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The development history and future prospects of artificial intelligence in facial recognition technology

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Abstract. In recent decades, with the fast development of various algorithms and the rapid improvement of computer hardware performance, the development of facial recognition technology has been very rapid. This technology used to only appear in science fiction movies, but now it has been widely used in mobile payments, identity recognition, and other fields, and it also has very reliable performance. This article introduces the different facial recognition methods used in different periods of facial recognition technology from the 1960s and 1970s to the present day, to help people understand the development process of facial recognition technology. Among them, the focus is on early methods based on geometric features, grayscale information, and feature extraction, as well as recent applications based on deep learning and convolutional neural networks. In response to some challenges faced by current technology, some speculations on possible future development directions are proposed.

Keywords: Artificial Intelligence, Facial recognition technology, Deep learning, machine learning, Feature extraction.

1. Introduction

As a biometric technology, facial recognition has simpler requirements for devices compared to identifying identity through fingerprints or iris. It only requires a mobile phone with basic camera functions and corresponding software to complete facial recognition. Moreover, compared to fingerprint or iris verification methods, facial recognition can reduce people's contact with devices in public places. It can reduce the health risk of infectious diseases through contact detection devices. For most people, they are also more willing to use facial recognition methods to verify their identity psychologically.

As one of the important applications in the field of artificial intelligence, facial recognition technology has made significant progress in recent years. Early facial recognition methods mainly relied on geometric features and grayscale information, but they did not perform well in dealing with lighting, posture, and occlusion.

However, with the rise of deep learning technology, face recognition methods based on convolutional neural networks have become mainstream, greatly improving the accuracy of face recognition and the ability to cope with interference. However, current facial recognition technology still faces issues such as poor data quality, as well as privacy and security protection.

Therefore, this article aims to sort out the development history of facial recognition technology, analyze some existing problems of current facial recognition technology, explore possible

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development directions of future facial recognition technology, and provide some reference for solving some challenges that this technology still needs to face.

2. The development history of facial recognition technology before adopting artificial intelligence technology

Face recognition technology started in the 1960s and 1970s. Before introducing AI-related technologies into face recognition technology, researchers explored many solutions to achieve a stable and reliable face recognition method. Some of these solutions have performed quite well under ideal conditions, but still have problems with poor robustness and easy to be disturbed.

Although these methods did not perform well in practical applications, they laid the foundation for the later application of artificial intelligence technology in the field of facial recognition and inspired the development of subsequent technologies.

Among them, there are three representative methods in different periods.

2.1. Early geometric feature-based methods(1970s--1990s)

Face recognition based on geometric features is an early method of face recognition technology. It mainly analyzes the relative position and distance between people's eyes, nose, mouth, and other highly personal characteristics to distinguish between different faces [1].

Its principle is not complicated. Firstly, it needs to locate the position of the eyes, nose, etc. in the face image. Then calculate the distance and proportion between them. These distances and proportions are usually referred to as the geometric features of the face. Then describe each face by combining the distance and proportion into a feature vector. This feature vector is a simplified representation of the geometric structure of the face, mainly used for subsequent recognition and matching. Finally, use these feature vectors for template matching or classification to identify or verify the face. In template matching, the system compares the similarity between the feature vector of the input face and the known face feature vector stored in the database, thereby determining the identity of the input face.

This geometric feature-based method is very simple and easy to understand. However, it is easily affected by factors such as lighting, pose, and occlusion, resulting in low accuracy in practical applications [2].

2.2. Method based on grayscale information(1980s--1990s)

The face recognition method based on grayscale information mainly identifies different faces by analyzing the grayscale of the face and comparing the grayscale of different regions. Specifically, they can use edge detection techniques to extract facial contours and texture analysis techniques to capture subtle texture features on the surface of the face.

By comparing and matching the extracted edge and texture features, these methods can recognize and validate faces. Compared to methods based on geometric features, methods based on grayscale information can better cope with factors such as lighting and pose changes, improving the accuracy of face recognition. However, this method requires high image quality and is also easily affected by facial occlusion.

2.3. Feature extraction based methods(1990s--2000s)

Face recognition methods based on feature extraction are used to distinguish different faces by analyzing local or global features in face images. These features can be key points, textures, shapes, etc. Common methods include local binary patterns, Gabor filters, Haar features, and artificial neural networks.

By extracting and quantifying these features, and then using machine learning algorithms for classification or matching, facial recognition or verification can be achieved. Compared with traditional geometric feature extraction methods, feature extraction-based methods are more flexible and can better adapt to face recognition tasks under different lighting, pose, and occlusion conditions [4].

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However, this method also has problems such as high computational complexity and poor anti-interference ability.

3. The application history of artificial intelligence in facial recognition

With the development of AI-related technologies and the continuous improvement of computer hardware and software functions, face recognition technology has begun to introduce AI technology to help improve its performance. It is also AI that has enabled face recognition technology to reach the level that can be applied on a large scale today [5].

The following will introduce how face recognition technology has developed into a very complete and mature technology step by step after the introduction of artificial intelligence technology.

3.1. Support Vector Machines (SVM) and other machine learning algorithms (early to mid--2000s)

Around 2000, with the explosive growth of data and the improvement of computing power, artificial intelligence developed rapidly and gradually began to be applied in the field of facial recognition. SVM was the most high-performance algorithm at that time.

SVM is a supervised learning algorithm whose main idea is to separate data of different categories by finding an optimal hyperplane, maximizing the interval between two categories, and thus achieving accurate classification of new data.

SVM can be used to train a classifier to classify different facial images into different categories. By extracting features from facial images and using them as input, SVM can learn the differences between different faces and recognize corresponding person identities in new facial images [6].

The application of SVM in the field of facial recognition has been widely studied and applied. Compared with early facial recognition algorithms, its advantages include effective processing ability for high-dimensional data, good stability for outliers, etc. However, this algorithm still has high complexity and is not suitable for multi-classification problems.

3.2. Methods based on deep learning and the application of convolutional neural networks (2010s--present)

Since the 2010s, the development of deep learning technology has brought major breakthroughs in face recognition, especially AlexNet's great success in the 2012 ImageNet image recognition challenge. The emergence of AlexNet marked the beginning of deep learning's important role in the field of computer vision. In 2014, Facebook proposed the DeepFace system using deep learning technology to achieve efficient face recognition, marking the successful application of deep learning in the field of face recognition.

Among them, the application of Convolutional Neural Networks (CNN) in face detection and recognition has become mainstream. CNN can extract rich feature information from facial images and achieve efficient classification and recognition through multi-level convolution and pooling operations.

Its advantage lies in the ability to automatically learn feature representations of images, without the need for manual feature design. In addition, the CNN model has a small number of parameters, and the training process can be optimized end-to-end through a backpropagation algorithm, making the model more accurate and efficient [9].

With the continuous progress of deep learning technology, CNN-based face recognition methods are also constantly evolving. For example, using multi-task learning to simultaneously handle face detection and recognition tasks, and introducing attention mechanisms to improve the robustness and generalization ability of the model. In addition, by combining transfer learning and data augmentation methods, the performance of the model can be further improved when the data volume is small [10].

In summary, deep learning-based methods, especially the application of convolutional neural networks, have brought significant progress to facial recognition technology and provided important technical support for achieving more accurate, fast, and robust facial recognition.

4. Current technical challenges and future prospects

One of the challenges currently faced by face recognition technology is data quality and sample bias. Images in the dataset may have various noise, blur, and occlusion issues, which can easily affect the performance and accuracy of the model [11]. On the other hand, the imbalance and bias of data samples is also a challenge. The number of samples in different categories in the dataset may vary greatly, resulting in insufficient learning of the model for the less common categories. In addition, there may be biases in data collection, such as insufficient data collection for certain categories, which affects the generalization ability of the model [12]. At the same time, face recognition technology involves personal privacy and data security in the collection, storage, and use of face data. Without strict protection measures to protect personal information, it is easy to cause leakage and abuse of personal information [12].

The current face recognition technology faces many challenges, among which data quality and sample bias are one of the main problems. One possible future development direction is to improve the quality and diversity of datasets through data augmentation and cleaning technologies. Image processing techniques can be used to remove noise and blur in images while generating richer data samples through data synthesis and enhancement techniques to improve the performance and robustness of facial recognition training models [13].

On the other hand, exploring methods such as sample balancing and transfer learning is also an important way to solve the problem of data bias. Transfer learning can utilize existing large-scale datasets and models to effectively learn and identify small samples or specific domain data, thereby improving the model's generalization ability.

In addition, the optimization of deep learning models may also be one of the key directions in the future. By designing network structures that are more suitable for complex scenarios and diverse data, as well as studying new loss functions and regularization methods, the robustness of models to noise, occlusion, and other problems can be improved, thereby improving recognition accuracy.

Privacy protection and security protection are also important in the future development of face recognition technology. Strengthening privacy protection and security measures for face data to ensure the reliability and security of face recognition systems is a problem that must be considered and faced in the practical application of face recognition. In the future, there may be more sophisticated algorithms for encrypting face data to prevent users' face data from being used by others [14].

In summary, future facial recognition technology will develop towards improving training data quality, enhancing model robustness, and privacy protection, in order to achieve faster, more accurate, and secure facial recognition systems.

5. Conclusion

This paper reviews the development process of facial recognition technology before and after the adoption of artificial intelligence technology. It can be found that facial recognition technology has made tremendous progress under the promotion of artificial intelligence, but there are still many problems that need to be solved, such as data quality and sample bias issues, data sample imbalance and bias issues, as well as personal privacy and data security issues.

In order to achieve more accurate, fast, and secure facial recognition systems, future research directions in facial recognition technology may mainly focus on improving data quality, optimizing deep learning models, strengthening privacy and security protection, etc., to meet the growing demand of users for facial recognition technology.

Through cooperation between different disciplines and continuous technological innovation, I believe that face recognition technology will surely achieve greater breakthroughs and progress in the future, and reach new heights.

There are also some shortcomings in this paper. Some related papers may not have been found due to their age or language niche, so there may be incomplete reviews of certain development processes in this paper. Especially regarding the introduction of early facial recognition methods, there were many different expressions and implementation methods based on grayscale information in many different papers at that time, and the performance evaluation methods of these methods were also different. Therefore, the method I introduced may not be the most representative and best-performing method at that time.

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