Face Recognition Research: A History of Advancement

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Abstract. Face recognition technology has come a long way in the past three decades and is now one of artificial intelligence's most pressing research questions. The technology of face recognition has already been used in the field of financial transactions. In the future, it will find increasing application in various spheres of life and work. This not only needs to make the algorithm for the face recognition technology more practical, but it also needs to make the algorithm more efficient continuously. In addition, it is essential to improve recognition accuracy, which is a task that still needs to be completed.

Keywords: Face recognition, artificial intelligence, recognition accuracy, efficiency.

1. Introduction

Face recognition technology uses computers to analyze the face image, using different methods to accurately calculate the face features of other people to achieve the recognition function. Technology for face recognition has been applied in a wide range of industries, including public safety, transportation, banking, education, and entertainment [1].

Tab. 1 Important areas where face recognition technology is used:

Public safety	Searching for lost persons, detecting wanted fugitives
transportation	'Face-brushing' at the railway station
finance	face payment
education	face payment
entertainment	interactive games, face video stitching and segmentation, etc

As facial recognition technology advances, we anticipate using it in other fields, including the military, information security, and encryption. Many important activities will become simpler when facing recognition algorithm accuracy increases in the current field. For instance, monitoring fugitives can be based on big data to identify fugitive information more rapidly and make the best decision possible in the shortest amount of time. The fact that people have been inventing and patenting throughout the past few decades and that the quantity of patent applications has changed to mirror the history of technology from emergence to maturity and ageing is the source of the optimistic outlook we have maintained throughout this piece. Figure 1 depicts the trend in the number of domestic and international patent applications over time. Globally, the number of patent applications has been increasing; since 2012, the number of applications has surpassed 1,000 annually. Nowadays, the number of face recognition patents worldwide has reached more than 120,000, with China, the United States, South Korea and Japan being the four cities with the highest number of applications.

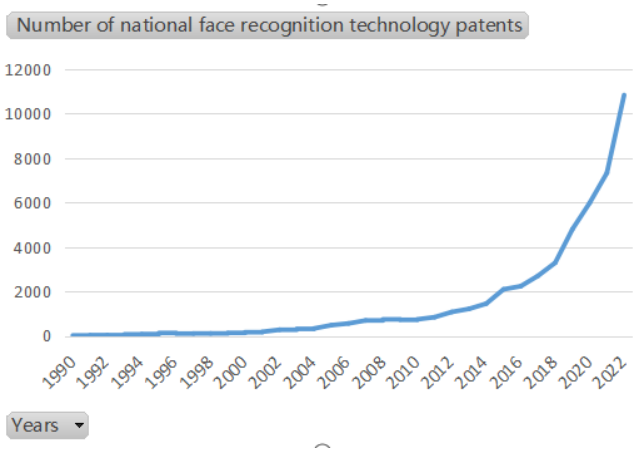


Figure 1 The development of patent applications for face recognition (Photo credit: Original)

Face recognition technology has been researched for more than 60 years of history in Western countries; face recognition technology development so far, researchers have proposed many methods, which have become more and more practical; for example, Research methods based on geometric features, subspace, and deep learning. Many problems were overcome in the research process, such as Facial features, lighting, and occlusion problems. But when most face recognition methods When applied to the actual situation, The success rate is usually lower than expected. The main reason is that in practice should In use, lighting conditions, face rotation Angle, expression, and Changes in factors such as hairstyles and backgrounds have resulted in training vs Identifying mismatches between data to shadow the Ring recognition algorithm performance significantly [2].

In the past 20 years, Deep face recognition has advanced significantly and has seen a lot of use in practical applications thanks to the development of deep learning technologies and large-scale data sets. However, there are still some problems that need to be solved. Face recognition technology is a problem worth further study; in this article, we will review face recognition technology since the development of various issues and how to solve the scholars; we will also analyze the existing challenges and development prospects.

This paper aims to make it more convenient for future scholars to analyze and hope that face recognition technology can become more mature and popular.

2. Development history

We hope that this article can make it easier for future researchers to investigate face recognition technology and that it can become more mature and more popular. In this research, we categorize the development of face recognition technology into four phases and analyze a few fundamental discoveries.

Tab. 2 The history of face recognition technology:

Primary stage (1965s-1990s)	Geometric Features-based Face Recognition Method [3]
Classical algorithm appearance stage (1991s-1997s)	Linear discriminant analysis-based face recognition method [4]
Manual feature extraction stage (1998s-2013s)	illumination cone [5] Gabor-Fisher Classifier [6]
Deep learning stage (2014 until now)	Deep Convolutional Neural Networks [7] AlexNet [8] Face Boxes [9]

2.1. Geometric Features-based Face Recognition Method

It is believed that the geometric features-based approach, which Sirovich and M. Kirby proposed in 1987[3], was the first face recognition technology to be successful. The author defines a collection of feature vectors utilized in machine vision for face recognition using the term "feature face," which the author also introduces. The covariance matrix of the facial image is utilized in the computation of these feature vectors, which take place in a high-dimensional vector space. Additionally, it has been suggested that the faces should be written into the coordinate axis through the method formula, through the grayscale size of the face, to recognize it (Figure 2). However, there needs to be a more practical use of the featured face. That problem is that the recognition rate will be significantly reduced under various lighting conditions and imaging angles. As a result, using feature faces should prevent users from relying on positive images for recognition under conditions of uniform lighting [14].

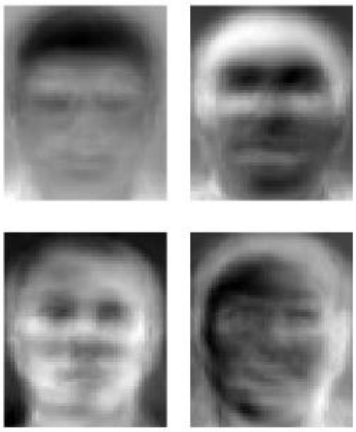


Figure 2 Detect face features by grayscale(http://www.cl.cam.ac.uk/research/dtg/attarchive/)

2.2. Linear discriminant analysis based face recognition method

LDA, a paper presented at the Neural Information Processing Systems conference [4], authored by David Blei, Andrew Y. Ng and Michael Jordan, shows that when data is projected into a low-dimensional space by applying the linear discriminant analysis (LDA) principle of face recognition methods, the same types of data are as compact as possible and different types of data are as scattered as possible, which has been shown to have a significant impact on various areas of machine learning. Linear discriminant analysis is the basis of the FisherFace algorithmic approach (LDA). When considered as a set of coordinates in a high-dimensional space, each pixel in an image can be regarded as an independent point. It creates well-separated classes in the low-dimensional subspace and places specific facial appearances in the three-dimensional ionic linear subspace of the high-dimensional image space [10]. This ensures that accurate face recognition is maintained regardless of lighting conditions. However, the FisherFace algorithm has only been proposed for people who are largely unaffected by changes in facial features, meaning that more thought needs to be given to the relationships between individual distributions of samples [12]. Another study from this period experimented with face recognition using visible and thermal infrared images. The results showed that the performance was often better with thermal infrared images, and in some cases, the performance was the same in both modes [15].

2.3. Illumination Cone Models

Over the past two decades, standard face recognition technology has been challenged to become more resilient against shifts in illumination and posture brought on by less-than-ideal acquisition conditions or incompatible objects. As a result, characterization and perspective are gradually becoming the research focal points. Geovghiades came up with the idea of using an illumination cone to solve the problem of face recognition in varying lighting conditions and angles. The 3D information of the input face can be estimated using this method based on multiple (at least three) input images

with the same attitude but differing lighting conditions. This method is a modern take on the more traditional photometric stereo technique. It estimates the illumination, the three-dimensional face shape, and the surface point reflectance by iteratively using SVD. Finally, it uses prior knowledge of the three-dimensional face shape distribution as a constraint to solve the three-dimensional face shape [5]. For example, symmetry, the nose being the nearest point, etc.

2.4. Gabor-Fisher Classifier

[6] This paper introduces a new Gabor Fisher (1936) classifier (also called GFC) for face recognition. The GFC method is robust to changes in illumination and facial expression. An extended Fisher linear discriminant for the extended Gabor feature vector was obtained from the Gabor wavelet representation of the face image. Model (EFM)) is applied. As a result, a highly accurate method is achieved. The novel contributions of this paper are 1) derivation of the extended Gabor feature vector with further dimensionality reduction considering data compression and recognition (generalization) performance with EFM, 2) development of a Gabor-Fisher classifier for multi-class problems, and 3) extensive performance evaluation studies. In particular, similarity and difference were investigated in terms of similarity measures and their application to classifiers. Furthermore, comparative experiments have been conducted on various face recognition strategies, including the newly developed GFC method, the Gabor wavelet method, the Eigenface method, the Fisher face method, the EFM method, as well as combinations of the Gabor and Eigenface methods and the Gabor and Fisher face methods. Face recognition was successfully carried out to test the practicality of the novel GFC method. Two hundred frontal face images corresponding to 600 subjects from the FERET database were used for the tests. These images of subjects with different facial expressions were taken and digitally processed under different lighting conditions. With only 100 features, the innovative GFC method achieved a face recognition accuracy of 62%. In 2006, researchers presented a novel patch based GFC (PGFC) method, significantly increasing the algorithm's processing speed [11].

2.5. Gentle AdaBoost

A typical face detection technology techniques is discussed in this literature[20]. One of the early efforts on face identification prior to the advent of deep learning is the Viola-Jones face detector, which combines a variant form of AdaBoost classifiers called Gentle AdaBoost with Haar characteristics to create a cascaded structure. This research has a high accuracy rate and can accomplish basic item detection, which is crucial for the initial phase of face recognition technology. High brightness, however, will make this approach appear to detect dislocation.

2.6. Deep Convolutional Neural Networks

The term "DCNN" refers to a process in which manual design features are gradually replaced with end-to-end autonomous learning features over time. Local connection, weight sharing, pooling, and multi-network layer are the four essential technologies that make up DCNN. These four technologies allow DCNN to realize end-to-end independent learning and produce high-level and abstract feature representation vectors.

Practicability: Recognition accuracy has been significantly increased and is now widely used. On the other hand, the currently utilized face recognition method still has the following issues: There is a significant demand for supervised learning.

Quantity label sample: There has not been a significant advancement in theoretical research. Adjustments based on manual experience and intuitive reasoning are required for DCNN issues such as overfitting and gradient instability. It can't be a teeny-tiny network at all. Otherwise, it is simple to appear to have the best possible solution locally. The amount of time spent in training is substantial, and the amount of money spent on computing resources is significant [7,13].

2.7. AlexNet

Alex Krizhevsky made the initial suggestion for AlexNet in 2012[8]. It solved the gradient dispersion problem that Sigmoid had in deep networks, demonstrated that ReLU's effect was superior to that of Sigmoid in deep networks, and successfully deployed ReLU as the activation function of CNN by employing data augmentation. To make the model more applicable to real-world phenomena, "local response normalization" is proposed as a method for producing a competitive mechanism for the activity of local neurons. This is done to expand the model's applicability. This process increases the values of neurons with relatively high responses while inhibiting the activity of other neurons with relatively low feedback.

As a result of the development of deep learning technology, the face recognition algorithm's recognition accuracy has reached 99% under ideal conditions, comparable to the accuracy of human eyes. However, under complex needs, such as lighting, angle, expression, age, and other factors, the system's robustness and accuracy are significantly lower than that of human beings, which is especially true in situations where multiple factors are at play. Under less-than-ideal conditions and when cooperation is unavailable, the performance of the face recognition method needs to be improved, which will require additional research to be carried out in the future.

2.8. Face Boxes

The effective models used for face detection are frequently computationally slow, so one of the challenges that still need to be overcome is achieving real-time speed while maintaining high performance on the CPU， which is even though face detection has come a long way in recent years—a novel face detector known as FaceBox has been proposed to solve this problem. FaceBox boasts superior performance in terms of both speed and accuracy. To be more specific, their method utilizes a network structure that is both lightweight and powerful. This structure comprises a fast-digesting convolutional layer (RDCL) and a multiscale convolutional layer (MSCL). The purpose of the RDCL is to make it possible for FaceBox to improve its real-time performance on the CPU. The Multiscale Statistical Characteristics Library (MSCL) aims to enrich the perceptual field and discretize the anchor points onto different layers to handle different face scales. In addition, they suggest a new strategy for anchor densification, a method that enables various kinds of anchor points to have the same density on an image.

Consequently, the proposed detector can process VGA-resolution images at 125 frames per second when using the GPU, while it can process images at a rate of 20 frames per second using a single core of the CPU. In addition, the speed of FaceBoxes is not affected by the total number of faces In the database. They conducted an exhaustive analysis and demonstrated state-of-the-art detection performance across various face detection benchmark datasets [9].

3. Conclusion

In this article, we have introduced several achievements made by face recognition technology from its development to the present day. In short, face recognition technology, one of the very important technologies of artificial intelligence, is helping people in many different fields. However, some problems still need to be researched and improved.

Main problem One is the problem of illumination. Due to the three-dimensional structure of the face, shadows are created by light, which either emphasizes or weakens the original facial features. Especially at night, the recognition rate drops dramatically due to shadows on the face caused by insufficient light, making it difficult to realize a practical system. The second is the problem of facial expressions and gestures: research began in the 19th century, and Darwin elaborated on the relationships and differences between human and animal facial expressions in 1872[17]. In 1971, Ekman and Friesen studied the six basic human facial expressions (happiness, sadness, surprise, fear, anger and disgust), identified the categories to be recognized and systematically built a database of thousands of images of different facial expressions, work that would pioneer modern facial expression

recognition[18] In 1978, Suwa Suwa made the first attempt to recognize facial expressions on video animations of human faces and proposed an automatic analysis of facial expressions in image sequences. Automatic analysis[19], followed by optical flow to determine the main direction of muscle movement by K. Mase and A. Pentland Expression recognition using the optical flow method proposed by Mase and A. Pentland, ushered in a new era of automatic expression recognition. As technology advances and psychology continues to develop, the study of facial expressions will become more and more in-depth, from facial contours to muscle tremors, and the next research will focus more on micro-expressions, which will be used to cope with more subtle facial changes and make the algorithm's recognition more correct. Thirdly, the problem of plastic surgery and makeup is a relatively new topic. At present, the accuracy of face recognition decreases significantly after plastic surgery, which makes many criminals escape from the law through plastic surgery, which is a major problem concerning security. There is yet to be a good solution, and people need further research[16].Large-scale, open-faced datasets are urgently needed. Especially under the current deep learning-centred AI R&D model, software development will gradually move from the traditional software era to a data-centred data era: in 2018, the most practical face test dataset, the LFW dataset, will be revamped in terms of recognition rates and now there is also Columbia University's public face dataset - PubFig, which contains 200 face images, all with high transparency. The Large-scale CelebFaces Attributes (CelebA) Dataset, a large face recognition dataset containing 200,000 face images with more than 40 facial attributes, published by Professor Xiaogu Tang's laboratory at the Chinese University of Hong Kong, and The Colorferet, which consists of more than 1,000 photographs. However, existing face recognition systems cannot accurately recognize datasets of more than one million people. Existing face recognition systems cannot accurately recognize datasets of more than one million people. Therefore, there is an urgent need for more challenging public face datasets in the future.As more and more people use face recognition technology, people's facial information is stored in various fields where face recognition technology is applied, most importantly in the payment field, which is a big challenge for cyber security as the possibility of our information being stolen is increasing. A more secure system is needed to protect our property and privacy from being stolen. Existing commercial face recognition systems do not meet such needs.

In general, the market share of facial recognition technology will continue to expand in the future for an extended time, and its use will become increasingly widespread. This article presents a chronological breakdown of various significant approaches to facial recognition in the hope that it will stimulate new lines of inquiry for scholars in the future. In conclusion, we need to protect ourselves from the dangers posed by facial recognition technologies. We need to understand the value of face data, enhance privacy self-protection awareness, and stop the disclosure of private information as soon as possible to improve the use of human biological information, including the laws and regulations governing face recognition. In addition, when we collect data on faces, we need to be aware of the potential uses and risks involved.

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