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Analysis of face recognition technology based on deep learning

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Abstract. The emergence of face recognition technology has brought great convenience to human society. After years of research and improvement, face recognition technology has matured. This paper mainly studies face recognition technology based on deep learning, and introduces five main applications, including occlusion face recognition, 3D face recognition, and expression recognition. The typical algorithms listed show that, compared with the traditional feature face algorithms and local binary patterns, algorithms such as DeepFace, FaceNet, ResNet, etc. have made significant progress in recognition efficiency and accuracy in recent years. After combining the development status of face recognition technology with the problems and security risks of the current technology, this paper proposes three solutions: increasing the amount of data, optimizing the model, and government control. In the future, legal data sharing and code open source will be major progress in this field, and dynamic face recognition technology will also be widely used.

Keywords: deep learning, face recognition algorithm, problems and solutions, prospects

1. Introduction

The development of face recognition technology can be traced back to the 1960s. At that time, face recognition mainly relied on artificial methods for feature extraction, but due to various limitations of artificial and early computers, the accuracy and efficiency of recognition were not high. With the continuous innovation and development of computer technology and image processing technology, face recognition technology initially entered the application stage in the late 1990s. Since then, the United States, Germany, Japan, and other countries have mastered the cutting-edge algorithm of face recognition technology. Later, the rise of deep learning technology has also improved the accuracy of face recognition technology, and face recognition algorithms based on deep learning have become one of the most popular mainstream research topics. This paper mainly focuses on face recognition technology based on deep learning. By reading a large number of papers, this paper summarizes deep learning and its application in the field of face recognition, lists some face recognition algorithms and the challenges faced by this technology, and finally gives some reasonable solutions. It is of great significance to promote the research and application of this field, academic communication and development, and the standardization and legalization of technology.

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2. Face recognition and deep learning

2.1. Deep learning

As a branch of machine learning, deep learning has become the most popular research direction, and its introduction makes machine learning more inclined toward artificial intelligence. Deep learning itself is also a combination of theoretical knowledge and technology. Its purpose is to imitate the neural network of the human brain, and learn the internal laws of sample data through the combination of multi-layer neural networks, so as to have the ability to organize images, words, and sounds [1]. With the emergence of high-performance hardware devices and massive sample data, the bottleneck of training efficiency has been broken. Deep learning has been widely used in natural language processing, machine translation, image classification, object detection, and other technologies.

2.2. Application of deep learning in face recognition

In recent years, deep learning has become more widely used in the fields of computer vision and image processing. As one of the technologies that integrates knowledge from multiple research fields, face recognition is also maturing due to the development of deep learning. As a new biometric recognition technology, face recognition technology is more convenient and flexible in application compared with other feature recognition technologies. The technology is widely used in medical, security, schools, public security systems, and other fields, from companies and schools to punch time and attendance to military departments and national defense units. However, in real scenes, face recognition technology faces more obstacles. Due to the influence of illumination, occlusion, pose change, clarity, and other factors, face images will have strong complexity and instability, which brings great challenges to face recognition technology. The face recognition algorithm based on deep learning has become an advanced technology in the industry. These algorithms can read and learn high-level features of face images, resulting in high recognition accuracy and robustness [2-3].

There are several main applications of deep learning [4-8]:

(1) Face recognition technology based on deep neural network;
(2) Occluded face recognition technology based on deep learning;
(3) 3D face recognition;
(4) Facial expression recognition technology based on residual network;
(5) Face pose change detection;

3. Traditional face recognition algorithms

3.1. Eigenface method

The eigenface method extracts facial features based on the principal component analysis of the face image, and the eigenface method converts the training image into a basic image, that is, an eigenface. Eigenfaces can also be viewed as a linear combination of original images. The method of face recognition using eigenfaces was proposed by Sirovich and Kirby and then used by Turk and Pentland for face classification. This method is considered to be the first effective face recognition method.

The implementation process of the eigenface method (figure 1):

3.1.1. Dataset preparation. A dataset containing multiple grayscale face images of the same size needs to be prepared. Each image in the dataset was taken under the same lighting conditions, and has been pre-processed, such as normalization and alignment.

3.1.2. Compute the average face and eigenface. Compute the average face image by dividing the sum of the pixel values of the face images by the number of images, which represents the average appearance of all the faces in the dataset, then calculating the eigenfaces in the dataset by principal component analysis. Eigenfaces are computed from the covariance matrix of face images in high dimensional vector space.

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3.1.3. Calculate the projection and recognize the face. The projection coefficient is obtained by calculating the difference between the face image and the average face and the inner product of the eigenface. When a new face image needs to be recognized, the image only needs to be projected into the eigenface space, and the face image with the smallest distance is the final matched face.

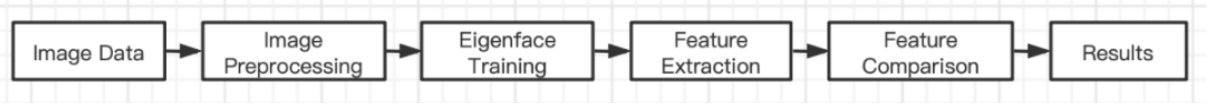

Figure 1. Implementation process of eigenface method.

However, there are many limitations of the early eigenface method, for example, the recognition accuracy can be greatly reduced due to some uncontrollable factors such as attention intensity, face pose and Angle.

3.2. Local Binary Pattern (LBP)

Local binary pattern is a feature extraction algorithm for image processing and computer vision that was proposed in 1992. Local binary patterns were originally used for texture analysis and have since been widely used in the field of object recognition. LBP encodes the result of comparing the gray value of each pixel with the gray value of surrounding pixels into binary numbers, which can describe the texture information of the image. Compared with the eigenface method, this method is relatively less affected by illumination, but still cannot deal with complex illumination and expression changes.

Through the definition of the LBP feature, it can be seen that the LBP feature is robust to illumination changes, and the effect is shown in figure 2.

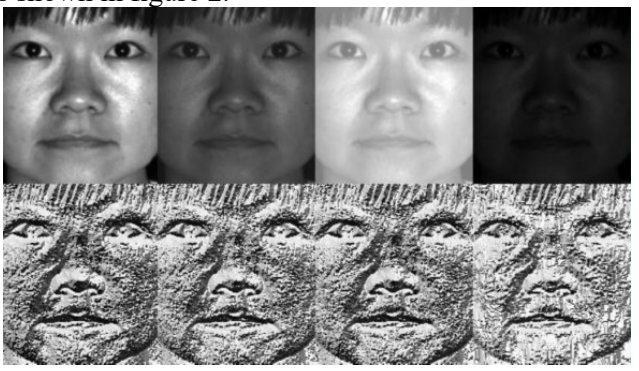

Figure 2. Effect drawing.

4. Face recognition algorithm based on deep learning

4.1. DeepFace.

Facebook proposed DeepFace in 2014. The algorithm is mainly divided into two stages: face detection and face recognition. In the face detection stage, DeepFace can use the DPM detector or the Viola-Jones detector to detect the face region in the image, use the 3D method to align the face, and then input the processed face image into the multi-layer Convolutional Neural Network (CNN) structure for operation. DeepFace does not require hand-crafted features, but extracts high-quality facial features from raw image data. With the increase in the size of the training dataset, the recognition accuracy of the DeepFace algorithm has greatly improved [9].

4.2. FaceNet.

The FaceNet algorithm was proposed by Google in 2015 and is widely used in the fields of face detection and face alignment. The main idea of the FaceNet algorithm is to map the face image into a high-dimensional space, and transform the feature vector learned in the neural network into a 128-dimensional Euclidean space. The Euclidean distance directly corresponds to the measure of face similarity, and the smaller the Euclidean distance, the more consistent the image is with the face.

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FaceNet uses a large number of face images for testing and training, and uses a new triplet loss function to replace softmax loss for face training.

The core idea of this method is to minimize the distance between the same face images and maximize the distance between different face images. The output of the model is a 128-dimensional facial feature vector, not just the result of face classification. In practical applications, the recognition rate of the FaceNet algorithm on the LFW dataset is as high as 99.63%, which is the algorithm with the highest recognition accuracy and recognition efficiency among the algorithms in the same period. Due to its high robustness, FaceNet can also be used for face recognition under different lighting conditions while reducing the number of parameters and computations [10].

4.3. ResNet.

The Residual Network (ResNet) algorithm is a deep residual network proposed by Microsoft Asia in 2015. It can be seen from previous research that a deeper network means more feature information can be extracted, which leads to better performance of the network. The core idea of ResNet is to map facial features into a low-dimensional feature space, introduce a residual module and add skip connections between convolutional layers, which effectively solves the problems of gradient disappearance, gradient explosion, and network degradation in deep neural networks.

In addition, the application of techniques such as batch normalization and global average pooling further improves the feasibility of deep residual network in the field of face recognition. Deep residual network has become a more advanced technology, and has been widely used in image classification, object detection, semantic segmentation, and other fields [11].

5. Challenges of face recognition technology

5.1. External environmental interference

Changes in illumination and angle will increase the difficulty of face recognition to a certain extent, as facial features will be greatly strengthened or weakened under projection. Thus, face recognition under bright and dark conditions is still one of the important problems that needs to be solved urgently. Face recognition is mainly based on the appearance features of the face, however, changes in posture and angle can cause some facial features to be undetectable. Therefore, facial expression recognition is also an important topic in the field of face recognition.

Large expression changes, such as laughter, anger, and crying, can distort, aggregate, or disperse the facial features of the face, which can lead to recognised shoulder features in the face image data in the database.

Changes in facial appearance with age are also an important factor that should not be ignored, and this phenomenon is most obvious in teenagers. Additionally, facial similarity is also a factor that must be taken into account. For example, twins may have similar facial features, and the human eye is sometimes unable to distinguish between the two. So, the inability of face recognition technology to distinguish the extremely small differences in facial features can also hinder the implementation of the technology.

In addition, face recognition under occlusion has become a mainstream research direction. Partial occlusion of the face by hair, mask, and scarf, etc. leads to a lack of facial feature information, which brings great difficulties to face recognition. Therefore, how to correctly process image data to achieve accurate face detection under occlusion is still one of the current challenges [12-13].

5.2. Insufficient data set

Commonly used datasets in the field of face recognition include LFW (containing over 13,000 face images), CelebA (containing over 200,000 images of celebrities, each with 40 attribute labels such as gender, age), YTF, FDDB, MegaFace, CASIA-WebFace, etc. However, deep large-scale neural networks generally have better performance only on large data sets, and poorly on small samples [14]. Moreover, the fact that most datasets are collected in human-controlled environments makes the existing

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datasets unable to cover face images under various complex conditions, which weakens the accuracy of the models in processing unknown face images. Therefore, the lack of datasets has become a huge obstacle to the development of face recognition technology.

5.3. Equipment performance is not good enough

With the continuous optimization of the training model and the increase in the amount of data, the requirements of the experiment on the performance of the equipment are gradually increasing. The training of face recognition experiments in neural network consumes a lot of time and energy, and high-quality image data can save some time for the experiment. Therefore, a high-pixel, high-definition camera has become an important condition for face recognition experiments. In addition, the picture quality is also affected by other factors, such as the lens quality of the camera and the sensitivity of the sensor [15].

5.4. Information security issues

Since face recognition experiments require a large amount of image data support, researchers will collect massive amounts of face videos and image data through the Internet to make datasets, which will undoubtedly increase the risk of data leakage. In addition, as biometrics have been widely used in electronic device unlocking, access control, security checks, bank payments, and other scenarios, face recognition technology will likewise face the phenomenon of malicious copying and use of facial features. This will lead to the disclosure of personal safety and property safety [16-17].

6. Solutions

6.1. Increasing data volume

Extensive collection of face image data is a cornerstone of model training, to the extent ethically and legally permitted. Studies have shown that increasing the depth and number of layers of neural networks can indeed improve the performance of the network, but face recognition under deep learning usually requires a large amount of data to show a better recognition rate, and the performance of the model is not outstanding when training with a small amount of data [18].

6.2. Optimizing model performance

Although the recognition accuracy of the existing face recognition algorithms has been able to approach 100%, optimizing and improving the model is still a necessary step in the research. In future research, on the basis of improving the performance of CPU or GPU devices, improving the adaptability of the model to complex environments and the perception of occluders will be the key directions of research. Face image inpainting, feature transfer, depth and number of layers of the neural network, pooling method, and loss function optimization also need attention.

6.3. Responsibilities of government

The government should formulate relevant laws and regulations to prevent incidents that threaten the security of people's information. Secondly, it is necessary to ensure that technology companies adhere to data privacy and security standards, and require companies to implement data encryption, limit data collection and storage, and regulate data access and sharing. Due to the wide range of applications of face recognition technology and the huge amount of data, it provides an opportunity for lawbreakers to steal other people's personal information. Such vicious incidents will not only jeopardize personal safety, but also seriously endanger national security. Therefore, the government is obliged to formulate relevant laws to curb the occurrence of such vicious incidents. Moreover, the government also needs to strengthen supervision, establish a mandatory review mechanism, and implement it to ensure that research complies with relevant regulations. If there is any violation of the law, its behavior should be severely investigated and punished in accordance with the law. Finally, the government can improve public awareness and understanding of face recognition technology through publicity and education,

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and encourage the public to protect personal privacy and data security.

7. Prospects for development

With the continuous development and progress of the era of artificial intelligence, face recognition models and algorithms based on deep learning will be constantly optimized and updated to simplify the algorithm and improve adaptability, recognition accuracy and efficiency while controlling the complexity of the network. Real-time recognition ability will be enhanced, and future face recognition technology will not only be limited to image recognition, dynamic face recognition technology will also be popular in various industries.

In addition, legal data sharing and algorithm open source will become the trend in the field of deep learning in the future, which will undoubtedly promote the sustainable development of face recognition technology and realize its social value, so as to provide a scientific and accurate quantitative basis for each application field.

8. Conclusion

This paper introduces five main applications and common algorithms of deep learning in the field of face recognition. Combined with the actual situation, the influence of the external environment, the model itself, data security, and other factors on the development of technology and development prospects are analyzed, and a response plan is put forward for the R & D team and the government. There are still some shortcomings in this paper. When listing the face recognition algorithms, the algorithms are not tested one by one, and the summary of the application of deep learning in the field of face recognition and common algorithms is one-sided. In order to further deepen the research and understanding of deep learning and face recognition technology, it is necessary to extensively read the literature in this field and deeply study the underlying logic of this technology.

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