Review of Face Recognition Technology

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Abstract: This paper first introduces the theoretical background and research status of face recognition technology. Then we focus on the current commonly used face recognition algorithms and their advantages and disadvantages. Finally, in view of the main problems existing in face recognition at present, the corresponding solutions are put forward.

1. Introduction

Face recognition is one of the most important applications in image analysis and understanding. Another great attempt of human beings to develop their own biological characteristics. The so-called face recognition is the use of computers to analyze face video or images. And effective recognition information is extracted from it. Finally, the identity of the face object is identified.

The research of face recognition can be traced back to the late 1960s. With the development of human-computer interaction, the requirement of image understanding and automatic identification has been improved rapidly. However, the development of real face recognition technology was promoted in the 1980s and 1990s because of the decrease of the cost of computer hardware. In recent years, especially after the "911" terrorist attack, due to the urgent need for security system in all aspects. Research on face recognition has become very popular. It is common for us to find relative information online with one image. Various research results on face recognition have emerged in endlessly, including the introduction of new technologies, the improvement of classical theory, as well as the synthesis of various theories. Overseas, there are also international conferences on face recognition, such as AFGR (the International Conference on automatic face and gesture recognition) and AVBPA (the intentional Conference on audio and video-based person authentication). This research direction is attractive. So much attention is essentially due to the implications of this field.

In the era of rapid development of science and technology, people urgently need a new security technology: this technology can ensure the safety of everyone, while at the same time, this technology cannot disturb everyone's normal life. Other security technologies, such as fingerprint identification, retina and iris scanning, are now very reliable, but the prerequisite for their application is the cooperation of participants, which inevitably affects people's normal life. But in this era when personal living space is more and more valued, this is exactly what many people hate. The technology of human detection and recognition can solve this problem well, so many institutions around the world are engaged in this research and are highly valued and funded by the military, the police and many large companies. As a whole, a face recognition system should include two parts: face detection [2] and face recognition [3], human beings. Face detection refers to any given image. A certain strategy is used to search it to determine whether there is a face in it. Face recognition refers to the use of known face identity database to identify the face in the image under test. These two parts are closely related. Face detection is the basis of face recognition. If the effect of face detection is not ideal, then the best face recognition strategy is empty talk. Conversely, if the effect of face recognition is not satisfactory, even if there is a complete and accurate face detection system, the final system cannot correctly judge the identity of the detected person. Nowadays, the face detection technology based on Adaboost technology [4], which is very mature and can solve the related problems well. With the technology of facial recognition, it is more readily and efficiently for police to control the crime. Moreover, some companies are even trying to put the technology into

people's daily life, such as access control system and payment system. We can nowadays search for similar images online as well.

2. Facial Recognition Common Algorithms

It has been a long time that the research of face recognition algorithms can be divided into six categories: face recognition based on geometric features, face recognition based on subspace analysis, face recognition based on template matching, face recognition based on hidden Markov model, face recognition based on neural network, and face recognition based on 3-D.

2.1 Method based on Geometric Characteristics

First of all, in recognition method of Geometric Characteristics, face is represented by a geometric feature vector. Meanwhile, classifier is designed by hierarchical clustering in pattern recognition. In this kind of recognition, the matching between feature vectors and decision based on Euclidean distance is the most commonly used recognition method [5].

Silhouette recognition is the earliest face recognition method based on geometric features. It starts with extracting feature points from the contour line of face. Generally, it simplifies the silhouette to extract some reference points from the contour curve. The geometric features between these points are used for recognition. Nowadays, most of the documents and photos are positive, so the research on side face recognition is not very common recently. The most important step of this method is approximate normalization. It does not depend on the scale or rotation of the face position in the image. Geometric features used in recognition include dangerous features such as eyes, nose, mouth and other local shape features, facial features and geometric relationship features of facial features distribution on the face. The feature vectors based on the shape and geometry of the facial organs usually include the Euclidean distance, curvature and angle between the two points specified by the face.

Geometric feature-based recognition method has many advantages: 1) it conforms to the mechanism of human face recognition and is easy to understand; 2) it only needs to store a feature vector for each image, which has a small storage capacity; 3) it is not sensitive to light changes. However, anything has two sides. At the same time, the technology has the following problems: 1) It is difficult to extract stable features from images. Especially when the feature is occluded; 2) the robustness to strong expression and attitude changes is poor; 3) the general geometric features only describe the basic shape and structure relationship of components, ignoring the local subtle features. Some information is lost. The typical algorithms include active contour model and deformable template model.

2.2 Face Recognition based on Subspace Analysis

In the method of Subspace Analysis, it is important for the idea to compress the features of high-dimensional face images into a low-dimensional subspace through spatial transformation (linear or non-linear).

The original subspace is regarded as a set of orthogonal normalized basic vectors, so the method of statistical orthogonal expansion has been applied. In the late 1980s, researchers introduced the idea of K-Van transform into the field of image representation and developed an optimal technique for describing face images in the sense of minimum mean square error [6]. From the point of view of the extracted features, the basic linear subspace method includes two categories: expressive feature extraction method and discriminatory feature extraction method. There are two representative techniques in expressive feature extraction: principal component analysis (PCA) and independent component analysis (ICA). Discriminant feature extraction methods can also be divided into two categories: linear discriminant analysis (LDA); feature analysis (CFA); PCA method is actually de-correlated on second-order statistics [7], while ICA is de-correlated on all second-order statistics, so that the second-order statistics and high-order statistics of signals are effectively utilized. Its basic idea is to find a set of independent bases (independent components) from the sample by linear

transformation. Sample data are then described. ICA method can be regarded as a generalization of PCA method [8]. It is widely used in face recognition. In face recognition based on linear subspace, the complex changes of facial expression, pose and illumination in face image are simplified linearly, so it is impossible to get the description of human age.

2.3 Face Recognition based on Template Matching

The basic idea of template matching is to use the gray-scale image of face as a template in the database [9]. By calculating the normalized correlation between the unknown samples and the known templates, the recognition is able to come true. An attempt is made on the whole face or the local template eyes, nose and mouth. Usually, people would like to compare the method of template matching with the method based on geometric features in a personal face database. After the experiments, the results show that the template matching method could achieve higher recognition accuracy under stable facial scale, illumination and posture conditions. In addition, after evaluating the performance of the template, experimenters concluded that the eye area of the template works best, and then would be nose, mouth and whole face. The method of simple template is easy to implement. However, since the size is fixed, it is hard for the recognition method to detect the position of human face dynamically. Therefore, another method based on elastic template is proposed in this paper. Elastic template is composed of a parameterized adjustable template set according to the shape of the object under test and its corresponding energy function, which is designed according to the prior knowledge of gray level information of the image and the contour of the object under test. The parameters of the elastic template are adjusted to the direction of energy reduction. When the energy reaches the minimum, the template shape corresponding to these parameters is the most consistent with the characteristic shape. Because the elastic template can be adjusted, it can detect objects with different sizes and deflection angles.

Although it is simple and intuitive to use the method of Template matching for face recognition, the computation of similarity between two samples is very heavy because the dimension of feature vector is usually the number of pixels in face image. Therefore, if the number of template databases was large, the recognition speed of this method would be unbearable. In addition, this method needs to store image data as template file, which would cause the problem of incompact storage. Nowadays, the non-linear subspace methods used in face recognition include kernel principal component analysis, kernel fisher discriminant analysis and kernel independent component analysis.

2.4. Face Recognition based on Hidden Markov Model

In face recognition, the recognition object should include the numerical characteristics of each organ of the face and the information of each organ's connection characteristics. Hidden Markov Model (HMM) [11] provides a solution to this problem. According to this model, the observed features are seemed as a series of implementations of another group of unobservable "states". Therefore, different people can be represented by different HIM parameters, while multiple observation sequences of the same person due to changes in attitude and expression can be represented by the same HMM model.

At first, Samaria gave the idea of Hidden Markov Model (HMM) for human faces. Hidden Markov process is a double stochastic process, one potential process is called "state" process, and another one is called "observation sequence", which is determined by the hidden state process. The development of HMM-based face recognition method allows facial expression changes and large head rotation, and it has a high recognition rate. However, the disadvantage of face recognition based on HMM is that the method requires a large amount of computation to extract features and training model parameters simultaneously. So, it is less applied.

2.5. Face Recognition based on Neural Network

The so-called artificial neural network is a dynamic model of distributed parallel information processing algorithm structure which imitates the behavior characteristics of biological neural

network. Applying artificial neural network to face recognition, an intuitive idea is to establish a neural network in which each neuron corresponds to a pixel in the image.

The first person to use artificial neural network for face recognition was Kohonep. He built a face memory system by using association graph. When the input image contains a lot of noise or partially occluded, it can accurately recall the face. However, because of the high dimension of the image, it is difficult to train the image vector directly. Therefore, the input image is not directly trained and learned, but the original image is first processed by dimension reduction. In this regard, Cottrell and Fleming proposed a solution [13]. They introduced a self-associative model with two layers of neural network structure: the first layer of neural network for dimension reduction; the second layer for classification. Unfortunately, experiments show that the face recognition effect of this type of neural network is not better than that of "feature face" method. In order to give full play to the non-linear learning ability of neural networks, other types of neural networks have been studied and applied in the field of face recognition. For example, face recognition based on convolution neural network has the invariance of image translation, rotation and local deformation to a certain extent, because convolution neural network integrates the correlation information between adjacent pixels, so better recognition results can be obtained. However, artificial neural network will also encounter many problems, such as over-fitting when the input training sample set is large, and over-learning when the input sample dimension is too high. In addition, the neural network must have multi-sample input when training the optimal parameters, so it cannot do anything about single-sample face recognition.

2.6 Face Recognition based on 3-D

At present, the study of face recognition mainly focuses on two-dimensional image or two-dimensional dynamic video sequence. Two-dimensional image recognition technology is now widely spread in many fields. However, since face is a plastic variant, it is hard to recognize face by two-dimensional image recognition technology. What’s more, face recognition based on two-dimensional images could inevitably affected by many factors, such as environmental light, background, perspective and face pose, expression, occlusion and other adverse effects. Thus, its recognition accuracy is difficult to further improve.

For the purpose of overcoming the shortcomings of face recognition technology based on two-dimensional images, researchers have push to study three-dimensional face recognition technology. Bronstell gave an idea for 3D face recognition which allows facial expression-related deformation to transform 3D face data into "feature form" so that it becomes an invariant of the shape change of the model: Gokberk divided the methods based on extended Gauss image, CP matching, distance contour, PCA and linear discriminant analysis (LDA). Instead of being used for 3D face recognition and using the data used by Bamie and Archer, Lee proposed a 3D face recognition method based on the curvature values of eight feature points: Lu and Jan developed the previous C-based face recognition method. Chang maps the face data into a circular distance image and introduces the multi-region method into 3D face recognition. Chang is a classifier ensemble method which matches multiple overlapping sub-regions around the nose with C matching and merges multiple 3D matching. Passal adopts the method of C matching and merging multiple 3D matching. Research on annotated variable models 3D face recognition calculates the average 3D face based on statistics for training sets

For the current three-dimensional face recognition technology, the biggest difficulty is the acquisition of three-dimensional point cloud data. In recent years, optical three-dimensional topography measurement technology has made great progress. There have developed many promising three-dimensional topography measurement technologies, such as structured light projection phase-shifting technology and structured light projection Fourier transform technology, which make the idea of recognizing three-dimensional face come true. However, projecting structured light to face is actually a contact recognition method. It is not practical to identifying people. It lost the ability of information covert collection as well, which greatly weakened the advantages compared with fingerprint recognition. Therefore, how to quickly, efficiently and

covertly acquire the three-dimensional face information of the recognized person is definitely the next focus point for future research.

3. Main Problems and Solutions of Face Recognition

At present, face recognition technology has moved from theory to practice, and has been widely used in all kinds of occasions worldwide. However, there are still some problems with the technology, such as the recognition effect caused by the change of face posture, illumination and expression is not ideal.

For attitude change. The method of general 3D model and deformation model is a better choice nowadays. If the 3D model of human face was built, any pose image could be easily generated by geometric transformation. Using image or video sequence and adjusting the general 3D model, we can get a specific person's 3D model. But it also has limitations that it requires high image quality and it needs to locate feature points automatically and accurately. The model with fewer feature points is inaccurate, and the effect of this error on recognition performance needs to be further validated in large databases. Based on the 2DAAM method, it is necessary to establish multiple perspective-based AM models since it can only deform in a small range of changes, which are not good enough to deal with simultaneous changes of illumination and attitude. With the help of 3D data and deformation model, we can deal with many kinds of changes such as pose, illumination, expression and get good recognition results. However, fast matching of 3D models to 2D images is the key. It is a good choice to estimate low-dimensional embedded structures by F) MAR14 to eliminate the non-linear features of attitude changes. The application of these methods in face recognition is still less.

For illumination change, text image is an effective method to deal with illumination change. The combination of image deformation technology can better deal with the changes of illumination and posture. Earlier studies have shown that face images with varying illumination are located in a low-dimensional subspace, which is proved theoretically by spherical harmonic function analysis. Shadow-based shape recovery technology can simultaneously restore 3D shape and surface reflection coefficient 111, thus synthesizing face images with arbitrary pose and illumination changes. The main problem is that it needs several different illumination images under control, so it is difficult to apply them in practice. Moreover, the modeling algorithm of this method is complex, and the model is greatly affected by noise. There are still many studies on the method of illumination subspace, but from the perspective of vision, there are few studies on how to eliminate the influence of illumination and restore the image with uniform illumination, which is far from enough. It is important for us to do more research on the technology of face recognition which could definitely benefits our life a lot.

4. Conclusion

In the society which is developing leaps and bounds, face recognition is gradually affecting more and more in people’s lives. The technology has been applied on security authentication, personnel attendance, port management and other fields. Although there is still a certain error rate, with the progress of society and computer technology, the deepening of face recognition technology, as well as the face recognition technology will usher in a larger period of development, and then promote the transformation and application of face recognition results, providing convenience for people's lives in all aspects.

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