Survey of the Facial Expression Recognition Research*

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Abstract. Facial expression recognition is one of the hot spots in recent years, it applies in the emotional analysis, pattern recognition and interpersonal interaction. This paper introduces the recent advances and applications in facial expression recognition from the face detection, feature extraction, classification, and the ethnic expression recognition. The methods of feature extraction are divided to several different characteristic categories. Researches of classifications are based on space or time and space. What's more, according to the facial expression recognition history and achievements, the development of ethnic facial expression recognition and the trend of facial expression recognition are given.

Keywords: Facial Expression Recognition, Facial Expression Classification, Ethnic Minority Facial Expressions.

1 Introduction

Facial expression is an important form of emotional state and mental state. Psychologist [1] Mehrabian's research shows that only 7% of the total information is passed by language, and 38% is transported by language auxiliary, such as the rhythm of speech, tone, etc. But the Ratio of information which passed by facial expression has reached 55% of the total. Therefore, a lot of valuable information can get by facial expression recognition that gives an effective way to the perceive person's consciousness and mental activity. Because of this, facial expression recognition, showing important theoretical research value, practical value and the life application value, has become an important research topic.

Facial expression recognition researches date back to the 19th century. In 1872, Darwin [2] firstly announced the consistency of expression .In his opinion the meaning of facial expressing was not judged by gender and race. In the 1970s, Ekman and Friesen [3, 4] made a pioneering work for facial expression recognition that they defined six basic expression categories of human: surprise, fear, disgust, anger,

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happiness and sadness which provided a way for current expression recognition research[1]. Until the 1990s, the developing of image processing and pattern recognition technology made the facial expression recognition computer automated processing possible. In 1991, Mase and Pentland proposed a new theory using optical flow method to recognize facial expression [5]. Since then, using computer technology in feature extraction and classification of facial expression has aroused widespread attention from researchers. Facial expression recognition have been widely used in human computer interaction, affective computing, intelligent control, psychological analysis, pattern recognition, security monitoring, social cognition, machine vision, social entertainment and other fields [6].

Based on research literatures at home and abroad in recent years, from the expression feature extraction, classification and face recognition, the present paper reviews the studies and research results of facial expression recognition ,then points out the trends. The rest of this article is organized as follows: Section II introduces expression recognition system framework, Section III describes the state of the art including face detection, feature extraction, training classifier , and the application and development of ethnic expression recognition , Section IV gives the development bottleneck and research trends, Section V is conclusion.

2 Facial Expression Recognition System Framework

According to people's way of thinking from face, facial expression recognition use computer for feature extraction, analysis of facial expression information, analyzing and understanding human emotions, such as happiness, surprise, anger, fear, disgust , sadness and so on. In general, facial expression recognition is divided into training and testing, shown in Figure 1.

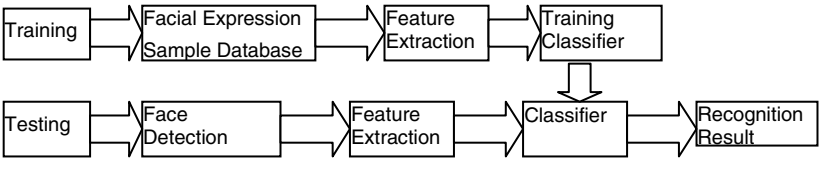

Fig. 1. Facial expression recognition system framework

In the training phase, the researchers need to extract features in the sample images, at first train the feature classification and lastly get the feature classifier. In the testing phases, first they need to detect human faces from the obtained face images then extract facial expression features, after that classifies facial expression features with the trained classifier, finally output recognition result [7].

[1] Ekman and Friesen established facial movement coding system (Facial Action Coding System, FACS) [4], with approximately 44 independent and interrelated action units(AU) to describe facial movements, and the unit's movement characteristics are analyzed for the detection of facial expression, the relationship between the expression and facial region.

3 State of the Art

3.1 Facial Expression Feature Extraction

Expression feature selection methods can be divided into three categories: deformation feature extraction method, motion feature extraction method, and statistical feature extraction method.

3.1.1 The Deformation Feature Extraction Method

Deformation feature extraction method means extracting some facial deformation informations, such as: geometric deformation or texture changes, the former one mainly refers to the changed relative distance between feature points caused by the variety of expression, the latter one mainly refers to the textures' appearance or disappearance and changes in gradient caused by the changing expressions.

Based on the geometrical feature extraction method, Gao Wen et al [8] established facial image model based on the component decomposition and combination, put forward the expression classification tree based on analyzing facial features' location and distance to express face in a set of feature vectors. Essa et al [9] constructed a parameter which can express the independent muscle motor unit on face to accurately estimate the facial deformation. Lanitis,Taylor and Cootes [10] recognized facial expression through detecting feature points' position and shape, and made a deformable model which comprised of a series of characteristic points on face. This recognition method based on the geometric feature has the following advantages: 1, It has a relatively simple and easy recognition processing; 2, It requires a small memory space due to expressing each image in a set of feature vectors, which leads to the less calculation for the feature classification;3, The feature requires less about the illumination difference. However, this method also has disadvantages: it contains incomplete facial information, no local subtle features make it easy to loss information and have not accurate judgment results.

Based on the texture feature extraction method, Liu Shanshan [11] used Gabor wavelet transform to extract facial feature from the segmented expression sub-regions, then used Fisher linear discriminate analysis for selection what can effectively eliminate the redundancy and the relativity of facial feature; Ma et al [12] proposed a method to combine the Gabor wavelet transform with the two-dimensional principal component analysis, The author did Gabor wavelet transform to extract facial feature from facial images and got the wavelet transform coefficient as the feature vector; Ye [13] used Gabor wavelet transform to extract facial feature vector from the segmented expression to structure the expression elastic graph. The texture feature extraction can contain the expression information effectively, and is insensitive to light intensity changing and individual differences, but it has a large amount of calculation that it should be cooperated with other dimensionality reduction algorithms.

3.1.2 Motion Feature Extraction Method

Motion feature extraction method is mainly used to extract some feature points or feature area's motion information from sequential expression images, such as: the movement distance and direction of feature points. The common methods include: feature point tracking, optical flow approaches, and model methods.

Feature point tracking method means tracking the movement of feature points which are chosen in face feature region, and getting parameters to do the face recognition. At present, this method has little calculation to extract only part of the feature points, but it loses some useful features. Lien et al [14] found feature point tracking useful to subtle motion such as eye blinking, but it lost tracking for large motion such as suddenly raising eye brows and mouth opening mouth. These feature points are mainly labeled by artificial which leads a big automatic tracking error.

Mase [15] used optical flow to track the movement units. Lien et al [14] analyzed the movement of entire face using the method of wavelet-based multi-resolution analysis optical flow; Otsuka et al [16] analyzed the movement of some special area such as: area around eye and mouth, etc; Jin Hui et al [17] analyzed the expression movement with feature-flow; Yang Guoliang [18] proposed a facial expression recognition algorithm based on the improved optical flow and HMM. Optical flow focuses on the facial deformation. Although it can reflect the trend of the face movement well. The method is easy to be affected by uneven illumination and non-rigid facial movement.

3.1.3 Statistical Feature Extraction Method

Statistical feature extraction method describes the characteristics of expression images by statistics, such as: histogram or moment invariant. Choudhury et al [19] processed special parts such as the eyes and eyebrows in the way of using consecutive frames subtraction, and then obtained the expression characterization. Shinoharal et al [20] used 35 kinds of high-order local autocorrelation features as face features. Other researchers calculated the moment invariant of some regions as expression features [21, 16].

Because of it's invariance, statistical feature extraction method is more useful than other methods to the image's rotation, translation and size variation .At the same time it requires a long time for the large amount of computing, and it is easy to ignore specific information of local subtle features.

3.2 Expression Classification

The classification algorithms are usually divided into space-based method, time and space-based method. The former mainly contains neural networks, support vector machine, AdaBoost method, K-Nearest-Neighbor (KNN), independent component analysis (ICA), Fisher linear discriminant analysis et al .The latter contains the hidden markov model method (HMM), regression neural network method, spatial and temporal motion energy templates method. In recent years, hidden markov model, artificial neural network (ANN), Bayesian classification, support vector machine (SVM) and AdaBoost have become the most mainstream method of facial expression recognition [22].

3.2.1 Methods Based on Hidden Markov Model

Hidden Markov Model (HMM) is a markov process that contains hidden unknown parameters, and can effectively describe the statistical model of the random signal information. It's successful in speech recognition and has begun to be used in face recognition. Lien [16] used HMM to classify the extracted motion vector sequences in facial expression recognition. Yeasin et al [23] who proposed a two-step HMM

analysis method trained the data set using discrete hidden markov model. Researches on HMM become more in China , Zhou Xiaoxu et al proposed an embedded hidden markov model based on AdaBoost for facial expression recognition in real time [24]. Xiaojun et al [25] proposed a face recognition method based on one-dimensional hidden markov model and singular value decomposition. HMM-based face recognition methods have the following advantages: they allow expression changes and large head rotation, do not need to retrain all the samples after adding new samples, but part of parameters are given by experience.

3.2.2 Methods Based on Artificial Neural Networks

Artificial neural network (ANN) system is an algebra arithmetic system about information processing simulated human brain neural system. Tian et al [26] proposed a facial action analyzing system based on Gabor wavelet and FACS (Facial Action Coding System), the system used neural network as a classifier and the rate of recognition classification up to 90%. Artificial neural network has the advantage of the high-speed ability due to it's parallel processing mechanism, it's distributed storage lead to the ability to recover feature extraction and have a self-learning function, while it's high parallelism and non-linear characteristic limit development to some degree.

3.2.3 Methods Based on Bayesian Network

A Bayesian network is a probabilistic graphical model which is based on Bayesian formula and presents random variables via directed acyclic graphs. Sebe et al [27] used Cauchy Bayesian classifier that characteristics were distributed by the Cauchy distribution instead of the Gaussian distribution to improve the accuracy. Based on the Bayesian model, Shan et al [28] proposed a Bayesian classification that taked into account the prior test samples' impacting while classifying a sample in the image sequences. Research [29] applied Naive Bayes classifier, tree enhanced simple Bayesian classifier and HMM as the classification of feature expression. Bayesian network can improve the classification accuracy, but it requires a bunch of parameters that part of them are given by human experiences, and the estimated result deviates from the actual result if the number of training samples is small.

3.2.4 Methods Based on Support Vector Machine

Support vector machine method is based on structural risk minimization principle for classification method. In a high- or infinite- dimensional space, it constructs a hyperplane or set of hyperplanes that training data points are marked as belonging to one of the categories which has the largest distance to other categories. Osuna et al [30] proposed a decomposition algorithm for SVM's slowly training and complexity in time and space, and the algorithm achieved good results in face detection. Because of the difficult classifier training and big computing in testing and other issues, Ma et al [31] proposed a SVM-based hierarchical structure classifier which combined a linear SVM and a nonlinear SVM, the former ruled out most of the non-face region quickly in the image while the latter confirmed face candidate region. With the advantages like structural risk minimization of support vector machine, SVM's applied researches will become more.

3.2.5 Methods Based on Adaboost Algorithm

The core idea of Adaboost is combining weak classifiers together to a stronger final classifier (strong classifier) by changing the distribution of data. Wang et al [32] proposed a classification method based on the Adaboost algorithm, the author used Haar features to construct a weak classifier space, and got a facial expression classifier using continuous Adaboost algorithm for learning. Experiment results show that this method has the same accuracy but is 300 times faster nearly than support vector machine. However research also shows that this classification is not good in small samples [33].

3.3 The Ethnic Expression Recognition's Application and Development

China is a country of 56 ethnicities, in the history of thousands each nation's facial features are not disappeared while changing, but new features emerge and some different facial features compared to other nations still exist although there is mutual fusion. Timely research and maintain each nation's facial features are conducive to find out the differences between ethnics and study the development history, migration processing of the ethnic Chinese. It is convenient for further improving the knowledge of the relationship between different ethnic groups and it also has practical application value to individual identification.

Chen et al [34] has measured 27 marks on the face of 3182 adult cases of 15 ethnic minorities and has observed the morphological characteristics. He compared the result with the Han nationality, and draw a conclution that the Northeast Manchu ethnicity and Korean approximate to Han ethnicity. Li et al [35] has described 24 observational features in 5 kinds like eye, nose, et al, in order to calculate the genetic distance among populations, and found that it was more consistent in Northwest Yunnan's Qiang groups face using the method of cluster analysis with the reported data. Duan et al [36] have established a China face database of ethnic minorities and used face recognition technology for feature extraction, collected the face of global and local features by building a deformable template of those features .Research [37] extracted the algebraic features of human face images using LDA algorithm and located feature points using Gabor wavelet and ultimately distinguished facial features of ethnic minorities after learning on the dataset by the multi-feature -classifier. The average recognition accuracy rates of Tibetan, Uygur and Mongolian are respectively 82.2% and 92% using the algebraic feature method and geometric feature method.

The characters of ethnic studies in China are: 1.Cumbersome manual operation and large time-consuming. 2. Not establish an authoritative face database of ethnic minorities 3. Less researches in ethnic identification classification.Currently, the study is still at the beginning stage [38-40], Shakhnarovich used boosting, Xiaoguang Lu and Anil K. Jain used the nearest neighbor classifier to classify Asians and non-Asians. Satoshi Hosoi et al researched the Mongoloid, Caucasian and black people's feature extraction and recognition. These studies focused on major races' facial features, but different ethnicities of the same ethnic group are studied less in interethnic and domestic. These studies in ethnic facial recognition can affect the development of ethnic facial expression recognition.

4 Challenges and Research Trend

4.1 Difficulties in Facial Expression Recognition

There are many aspects to be studied [41]: It is large time-consuming and complicated that many models' feature points or specific areas are marked by hand. The expression images contain information of both the face identity and changes in expression, so sometimes the extracted features are often a mixture of expression changes and identity characteristics. Light on the face in different directions and different intensity impact significantly on feature extraction (Figure 2),but with few studies. The obscure key areas, such as eyes, forehead, etc, will affect the feature extraction and thus interfere with facial expression recognition (Figure 3).

Fig. 2. Subject captured with variant illumination conditions

Fig. 3. The subject with different accessories

4.2 Development Trend of Facial Expression Recognition

4.2.1 Measurement of the Distance

Expression images contain the identity information and the changing information in expression. Thus, an effective, accepted and accurate definition of the expression distance of any two images needs further study.

4.2.2 Feature Extraction of Micro-expression

Micro-expression refers to the short expression lasting not more than 1/4s, it's not easy to be perceived owing to the short time and the difficulties in automatic identification, but it can express the non-subjective emotion. [42]Ekman (2002) developed a new micro-expression recognition test: Japanese and Caucasian Brief Affect Recognition Test (JACBART).

4.2.3 The Psychological Study

Facial expression reflects person's emotion, changes in face also reflect psychological changes. How to analyze human emotional changes and the emotional state of mind by using the various parameters from extracted features with knowledge of psychology is a complex, but meaningful challenge.

4.2.4

China is a multi-ethnic country, it is valuable to the expression recognition and will become a hotspot to know the relations and different between different ethnic groups' facial features.

4.2.5 The Construction of Facial Expression Database

Face images collected in commonly used facial expression databases ignore the effect of time and age. Studying the effects of age on facial expression needs to take into account wrinkles,so the facial expression sequent images should be included in different ages. The current facial expression databases collect European or Japanese faces, China researchers should pay more attention on establishing a Chinese face database of ethnic minorities. A standardized training and testing database is required that contains sequent images of people displaying spontaneous expressions under different conditions [43].

4.2.6 Three-Dimensional Face Recognition

Compared to 3D face recognition, two-dimensional image recognition is vulnerable to the adverse effects of light, the face attitude, materials covered on the face. Constructing 3D database will provide completely information in facial expression recognition. It is notable that some 3D databases have been established, such as the BU-3DFE [44], MSU [45].

4.2.7 Face Recognition Based on Multi-feature Fusion

Multi-feature recognition system is used in order to optimize feature extraction and improve the robustness. How to find a reliable and accurate algorithm for local feature extraction and integration is an important research direction.

4.2.8 The Integration of Facial Expression Recognition with other Biometric Identification Technologies

Some human biological characteristics are individualities and will not easily change, such as: facial features, eye characteristic (retina, iris), and fingerprint. It should vastly improve identify system performance to mix together face recognition and other biometric identification technologies.

5 Conclusion

Expression recognition connects with many areas and is the basis of emotional study. This paper's objective is to introduce the recent advances in facial expression recognition. In order to do this, the paper has looked at details in the various aspects of

facial expression recognition and then describes the state of the art in face detection and extraction. The important parts are development of ethnic expression recognition, the challenges and development trend. There are still some difficulties, but researches of facial expression recognition have improved a lot over the past decade. Expression recognition machines will be developed and be used as an important role in real world.

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