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State of the Art on Face Recognition – A Review

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Abstract **- The high demand for face recognition applications has attracted the interest of researchers in this area. As a result of this, several methodologies have been proposed by scholars in this field. Face recognition methodology aims to detect faces in still image and sequence images. Local, global, and hybrid are approaches used in this area. The major issue of face recognition includes intensity, illumination, difficult to control as well as pose. Face images are highly dynamic and they pose difficult issues and challenges to solve when in use, researchers in pattern recognition, computer vision, and artificial intelligence have proposed many models in other to reduce such difficulties to improve the efficiency, robustness, and accuracy. The objective of this paper is to provide a survey of the current state of research on face recognition methodologies that has been proposed by different researchers. The underlining principles and application areas of face recognition are also presented. Finally, a conclusion on the current state of the art in face recognition was given.**

Keywords: Face, face recognition, methodology, features, algorithms

1. Introduction

Face Recognition (FR) application has gained very high attention from many researchers in diverse fields which includes researchers in computer science, education sectors, bioinformatics, neuroscientists, finance sector, and psychologists among others. This is a result of the fact that the process of FC does not require the knowledge of the particular person in the subject, neither does it require participation in the process of identification. FR has become one of the most active applications in visual pattern recognition due to its very high potential value for law enforcement, curbing examination malpractice, security, surveillance, as well as human-computer interaction. FR has become so imperative and has advanced to the point that it is being demonstrated in real-world settings. The development of active algorithms, the availability of a large database of face images, and methodologies for evaluating the performance of face recognition algorithms are seen as combined factors that have led to the rapid development of FR in today's real-life computing. Face recognition can be seen as a kind of recognition task pattern, where a face is categorized as either known or unknown after comparing it with the images of persons stored in the face database.

Research has focused on how to make FR systems fully automatic by tackling problems such as localization of an input face image or video clip and extraction of facial features such as the nose, eyes, mouth among others over the past 15 years. Meanwhile, significant advances have been made in the design of classifiers for successful FR. Though a variety of techniques have already surfaced for face recognition problems, it is still a developing field depending on the application scenario and scene constraints [21]. FR being a proliferating field requires a rich review of techniques available as of today to enable developers to choose the best that works for a particular application. This current review work, reviews initial works in this field and went further to review research work in the twenty-first century as FR software is on high demand. This work also provides possible remarks in the approaches reviewed.

2. Principles of Face Recognition System

This is an action that we humans perform routinely and effortlessly in our daily life activities, it happens to be an inbuilt activity of man. The person identification for the face that appears in the input data is the FR process. The process is shown in Figure 1.

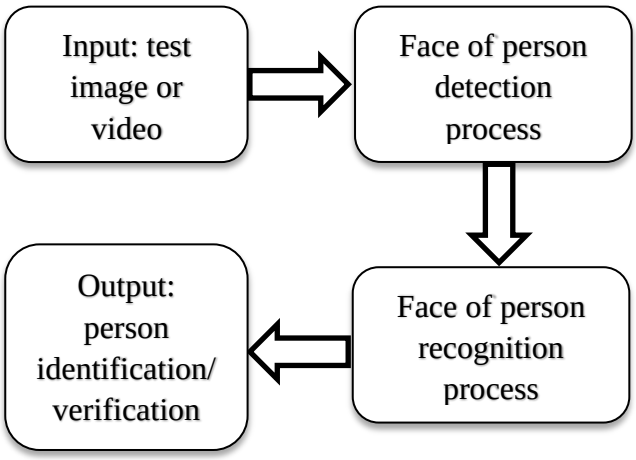

Figure 1: Face Recognition Process (Shakir, Firas & Pedroe, 2018)

3. Steps in Facial Recognition (FR) process

The process of FR can be conceptually divided into four steps [21]. They are:

- **Face Detection**- in this step the human face is detected from the cluttered scene. after the image is captured.
- **Image Normalization**- This step requires the image to be standardized according to its size, scale, illumination, pose, and orientation among others relative to the images stored in the FR database. This is a very important step in the FR recognition process since the recognition of the face will not be a successful process unless the properties of the probe image are more or less identical to the properties of the images stored in the FR database.
- **Feature extraction**- Here the unique features of the face are extracted to be used for recognition.
- **Face Recognition or verification**- this is the last step of the process, the input face to the system is unknown and it is then the responsibility of the system to find a match to the input face from a set of already known stored faces in the system. While in verification, the input face is claimed to be that of a specific person and the system is responsible also to either verify or reject the claimed identity of that input face [45, 12].

Figure 2 depicts the structure of the steps involved in the FR process.

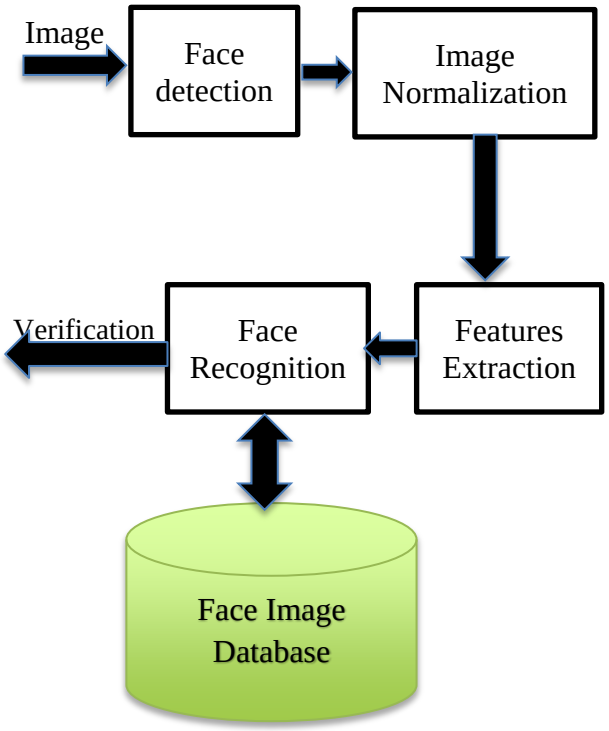

Figure 2: Face Recognition Structure (Jridi, Napoleon & Alfalou, 2018; Parmar & Mehta, 2013)

4. Face Recognition Approach

Face Recognition activity can be done in a still image as well as video sequencing which has its origin in still-image FR [15]. The different approaches of FR for still images can be categorized into three main groups, these are - Holistic, Feature-based, and hybrid approaches [45]:

- *In Holistic Approach*, the whole face region is taken into consideration as the input data into the face detection system. Some examples of holistic methods are eigenfaces (this is the most widely used method for FR), support vector machines,

probabilistic eigenfaces, fisherfaces, nearest feature lines (NFL), independent-component analysis approaches among others.

- The features on the face such as the nose and the eyes are segmented and used as input data for the structural classifier in a f***eature-based approach.***

- The idea of the Hybrid approach came from how humans perceived both holistic and the feature-based approach. The key factors that influence the performance of the hybrid approach include how to determine which features should be combined and how to combine, to preserve their advantages and avert their disadvantages at the same time [15].

5. Reviewed Literature

State of the Art on Model and Algorithm on Face Recognition

The challenges facing FR has long been an ongoing subject of research. Though research has been ongoing in the field, it cannot be considered to be a proliferated research point. A wide variety of approaches have been introduced and implemented and have proven to be successful according to the researchers. However, a robust FR system continues to be a challenge to meet with the high demand for FR software. This is due to the high variability of facial images, due to pose variations, image illumination factors among others. Face recognition technology has a wide range of algorithms that has been proposed, one of the algorithms referred to as Feature-Based Facial Recognition approaches. The key idea behind the feature-based algorithms is to use the geometric characteristics among the facial features like the eyes, nose, and mouth to perform a matching process between the distances of those features. This approach has been widely used for quite some time, but have proved very limited performance accuracy [6]. Another type of algorithm is called the Appearance-Based Facial Recognition approach [2, 3, 34, 37]. The algorithms based on this approach make use of the features based on pixel intensity. These researchers concluded that statistical similarities between people gave rise to a novel identification or a recognition method that does not focus on particular features of a face like the eyes or nose or mouth but rather it uses much more information by classifying faces based on general facial patterns. The technique is called template-matching technique since face images that are represented as two-dimensional arrays of pixel intensity values are compared with templates representing the whole face [6]. Appearance-based methods have naturally proven to have a higher efficiency than feature-based methods [26]. Some template-matching techniques have high performance when using the Principal Component Analysis (PCA) technique as well as Linear Discriminant Analysis (LDA), both offer a reasonable computational and complexity time [45, 41]. PCA is based on the second-order statistics of the image set and does not address high order statistical dependencies such as the correlation between three or more pixels. Therefore, methods based on Higher-Order Statistics (HOS) have been proposed, such as Kernel Principal Component Analysis (Kernel PCA) [14]. This technique can compute the higher-order statistics without the complexity of both time and memory that usually comes along with it. Fuzzy Fisherface was introduced for feature extraction and face recognition [3]. Fuzzy Fisherface computes fuzzy within-class scatter matrix and between-class scatter matrix by incorporating class membership of the binary labeled faces (patterns). Although it was proved to be effective, Fuzzy Fisherface did not completely incorporate the class membership into the definition of between-class and within-class scatter matrices and ignored the discriminative information in the null space of fuzzy within-class scatter matrix. Yang et al, introduced Complete Fuzzy LDA (CFLDA) for feature extraction and face recognition. CFLDA combines the complete LDA and fuzzy set theory. CFLDA redefines the fuzzy between-class scatter matrix and fuzzy within-class scatter matrix that makes fully of the distribution of sample and simultaneously extract the irregular discriminative information and regular discriminative information. The performance of CFLDA surpasses Fuzzy Fisherface.

Recently, Zhou et al, improves the face recognition system performance by incorporating spatially structured features into a histogram-based face-recognition framework [46]. In their study, the diffusion distance is computed over a

pair of human face images, and the shape descriptions of these images are built using Gabor filters that consist of a number of scales and levels. The oriented Gaborfilters lead to discriminative image representations that are then used to classify human faces in the database. Some other techniques use Neural Network (NN) classification [19]. The strength of NN comes from the fact that they are able to learn from data sets provided for them. This ability of theirs greatly shows in the fact that the error estimation is significantly minimized for previously unseen data. Neural networks have proven to have good performance even when the input images are very noisy or when portions of the images are missing. Neural networks have been used in face recognition to address three problems; gender classification, face recognition, and facial expressions [45]. There are systems that use the Dynamic Link Architecture (DLA) [16], which tries to solve some of the conceptual problems of conventional artificial neural networks; one important problem being the expression of syntactical relationships in NN. The DLA has been extended to the Elastic Bunch Graph Matching (EBGM) [40]. This approach has been applied to problems of face detection, feature finding, pose estimation, gender classification, sketch image-based recognition, and general object recognition. It is worth mentioning that the high performance of the systems based on DLA/EBGM is claimed to be due to its resemblance to the human visual system.

Research has shown that combining soft-computing techniques has always proven to be beneficial in solving most real-life problems, in terms of real-life computing. Neural networks and fuzzy logic can be combined to form what we referred to as Neuro-Fuzzy Systems. This is because a benefit of neural networks is that they are low-level, computational algorithms, while fuzzy logic provides a structural framework that makes use of those low-level capabilities. Hence, their integration produces high-performance algorithms [19]. In the application of FR, Artificial Neural Networks (ANN) have been combined with fuzzy logic and have shown high performance. However, real-life problems are usually too complicated for a single network to handle; therefore, the approach of divide-and-conquer has been applied through the method that is called Mixture of Experts (ME) [19]. While some research works have succeeded in enhancing feature extraction tools using fuzzy logic [42], others have combined fuzzy logic along with other computational intelligence approaches to build a high performing classifier [35, 19]. Their approach on the other hand, has focused solely on using fuzzy inference for the recognition phase. The benefit of using fuzzy logic as the inference engine for the recognition is that it can mimic the human way of thinking. It is very obvious that the recognition process is an everyday activity for a human being. Human being is able to recognize a certain person he/she sees based on the most vivid facial features of that subject person. The human subconsciously perceives the subject's significant features, compares them with a database of features representing persons that he/she meets/knows in his/her life, and based on that comparison the human is able to identify the subject person to either be someone he/she knows or does not know. Another interesting thing about using fuzzy logic is choosing PCA for the feature extraction tool. This is because PCA is also able to mimic the human recognition process. Since a human being does not recognize a certain person because of specific features of that person. For instance, we do not remember that a specific person had a small nose, large ears, and short hair, but a more complex and a more general process takes place instead. The human being is able to remember a more general form or appearance of a certain face without remembering specific details about certain facial features. This is why appearance-based facial recognition methods have an advantage over feature-based facial recognition methods and have proven to have a better performance than feature-based methods.

Further, on research, FR techniques use model-based strategies to develop models of human face that extracts facial features, which never made changes to alignment, lighting, and size of the face [40]. Kurmi et al, opined that there are advantages to these methods, such as rapid matching and compactness of the representation of face images [17]. The 3D strategies model for FR uses the 3D sensor to capture data from the face. This model is classified into two major categories - 3D poses estimation and 3D face reconstruction [24]. Hu et al presented "A novel Albedo Based 3D

Morphable Model (AB3DMM)" [9]. In their proposed methodology, they used the illumination normalization in a pre-processing stage to remove the illumination component from the face images. The output of their research reached 86.76% of recognition on the Multi-PIE database that was used to evaluate SSR + LPQ. Ding and Tao, also worked on 3D facial landmarks which were projected in a grid shape in the 2D image, and then by aligning five facial landmarks semantically of the corresponding face images with a generic 3D face model [7].

Elastic Bunch Graph Matching (EBGM) was another algorithm that identifies a human in a new appearance picture by comparing the new face image with other faces in the database [7, 5]. The process of this algorithm started by extracting feature component vectors using Gabor Jets from a highlighted point on the face. Next, the extracted features are matched to corresponding features from the other faces in the database [7, 5].

In another research work, the Holistic Based Model (HBM) which was based on methods that are based on global representations of faces instead of local representation on the entire image for identifying faces was used. This model takes into consideration global features from the given set of faces in the face recognition process. The **HBM** model is categorized into three main subspaces: Statistical (Linear and Non- Linear), Neural, and Hybrid [43, 5].

Principal Component Analysis (PCA**) is another** methodology used for dimension reduction and feature extractions. Bheleet and Mankar observed that Turk was the first to use PCA for human face recognition and face reconstruction was done by Swets and Weng [4, 37, 34]. The result of their strategy helped to reduce the dimensionality of the original data by extracting the main components of multidimensional data [31]. Using the Eigenface strategy, illumination normalization is very much necessary in FR. Instead of Eigenface, Eigenfeatures like mouth, nose, and eye among others are used. In calculating the subspace of the low dimensional, representation is used for data compression [27, 30, 11]. Abdullah et al, presented three experiments to enhance PCA efficiency by reducing the computational time while keeping the performance Constance. The results showed that the accuracy was the same as the second experiment, with less computational time. According to the result of their approach, the computation time was reduced by 35% as compared with the original PCA method, especially with a larger database [1]. Also, Gawande and Agrawal proposed a new face recognition system for personal identification and verification using different distance classifiers with PCA which was applied to the ORL database [8]. In addition, Poon et al presented several techniques for illumination invariant that they examined, and they determined a strong FR that worked better with PCA [25].

Another algorithm for face recognition is **Independent Component Analysis (ICA).** The main goal of this technique is in contrast to PCA, which supplies an independent image representation instead of an uncorrelated one of PCA [10]. ICA minimizes the input of both second-order and higher-order dependencies. It follows the Blind Source Separation (BSS) problem; it aims at decomposing an observed signal into a linear combination of unknown independent signals [28, 36]. The research of Sharma and Dubey provided a face recognition system using PCA–ICA, and training using neural networks, such as Hybrid feature extraction [30]. This technique extracts the invariant facial features by implementing a PCA/ICA-based facial recognition system to build a refined and reliable face recognition system. Also, **Hidden Markov Model (HMM) is yet another** approach employed in the development of the FR System. Face Recognition automatically split the faces into different areas, such as the mouth. Eyes and nose [28, 33].

Kernel Principal Component Analysis (KPCA) is a model applied in FR. The main idea here is to first of all map the input space into a feature space using nonlinear mapping and then to compute the principal components from feature space. It also requires the solution of an eigenvalue problem, which does not require additional optimization [17]. In the research done by Wang and Zhang, a new method for extracting suitable features and handling facial expressions was proposed [38]. In this study, the polynomial kernel was successfully employed based on the ORL database. Further research gave rise to **Linear Discriminant Analysis (LDA) -** This algorithm, was also called Fisherface, it uses a supervising learning method using more than one

training image for an individual class. This approach searches linear mixtures of features while preserving class independently. In addition, it tries to model the differences among different classes. It was observed that the LDA algorithm is less sensitive to light, poses, and expressions [20, 32]. In other to get the best approach, further research gave rise to **Kernel Linear Discriminant Analysis (KLDA).** This method consisted of nonlinear forms for any method that communicated fully.

Research has shown that there are several methodologies that employs Person Face Feature (PFF) extraction. The detailed diagrammatical representation of these methodologies is as shown in Figure 3.

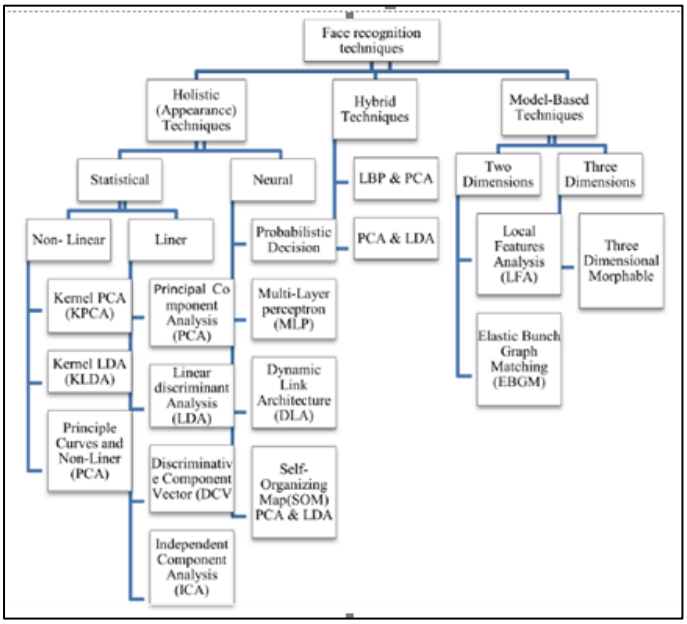

Figure 3: Face Recognition Methodologies (Parmar & Mehta, 2013; Parveeni & Thuraisingham, 2006))

6. Application areas of Face Recognition

In recent time, specifically in the twenty-first century, the use of biometric-based security applications have increased geometrically, principally in the area of FR. Hence, FR applications have become the most acceptable approach to accurately and robustly provide personal security [18, 23]. Some FR application areas are:

- **Face Identification**: Face recognition systems identify people by their face images. Face recognition systems establish the presence of an authorized person rather than just checking whether a valid identification (ID) or key is being used or whether the user knows the secret Personal Identification Numbers (PIN) or passwords. This can be applied in nationwide voter registration, National Identity, and JAMB (Joint Admission and Matriculation Board) examination registration. FR system directly compares the face images, it does not use ID numbers to differentiate one from the others.
- **Access Control**: The FR system of this application is capable of achieving high accuracy without much co-operation from the user. It is used to monitor continuously who is in front of a computer terminal at any time "T".
- **Security**: Security has become a burning issue in our society, in schools, at airports, shopping malls, in the banking sectors, homes as well as hospitals, terrorist alerts, tourism centres, secure flight boarding systems, stadium audience scanning, and computer security.
- **Face ID**: Driver licenses, entitlement programs, immigration, national ID.
- **Face Indexing:** Labeling faces in the video.
- **Access Control:** Border-crossing control, smart hospitals, vehicle access, smart classrooms, smart examination halls, smart kiosk, smart homes, ATM, computer access, and computer program access.
- **Image Database Investigations**: Searching Image Databases of licensed drivers, benefit recipients, missing children, immigrants, and police bookings.
- **General identity verification**: Electoral registration, banking, electronic commerce, identifying newborns, national IDs, passports, employee IDs.
- **Multimedia Environment:** Event detection, Face-based search as well as face-based video segmentation
- **Smart Cards Application:** Authentication of users and Stored value security.

- **Human-Computer Interaction (HCI):** Interactive lecture/learning, interactive games, proactive computing, interactive ATM.
- **Surveillance**: Terrorist Surveillance, Database surveillance, Video Surveillance, Nuclear Plant surveillance, Power Grid and Park surveillance, neighborhood watch as well as CCTV Control and portal control.
- **Face Databases:** Face indexing and retrieval, automatic face labeling, and face classification.

7. Future of Face Recognition.

Reviewed literature has shown that the future is very bright for FR application software. There is a geometric rise in the demand of the system. It was also observed that many approaches can be used for FR and each of these methods have its advantage and disadvantage such as local, global, and hybrid method. There is an important need for researchers to come up with a more robust methodology to be able to meet the high demand of the system. Else the high demand might lead to a crash in the system.

8. Conclusion

Face Recognition System has become an active research area due to its potential use in a wide variety of commercial, personal, and law enforcement applications including access control, security monitoring, and video surveillance. Unlike other biometric identification systems based on physiological characteristics, FR is seen to be a passive, non-intrusive system for verifying personal identity in a more user-friendly way without having to disturb user activity. More research should be focused on the application of hybrid systems using real-life computing methodology – Soft Computing Techniques.

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