lv and J. Zhao. **3D face recognition based on local conformal parameterization and iso-geodesic stripes analysis**. *Mathematical Problems in Engineering*, 2018.
51. S. Ohlyan, S. Sangwan, and T. Ahuja, June. **A survey on various problems & challenges in face recognition**. *International Journal of Engineering Research & Technology (IJERT)* (Vol. 2, No. 6), 2013.
52. S. Gong, S. J. McKenna, and A. Psarrou. **Dynamic Vision: From Images to Face Recognition**. *Imperial College Press(World Scientific Publishing Company), A Survey of Face Recognition Technique*s, 2000.
53. J. I. Olszewska. **Automated Face Recognition: Challenges and Solutions**. https://www.intechopen.com/books/pattern-recognition-analysis-and-applications/automated-face-recognition-challenges-and-solutions. Accessed on November 2019.
54. S. Cha, J. W. Kwak, and W. Kim. **Performance Analysis of Face Detection Algorithms for Efficient Comparison of Predection Time and Accuracy**. *Proceedings of the International Conference on Image Processing, Computer Vision, and Pattern Recognition (IPCV)* (p. 1). The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (WorldComp), 2014.
55. K. Reshmi and J. Grace.L.K. **Face recognition in surveillance system**. *Innovations in Information, Embedded and Communication Systems (ICIIECS)*, International Conference, pp. 1-5. 2015, 2015.
56. D. A. Chowdhry, A. Hussain, M. Z. U. Rehman, F. Ahmad, A. Ahmad, and M. Pervaiz. **Smart security system for sensitive area using face recognition**. 2013 *IEEE Conference on Sustainable Utilization and Development in Engineering and Technology (CSUDET)*, pp. 11-14, 2013. https://doi.org/10.1109/CSUDET.2013.6670976
57. Bayley Group. http://bayley.chem.ox.ac.uk/files/2018_grouppicture.jpg. Accessed on December 2019.
58. P. Debevec, T. Hawkins, C. Tchou, H. P. Duiker, W. Sarokin, and M. Sagar, July. **Acquiring the reflectance field of a human face**. *In Proceedings of the 27th annual conference on Computer graphics and interactive techniques*, pp. 145-156, 2000.
59. Y. Xia, B. Zhang, and F. Coenen. **Face occlusion detection using deep convolutional neural networks**. *International Journal of Pattern Recognition and Artificial Intelligence*, *30*(09), p.1660010, 2016.
60. T. S. Wingenbach, C. Ashwin, and M. Brosnan. **Validation of the Amsterdam Dynamic Facial**

Expression Set–Bath Intensity Variations (ADFES-BIV): A set of videos expressing low, intermediate, and high intensity emotions. *PloS one*, *11*(1), 2016.

61. W. Zhuang, L. Chen, C. Hong, Y. Liang, and K. Wu. FT-GAN: **Face Transformation with Key Points Alignment for Pose-Invariant Face Recognition**. *Electronics*, *8*(7), p.807, 2019.
62. M. A. Muqeet and R. S. Holambe. **Local binary patterns based on directional wavelet transform for expression and pose-invariant face recognition**. *Applied Computing and Informatics*, *15*(2), pp.163-171, 2019.
63. J. J. Yokono and T. Poggio, April. **A multiview face identification model with no geometric constraints**. *7th International Conference on Automatic Face and Gesture Recognition (FGR06)*, pp. 493-498, IEEE,2006.
64. O. Arandjelović and R. Cipolla. **Face recognition from video using the generic shape-illumination manifold**. In *European conference on computer vision*, pp. 27-40, Springer, Berlin, Heidelberg,2006.
65. B. Lahasan, S. L. Lutfi, and R. San-Segundo. **A survey on techniques to handle face recognition challenges: occlusion, single sample per subject and expression**. *Artificial Intelligence Review*, *52*(2), pp.949-979, 2019. https://doi.org/10.1007/s10462-017-9578-y
66. J. Harguess, C. Hu, and J. K. Aggarwal. **Fusing face recognition from multiple cameras**. *Applications of Computer Vision (WACV)*, 2009 Workshop, pp. 1-7, 2009.
67. S. Kokila and B. Yogameena. **Face Recognition Based Person Specific Identification for Video Surveillance Applications**. *Proceedings of the Third International Symposium on Women in Computing and Informatics*, pp. 143-148, 2015.
68. A. Hadid. **Learning and Recognizing Faces: From Still Images to Video Sequences**. Ph.D. Dissertation, Oulu University, 2005.
69. M. J. Leo and S. Suchitra. **SVM Based Expression-Invariant 3D Face Recognition System**. *Procedia computer science*, *143*, pp.619-625,2018.
70. M. M. Sawant and K. M. Bhurchandi. **Age invariant face recognition: a survey on facial aging databases, techniques and effect of aging**. *Artificial Intelligence Review*, *52*(2), pp.981-1008, 2019. https://doi.org/10.1007/s10462-018-9661-z
71. Y. Adini, Y. Moses, and S. Ullman. **Face recognition: The problem of compensating for changes in illumination direction**. *IEEE Transactions on pattern analysis and machine intelligence, 19*(7), pp.721-732.1997.
72. J. Hussain Shah, M. Sharif, M. Raza, M. Murtaza, and S. Ur-Rehman. **Robust face recognition technique under varying illumination**. *Journal of applied research and technology*, *13*(1), pp.97-105, 2015.
73. H. K. Ekenel and B. Sankur. **Multiresolution face recognition**. *Image and Vision Computing*, *23*(5), pp. 469-477. 2005.
74. F.Mokhayeri, E. Granger,and G.A.Bilodeau. **Synthetic face generation under various operational conditions n video surveillance**. *In Image Processing (ICIP), 2015 IEEE International Conference*, pp. 4052-4056, 2015 https://doi.org/10.1109/ICIP.2015.7351567
75. B. Weyrauch, B. Heisele, J. Huang, and V. Blanz. **Component-Based Face Recognition with 3D Morphable Models**. *Computer Vision and Pattern Recognition Workshop*, Conference, pp. 85, 2004.
76. N. Hao, H. Liao, Y. Qiu, and J. Yang. **Face super-resolution reconstruction and recognition using non-local similarity dictionary learning based algorithm**. *IEEE/CAA Journal of AutomaticaSinica*, pp. 213-224. 2016. https://doi.org/10.1109/83.826787
77. X. Lanchi, G. Jingjing, and L. Zhihui. **A Novel Unsharp Mask Sharpening Method in Preprocessing for Face Recognition**. *2015 Fifth International Conference on Instrumentation and Measurement, Computer, Communication and Control (IMCCC)*, pp. 378-381, 2015.
78. A. Polesel, G. Ramponi, and V. J. Mathews. **Image enhancement via adaptive unsharp masking**. *IEEE transactions on image processing*, pp. 505-510, 2000.
79. Z. Rustam and R. Faradina, November. **Face recognition to identify look-alike faces using support vector machine**. *Journal of Physics: Conference Series*, Vol. 1108, No. 1, p. 012071, 2018. https://doi.org/10.1088/1742-6596/1108/1/012071