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AN EXTENSIVE STUDY ON GENERIC FACIAL RECOGNITION PHASES AND CLASSIFICATION OF 2D ALGORITHMS

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Abstract

Face Recognition (FR) is now the most growing recognition technology development, with a broad array of applications in both commercial and academic circles.In recent years, practical tools, algorithms, methods, and datasets havebeen proposed to study limited and unconstrained FR. Various solutions, including local, holistic, hybrid,and deep learning approaches, are developed. 2D methods have reached some stage of competence and have documented very high recognition rates.The performance was found in a predetermined environment where the achievement conditions, such as visibility, focal length, and range between the camera and the target, were all regulated. However, this efficiency will degrade significantly if the ambient conditions and the facial appearance change. This review paper addresses the generic phases of facial recognition and a broad range of approaches to identify 2D faces and address their benefits and drawbacks. Initially, we present the historical steps, problems, and potential applications, specific phases of face-recognition technology, the typical workflow, and 2D methodologies.

Keywords: face recognition; face detection,feature extraction, feature selection, classifier, 2D methods, assessment protocol, deep learning.

1. Introduction

Face recognition (FR) is a form of technology that can recognise or verify the identity of people in images or videos [1]. Many applications are beginning to use many biometric variables to develop information technology and authentication algorithms for recognition activities[2]. These bio-metric factors allow the identification of persons to be identified by their physiological or behavioral characteristics. Most identification systems have been introduced in recent years based on numerous bio- metric criteria, such as iris, fingerprints [3], voice [4], and face. While some degree of sophistication has been reached by the new computer earning and recognition systems, their success is confined to an unregulated environment. Variations in lighting, stance, and facial expression, as well as cluttered background, masks, and camera movement, are all obstacles that must be addressed [5].

Compared to other biometric characteristics, the human face is not always the most reliable biometric modality; it is generally less accurate than fingerprints or iris. Natural character, the advantages of being non-intrusive, and needing less cooperation make it the most common biometric attribute for individuality recognition [6]. FR can examine and correlate facial expressions and other biometric information with photos or images, such as the eyes. The study concentrates presently on unregulated situations under the deep learning technology [7] has improved the face recognition process.

2. Problems with face-recognition algorithms

The field of face recognition has long faced challenges, including factors that make accurate recognition difficult:

- **Pose**[20]**:**various poses are the problem of getting accuracy in face recognition, and in recent times it has been the focus of the central area of the research.
- **Occlusion**[21]**:**One of the main challenges is handling facial occlusion, among several problems connected with correct facial recognition. Facial expressions cannot be fully seen if a portion of the face is blurred, and detection by a recognition system is therefore jeopardized.
- **Illumination**[22]**:**Illumination is referred to as lighting differences where, due to lighting alteration, a face picture may look differently. Illumination significantly influences an image that results in a shift in position, shadow form, and contrast gradient reversal.
- **Expressions**[23]**:**Face-recognition technologies also influence human expressions resulting from the contraction of facial muscles..
- **Hair**[24]**:**Hair is sometimes used to conceal the forehead. As a result, many systems have neutralized hair in database images to prevent it from functioning as an obstruction to recognition.
- **Age**[25]**:**The problem of aging in the recognition system is seen as a form of variance in human faces within the class, which happens when there is a substantial time gap between the targeted face image of the same person.
- **Low resolution**[26]**:**Low-resolution problem arises when the test face's image has been significantlydegraded.
- **Appearance or nonappearance of structural components:** The standard features are mustaches, beards, glasses might be present, and there is a lot of variation among these components, such as appearance, color, and size.
- **Image point of reference and Imaging condition:** Facial images shift directly to rotations along the camera's optical axis.
- **Plastic surgery**[27]**:** Facial recognition methods do not recognise people's faces during the plastic surgery process.

3. Applications and Scenarios of face recognition

Recognition technique has been around since the 1960s, the recent advances in technology led to an enormous proliferation of this technology. Technologies for facial recognition will do more than recognise individuals today. We look at how facial recognition changes how various businesses operate now and, where appropriate, the promising possibilities it provides for the future, from business applications, commercial solutions, and even home solutions. Although this makes the technology an easy alternative for surveillance and authentication purposes, it can still support various sectors dynamically and repurposed. While some of these examples are still in active growth today, we can also highlight that many technologies are now proving to be an essential part of a category, challenging and transforming how people live, function, and play today.

Industry Segment areas[28]**:**Security companies use facial recognition to secure their premises, border protection and immigration checkpoints. Fleet management firms use it to secure cars and ride-sharing companies use it for passenger identification. IoT also benefits from facial recognition by providing better security and access control at home. Retailers use it to customize offers and track online buying patterns.

Law enforcement areas[29]**:**Facial recognition technology is used as a feature in AI-driven surveillance systems for law enforcement purposes such as video analysis, crime identification, offender tracking and forensic modernization. It is used to prevent and warn of potential offenses, recognize shopkeepers, monitor and prosecute offenders, conduct background checks, detect cheats and fraud in casinos, review events, detect welfare fraud, recover stolen items, and surveil criminal faces.

Security access control[30]**:**Face detection in environments where connectivity is extraordinarily secure and only to particular persons is highly used. Face recognitionis used to guarantee access control to facilities just for approved persons. Scenarios - Terrorism warning, safe flight boarding, stadium crowd screening, computer protection, computer application security, database security, encryption of files, intranet safety.

Wide-ranging individuality verification & Image database investigations[31]**:**Currently, many essential individual records, national documents, identity documents, passports rely on facial photographs of the individual to prove their identity. Scenario - License for drivers, entitlement services, immigration, national identity number, permits, registry of voters, and welfare rolls.

Forensic science[33]**:**In forensic science, recognition is an essential and key research focus. When no technology is usable, it is an essential activity done manually by forensic scientists. For law enforcement, as well as for comparative reasons, this may be useful.

Prevent Retail Crime[33]**:**Face recognition is currently being used to immediately recognise when known shoplifters, organized supermarket suspects, or individuals with a history of theft join retail establishments. Photographs of people can be compared against vast lists of offenders so that loss management and retail security practitioners can be immediately alerted anytime a shopper visits a store that removes a threat.

4. Face Recognition Systems

Facial recognition is the most focused biometric modality used in uncompromising circumstances. A concise summary of the challenges that need to be discussed and overcome to carry out the face recognition task correctly is critical before describing the techniques used. Various kinds of sensor types are used for data processing. These sensors can provide additional details and facilitate the detection of face images in both motionless and video sequences. Besides, the lighting variance, head orientation, and facial expression in a pure picture or video processing are three types of sensors that can better the trustworthiness and accuracy of face recognition.

i) Non-visual sensors - audio, depth, and EEG sensors - provide additional information and the visual component and improve recognition effectiveness in light variation and change of position.

ii) Precise facial sensors -sense a slight dynamic shift of a part of the face, such as eye-trackers, and help distinguish between the background noise and the images of the face.

iii) Target-focused sensors - infrasound sensors that filter useless visual content into FR systems.

A facial-recognition system's basic workflow

Capturing an image: The image has taken from a still or CCTV camera.

Image pre-processing: Image pre-processing makes use of image redundancy. The normalization, facial adjustment, and image enhancement are the form of pre-processing techniques.

Face Detection: From the whole image taken, the subject's face detects in this phase.

Feature Extraction: In this stage, the face template creates, and the relevant and unique features have been extracted from the observed face to match the corresponding images in the database.

Feature Selection: The best subset of the input function set is selected after feature extraction.

Matching: A prototype image with a database image. When the facial features match, then the individualwill test.

Verification/Identification: Final step is to recognise the person. These are the two primary tasks of facial recognition. If authentication is the goal, a ONE: ONE match is made, and a ONE: MANY matches are made for recognition and finally classifying the features [34].

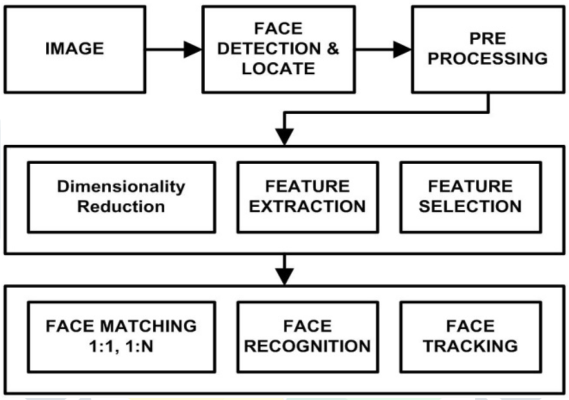


Figure 1: A generic facial recognition model

Face detection structure

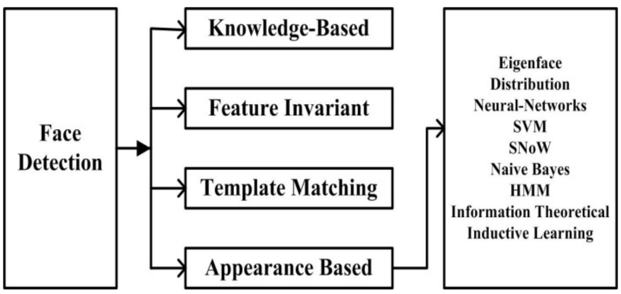
The objective of this strategy is to detect any human face available in the input image. The image is pre-processed after the face has been identified to obtain the area of interest and boost accuracy. FR is a concept that requires several sub-problems. These devices simultaneously identify and detect faces; others perform a recognition routine first and attempt to positively locate the face. Finding humanfaces in a given picture is the very first phase in the facial recognition process.

Many methods are used to identify and find human face pictures, especially the VJ - Viola- Jones detector, Histogram of the Oriented Gradient (HOG), and Principal Component Analysis (PCA).

Categories of Face Detection Methods

It has long been an issue to establish accurate face identification, and overcoming it is a crucial step towards other algorithms for facial processing. Since different face stances, contexts, additional lighting, and image quality can cause detection algorithms to fail, it's a challenge. Yang et al.[35]Surveyed these algorithms thoroughly and grouped them into four categories are shown in figure2.

Figure 2: Categories of Face Detection Methods



Face tracking

There is a video sequence in many facial recognition systems as the input. Such systems can include the ability to not only detect but also track faces. Face tracking's most basic approach aims to locate a specific image within a frame. Then to update the position of the face, it has to measure the variations between frames. Several challenges need to be addressed: partial occlusions, changes in lighting, computational speed, and facial deformation. Face monitoring is a topic of motion estimation. Many different approaches maybe used to do face tracking.

Feature Extraction

The process of extracting features can be defined as extracting relevant data from the input image. In the step of determining the subject with an appropriate error rate, this information must be helpful. This process aims to obtain the characteristics of the detected face images and represents a face with a vector collection of features defines with its geometry distribution the prominent aspects of the face image. Each face is defined by its structure, height, and form, allowing it to be recognised. In terms of processing time and memory consumption, the function extraction process must be successful. Extraction of features requires multiple steps - reducing dimensionality, extraction of features, and selecting features. In every pattern recognition method, dimensionality reduction is an important activity.

Feature selection

Feature selection algorithms choose the relevant features and ignoring non-relevant features. Following feature extraction, feature selection is performed. Therefore, characteristics are derived from the face images, and then an ideal subset of these characteristics is chosen. The collection of features is an NP-hard problem, so researchers propose a practical algorithm rather than an optimal one. The aim isto select another very desirable subset of features while reducing dimensionality and complexity.

Face classification

After the features have been extracted and chosen, the image must be identified. These algorithms based on appearance employ a variety of classification methods. For better results, two or three classifiers are often combined. Classification techniques are used in an assortment of areas like mining and data processing.

Learning-supervised, unsupervised, or semi-supervised-is usually required by classification algorithms. Due to the lack of tagged instances, unsupervised learning is the most challenging method. Many face-recognition devices, on the other hand, use an ordered group of people. As a result, supervised learning methods are used in the majority of face-recognition software. It is not uncommon for the collection of new tagged samples to fail. It necessitates semi-supervised instruction.

According to Jain, Duin, and Mao [45], there are three principles- similarity, probability, and decision boundaries. Table.2summarizesthe methods in face recognition.

Table 1. Various methods of Face Recognition Stages.

face recognition stages	
feature extraction	
feature selection	
face classifier	similarity based
	probabilistic based
	decision boundaries

5. Classification of Two-Dimensional Face Recognition Approaches

A typical 2D-FR system works on input sources taken from supervision systems, commercial/personal cameras, CCTV, or other commonplace devices. The device must first detect the face in the input source, from the detected region. Features extracted from the pre-processed image and appropriate classification systems based on the deliberate characteristics used to perform final identity recognition.

Based on the essence of the extraction and classification processes, the current procedures can be categorized into local, holistic, hybrid, and deep learning approaches.

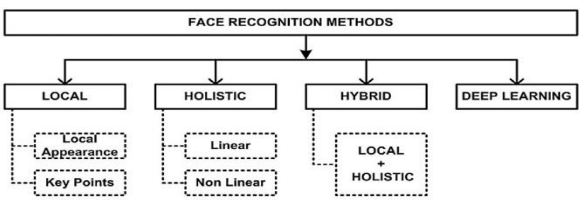


Figure 3: Classification of 2D Face Recognition Approaches

Local approaches:

The primary aim of the technique is to identify distinguishing features that can be divided,i) local appearance-based techniques - to remove local features when the face picture is divided into small regions [47]. As shown in Figure.4, local appearance methods steps are notified. ii) key-point-based techniques - define points of interest in the face image, during which the extraction of features, includingBRIEF, SURF, and SIFT, is located based on these points.

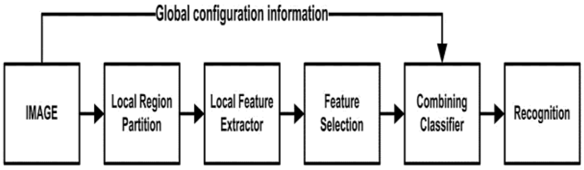


Figure 4: Framework of local appearance-based methods

The most considerable value of these feature-based local approaches is their relative robustness. The notified drawbacks of these approaches are the complexity of automating the identification of facial expressions and the fact that an arbitrary judgment on vital points must be taken by the individual responsible for applying these methods.

Holistic approaches:

Faces are represented using several subspace techniques divided into linear and non-linear approaches. The notable benefit of holistic methods is that they do not destroy image knowledge by concentrating only on regions or points of interest. On the other hand, this principle has a disadvantage since all picture pixels are of equal value. As a result, these techniques are prohibitively costly and provide a high correlation between the test and preparation sources. Geographic specifics typically overlooked by these methods, which means they are infrequently used to classify names.

Hybrid approaches:

Hybrid methods integrate local and holistic approaches for improved recognition under varying lighting and facial features. They merge the advantages of both for efficient and accurate identification.

Deep Learning approaches:

Deep learning-based face recognition (DCNN) performs better on longer tasks and has improved recognition performance compared to traditional methods. It also shows robustness in variations such as posture, position, and occlusion. However, it still has barriers such as the need for large-scale training data and advanced hardware.

Depending on how the methodology and architecture are used, deep learning can be divided into three major groups: unsupervised or generative (autoencoder, recurrent neural network), supervised or discriminatory, and hybrid. Several pieces of data for classification are expected to discriminate between deep discriminatory architectures or supervised learning. The best example of supervised learning is CNN; it encourages outstanding architecture and design skills for identifying pictures.

The popular CNN Architectures are LeNet, AlexNet, VGGNet, GoogleNet, ResNet, and SENet.Some of the most commonly available public data sets for CNNs are, CelebFaces+, UMDFaces,CASIA-WebFace, VGGFace, MegaFace, MS-Celeb-1M.

The techniques are DeepFace, Deep Identification, DeepID2+, DeepID3, Google-FaceNet, VGGFace, Multinomial logistic regression learning (MLR), L-Softmax, Noisy Softmax, feature transfer learning (FTL), L2-Softmax loss, Large margin Cosine loss (LMCL), attention-based neural network (ACNN), Pairwise Differential Siamese Network (PDSN), Inter-class Angular Margin (IAM), RotationConsistent Margin (RCM), Discriminative and Specialised Discriminative Large Margin Cosine.

Some benefits and drawbacks of holistic, local, hybrid and deep learning approaches to recognising faces are described in Table.3.

6. Performance Measures in Face Recognition

Depending on the application, an automated face recognition system activates in verification mode or identification mode. Verification mode (1:1)[49] determines the identity of an individual. The device carries out a one-to-one analysis to determine if the asserted identity is real or false. Authentication is usually used for affirmative identification to prevent multiple people from using the same name.

The performance evaluated by, False accept (FA) / false match (FM), false positive (FP), or TYPE-I error. False reject (FR) / false non-match (FNM) or false negative (FN) or TYPE-II error. The receiver operating characteristic (ROC) is classically tested by face verification systems with two types of errors: (1) True Accept Rate (TAR) (2)False Accept Rate (FAR), and the estimated mean accuracy (ACC).

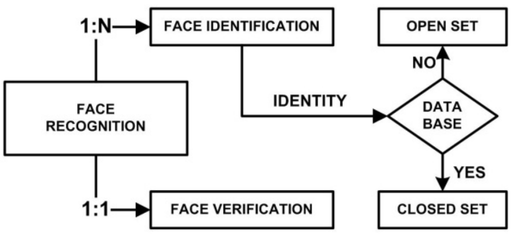


Figure 5: Face matching assessment protocols

TAR - The fraction of relevant comparisons that correctly exceed the similarity score. (threshold):

$$TAR = TP / (TP + FN) \quad (1)$$

FAR - the fraction of the comparison between impostors incorrectly exceeding the threshold level:

$$FAR = FP / (TN + FP) \quad (2)$$

ACC - a simplified statistic that indicates the percentage of proper classifications:

$$ACC = TRUE\ METRICS - (TP + TN) / ALL - (TP + FP + TN + FN) \quad (3)$$

(TP: True Positive - FN: False Negative)

The system identifies a person in the identification mode (1:N) [49]. Identification is a necessary task for dangerous applications for recognition; the purpose of such a method is to avoid multiple identities by single individuals. Open-set and closed-set study protocols can be used in two different cases[50]. The primary output of the calculation reported by Cumulative-Match-Characteristics (CMC) curve using accurate recognition rates. The FN identification rate (FN-IR) and the FP identification rate (FP-IR) are generated in the open-set face recognition case to measure the model's precision. A valid user identifier returns within the N-Top matches; Rank-N is an essential efficiency factor used to measure the model's accuracy.

7. Conclusion

Face recognition (FR) is a prominent research subject in computer science due to its technically vast appliance and theoretical significance. This paper is extensively used in empirical face recognition and various real-world applications, including security, protection, enforcement agencies, authentication, searching and database, human-machine interaction, and entertainment. The whole paper provides insights into the various stages of generic face recognition. It highlights current findings on the 2D face recognition process, focusing on local, holistic (subspace), hybrid, and deep learning approaches. It has finally compared all the approaches' benefits and limitations.

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