Available online at www.sciencedirect.com
ScienceDirect

ELSEVIER

April 2013, 20(2): 120–124
www.sciencedirect.com/science/journal/10058885

The Journal of China Universities of Posts and Telecommunications

http://jcupt.xsw.bupt.cn

Facial expression feature extraction using hybrid PCA and LBP

LUO Yuan[1], WU Cai-ming[1] (✉), ZHANG Yi[2]

1. School of Optoelectronic Engineering, Chongqing University of Posts and Telecommunications, Chongqing 400065, China
2. School of Automation, Chongqing University of Posts and Telecommunications, Chongqing 400065, China

Abstract

In order to recognize facial expression accurately, the paper proposed a hybrid method of principal component analysis (PCA) and local binary pattern (LBP). Firstly, the method of eight eyes segmentation was introduced to extract the effective area of facial expression image, which can reduce some useless information to subsequent feature extraction. Then PCA extracted the global grayscale feature of the whole facial expression image and reduced the data size at the same time. And LBP extracted local neighbor texture feature of the mouth area, which contributes most to facial expression recognition. Fusing the global and local feature will be more effective for facial expression recognition. Finally, support vector machine (SVM) used the fusion feature to complete facial expression recognition. Experiment results show that, the method proposed in this paper can classify different expressions more effectively and can get higher recognition rate than the traditional recognition methods.

Keywords facial expression recognition, PCA, LBP, eight eyes segmentation, SVM

1 Introduction

Facial expression recognition is an important part in the research of man-machine interface. At present, the methods used for expression recognition mainly based on template matching, neural network, the probability model and support vector machine, etc. The SVM [1] is a kind of machine learning method on the basis of statistical learning theory. According to the principle of minimization Vapnik structure risk [2], SVM made a tradeoff in function complexity and sample complexity, improved the generalization ability of learning and had excellent classification performance. SVM has already been used in facial expression recognition now. E.M. Bouhabba, et. al. [3] proposed a method combining Haar feature extraction and SVM for expression recognition. I. Kotsia, et. al. [4] proposed a method combining discriminant non-negative matrix factorization algorithm and SVM to fuse geometrical and texture information for facial expression recognition. Gwen Littlewort, et. al. [5] designed a classifier combining Gabor filter and SVM for facial expression recognition. However, the data size of feature extracted by all these methods is so large that it needs to be reduced.

Therefore, PCA [6] was introduced in this paper. PCA is a kind of analytical procedure based on subspace and can estimate original sample by using low dimensional characteristic vector. PCA can remove noise and redundant information by find the most important elements and structure of the original data. PCA also has advantages of simple, no parameters limit and good resolution capability in low dimensional space after the transformation, etc. But the global feature extracted by PCA, which is based on the whole image, is subject to the environment. This problem affects the recognition effect to some extent. So the method of LBP [7] for local texture information extraction is introduced in this paper. The local texture feature extracted by LBP can assist the global grayscale feature extracted by PCA to improve the recognition effect. Therefore, combined with PCA and LBP, SVM can further improve the accuracy and robustness of facial expression recognition.

In general, facial expression recognition system mainly

Received date: 24-07-2012
Corresponding author: WU Cai-ming, E-mail: wucaiming485@163.com
DOI: 10.1016/S1005-8885(13)60038-2

involves four parts which are face image collection, image preprocessing, feature extraction and expression recognition. And facial expression recognition system chart is shown on Fig. 1.

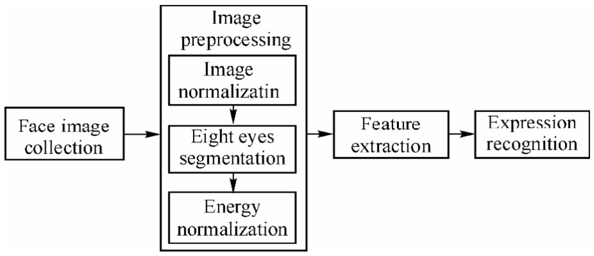


Fig. 1 Facial expression recognition system chart

The most important parts of facial expression recognition system are feature extraction and expression classification. Here we will introduce the important parts of the facial expression recognition system in the following parts of the paper.

2 Facial expression recognition system

2.1 Facial image segmentation

In order to acquire digital face images through a camera connected to an USB port, Adaboost classifier and Haar-Like feature extraction [8] are adopted to realize face detection and collection. There are many factors of the captured image, such as contrast, brightness, image size, much redundant information and so on, which affect the accuracy, robustness and instantaneity of facial expression recognition system. So it is most important to preprocess the captured image before expression recognition.

In this paper, the image preprocessing methods including geometry normalization, brightness normalization, histogram equalization, energy normalization and facial effective area segmentation based on eight eyes [9].

In the captured face image, both sides of ears are redundant areas relative to other areas of face image. According to the face standard of three courts five eyes, each ear area can be defined as one eye width. And to prevent useful facial expression information from deleting by mistake, the captured face image is divided into eight parts in horizontal direction. This kind of division is called eight eyes segmentation. Each eye width is deleted in both sides of captured face image in this method. The original image and segmented image are shown in Fig. 2.

(a) Original image (b) Segmented image

Fig. 2 Eight eyes segmentation

After the image segmentation based on eight eyes, brightness normalization, histogram equalization, energy normalization were processed to reduce the effect of illumination on facial expression recognition.

2.2 Feature extraction

In order to make sure that the feature to SVM is useful and the scale of feature is small, PCA was introduced to extract the global grayscale feature and reduce the data size. But the global feature is environment sensitive. Considering the face is non-rigid and the compute capacity, we select some local feature to assist the global feature to resolve this problem. Therefore, LBP for the local neighbor texture feature extraction was introduced to extract the local feature of the mouth area in this paper. Here we will introduce the algorithm principle of PCA and LBP in the following sections.

2.2.1 PCA

The essence of PCA is finding the best projection direction which represents the original data in the condition of least mean-square. Suppose there are C classes face image in the training set and class i(i=1,2,…,C) has M face images $\xi_{i1},\xi_{i2},...,\xi_{iM}$. Each image of the training set can be expressed as a 2-dimensional intensity array of size $m\times n$ and then can be converted into a vector of mn. If the training set of $N=C\times M$ images is defined by $\boldsymbol{X}_{\text{sample}}=[\xi_{11},\xi_{12},...,\xi_{ij}]$ (i=1,2,…,C, j=1,2,…,M), the standard training matrix $\boldsymbol{X}$ can be got by subtracting the mean image of the training set $\bar{\xi}$ The equation is defined as Eq. (1).

$$\boldsymbol{X}=\left[\xi_{11}-\bar{\xi},\xi_{12}-\bar{\xi},...,\xi_{ij}-\bar{\xi}\right]=\left[\zeta_1,\zeta_2,...,\zeta_k,...,\zeta_N\right]; \quad i=1,2,\ldots,C,\ j=1,2,\ldots,M,\ k=1,2,\ldots,N \tag{1}$$

where $\bar{\boldsymbol{\xi}}=\dfrac{1}{N}\sum_{i=1}^{C}\sum_{j=1}^{M}\xi_{ij}$.

Perform calculation on the covariance matrix $\boldsymbol{X}^{\mathrm{T}}\boldsymbol{X}$

to generate its eigenvalues and eigenvectors. Let $\boldsymbol{P}=[\boldsymbol{p}_1,\boldsymbol{p}_2,...,\boldsymbol{p}_r]$ ($r<N$) be the r normalized eigenvectors corresponding to r largest eigenvalues. Each eigenvector of $\boldsymbol{P}$ is called an eigenface. Now, each $\boldsymbol{\zeta}_k$ of the standard training matrix is projected into the eigenface space to obtain its corresponding eigenface based feature $\boldsymbol{Y}_k$ (k=1,2,…,N) which is defined as Eq. (2).

$$\boldsymbol{Y}_k=\boldsymbol{P}^{\mathrm{T}}\boldsymbol{\zeta}_k;\quad k=1,2,...,N \tag{2}$$

Then the dimension of original image vector is reduced to r($r<N$) and $\boldsymbol{Y}_k$ called the PCA feature of the original image.

2.2.2 LBP

LBP is used to extract the local texture information of grayscale image. Supposing $g_{\mathrm{c}}(x_{\mathrm{c}},y_{\mathrm{c}})$ is any pixel within a local area of a face image, g_{c} as the center of a 3×3 window and the other eight points are $g_0,...,g_7$. Define the local area texture as $T_{\mathrm{LBP}}=t(g_{\mathrm{c}},g_0,...,g_7)$ and carry on binary processing for the other eight pixels within the window using the threshold, here set the gray value of center pixel in the window as the threshold. The equation is as Eq. (3).

$$T_{\mathrm{LBP}}\approx t[s(g_0-g_{\mathrm{c}}),...,s(g_7-g_{\mathrm{c}})] \tag{3}$$

where $s(x)=\begin{cases}1; & x>0\\ 0; & x\leqslant 0\end{cases}$.

Read out an 8-bit binary number in the clockwise direction as an eigenvalue of the central pixel. Convert the binary number into a decimal number by the following formula for each symbol function. Then, LBP code which is described the spatial structure of local image texture feature is got through Eq. (4).

$$T_{\mathrm{LBP}}(x_{\mathrm{c}},y_{\mathrm{c}})=\sum_{u=0}^{7}s(g_u-g_{\mathrm{c}})2^u \tag{4}$$

A LBP operator is shown on Fig. 3.

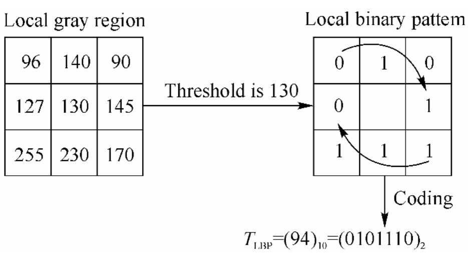


Fig. 3 LBP operator

After scanning a facial expression image by LBP operator, the LBP coding image of original image is got. Then the texture feature of image can be described by counting the facial expression image histogram. The process of LBP feature extraction is shown on Fig. 4.

Fig. 4 LBP feature extraction

The LBP coding image includes local micro-mode information of the original image, such as edge, feature points and spot, etc. So the local texture feature of a facial expression image can be described by a histogram which is formed by LBP codes.

Deng jiefang, et. al. [10] proved that the feature extracted from the area of the mouth is more important than other parts of the face for facial expression recognition. And experiments in this paper also show that the area of the mouth contributes most to facial expression recognition relative to other areas of facial expression image. Based on the experimental observation and the consideration of compute capacity, the area of the mouth is selected for local texture feature extraction in this paper.

PCA can extract the global grayscale feature of the whole facial expression image, but it is sensitive to lighting environment. LBP can extract the local texture feature of facial expression image. LBP helps to extract the nuances of changes among different kinds of facial expression, but ignores the global information of the whole facial expression image. Therefore, two methods, LBP and PCA are integrated in this paper for a more comprehensive and robust feature extraction. Fusing the global feature of the whole image extracted by PCA and the local feature of the mouth area extracted by LBP, the recognition rate of SVM can be improved to some extent.

3 Experimental results

Sum up all above analysis, the facial expression recognition system in this paper is design as Fig. 5.

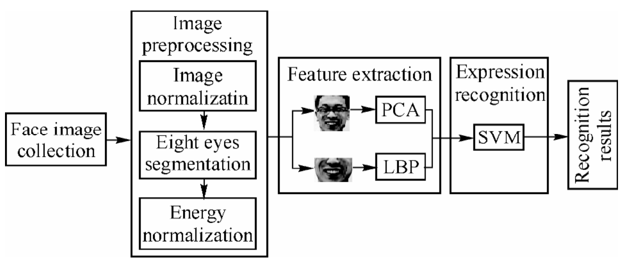


Fig. 5 Facial expression recognition system in this paper

The experiments are designed based on the soft environment of VC6.0 and the input device is PHLIPS camera. In the experiment, the training sample set includes seven different kinds of facial expression and the amount of them is each 50. Half of them are in better illumination and the others are in worse illumination. Each image of the training set is normalized into small size. Experiment results proved that small size image is better than big size image in recognition effect. Here we take the size 32×32. Two experiments were conducted in the different illumination condition in this paper. One is normal and the other is worse. And two experimenters conducted the facial expression recognition in the same experimental condition. We take 40 continuous recognition results for each expression in the experiment. Recognition results are shown in Table 1 and Table 2.

Table 1 Recognition results of experimenter 1

Expression	Method							
	PCA+SVM				LBP+PCA+SVM			
	Recognition rate/%		Average recognition rate/%		Recognition rate/%		Average recognition rate/%	
	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ
Happy	95.0	92.5	93.75	86.96	97.5	95.0	96.25	89.64
Surprise	92.5	90.0	91.25		95.0	95.0	95.00	
Sadness	90.0	85.0	87.50		92.5	87.5	90.00	
Anger	72.5	65.0	68.75		77.5	72.5	75.00	
Fear	87.5	77.5	82.50		87.5	77.5	82.50	
Disgust	92.5	90.0	91.25		95.0	90.0	92.50	
Neutral	95.0	92.5	93.75		97.5	95.0	96.25	

Table 2 Recognition results of experimenter 2

Expression	Method							
	PCA+SVM				LBP+PCA+SVM			
	Recognition rate/%		Average recognition rate/%		Recognition rate/%		Average recognition rate/%	
	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ
Happy	95.0	90.0	92.50	86.61	97.5	95.0	96.25	89.64
Surprise	92.5	85.0	88.75		97.5	95.0	96.25	
Sadness	87.5	85.0	86.25		90.0	87.5	88.75	
Anger	72.5	67.5	70.00		80.0	72.5	76.25	
Fear	87.5	80.0	83.75		87.5	75.0	81.25	
Disgust	92.5	87.5	90.00		92.5	92.5	92.50	
Neutral	95.0	95.0	95.00		97.5	95.0	96.25	

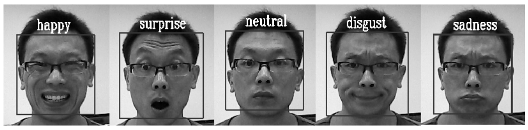
In Table 1 and Table 2, Ⅰ and Ⅱ are the recognition rates of each single expression in two different illumination conditions. Ⅲ is the average recognition rate of each single expression. Ⅳ is the average recognition rate of all seven different facial expressions. Table 1 and Table 2 show that the method proposed in this paper get a higher recognition rate than the hybrid method of PCA and SVM. We notice that happy, surprise, neutral, disgust and sadness get higher recognition rate under the same experimental environment.

In view of the above five expressions of higher recognition rate, SVM, PCA+SVM and the method proposed in this paper were conducted and compared in the same experimental condition. The average recognition rates of three methods are shown in Table 3.

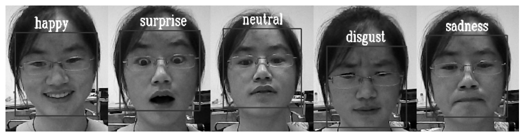
Table 3 Results of contrast

Recognition method	Average recognition rate/%
SVM	71.5
PCA+SVM	91.5
PCA+LBP+SVM	94.0

Table 3 shows that the method in this paper is better than traditional SVM and PCA+SVM in average recognition effect for facial expression recognition. Through the analysis of Table 1 and Table 2, happy, surprise, neutral, disgust and sadness have higher recognition rate and stable recognition effect. Here we only have these five kinds of expression to be recognized in the experiment. Experimental results of facial expression recognition are shown on Fig. 6.



(a) Recognition results of experimenter 1



(b) Recognition results of experimenter 2

Fig. 6 Experimental results of facial expression recognition

Fig. 6 shows that the method taken in this paper can recognize different expressions effectively and it is suitable for facial expression recognition. And these five kinds of expression can well be used for the motion control of the intelligent wheelchair, such as left, right, forward, back and stop, in theory. We conduct experiments on the intelligent wheelchair to prove the performance of the facial expression recognition method adopted in this paper. In the experiment, we used different expressions control the different movements of the intelligent wheelchair along the flat 8-shape route. And experimental results turn out that the method taken in this paper can recognize the different facial expressions accurately and the recognition results can be used for the motion control of intelligent wheelchair effectively and stably. But the method also have problem existed. It still is a bit sensitive to illumination changes, although we have made some processes. The next step of research will aim at this problem.

4 Conclusions

In this paper, firstly, geometry normalization, eight eyes segmentation and energy normalization were adopted to improve the quality of facial expression image in the stage of image preprocessing. Secondly, PCA and LBP were used to extract the global feature of the whole expression image and the local texture feature of the mouth area separately. Then, SVM used these two kinds of feature for expression classification and recognition. Finally, the facial expression recognition results were applied in the real-time motion control of the intelligent wheelchair effectively. Experimental results show that the method adopted in this paper is robust to facial expressions recognition. Even the same kind expression, people may have different shape. Therefore, in the experiment, each person has its own recognition model and the separated model can get a higher recognition rate. The future researches are resolve the residual problem, make further improvement of the method used in this paper and do more study and research in information accessibility.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (51075420), International Science & Technology Cooperation Program of China (2010DFA12160) and Program for Science and Technology Research Project of Chongqing (CSTC, 2010AA2055).

References

1. Nayyar A Z, David M S. Local adaptive SVM for object recognition. Proceedings of the 2010 International Conference on Digital Image Computing: techniques and applications (DICTA'10), Dec 1−3, 2010, Sydney, Australia. Piscataway, NJ, USA: IEEE, 2010: 196−201
2. Asian O, Yildiz O T, Alpaydin E. Calculating the VC-dimension of decision trees. Proceedings of the 24th International Symposium on Computer and Information Sciences (ISCIS'09), Sep 14−16, 2009, Guzelyurt, Northern Cyprus. Piscataway, NJ, USA: IEEE, 2009: 193−198
3. Bouhabba E M, Shafie A A, Akmeliavati R. Support vector machine for face emotion detection on real time basis. Proceedings of the 4th International Conference on Mechatronics (ICOM'011), May 17−19, 2011, Kuala Lumpur, Malaysia. Piscataway, NJ, USA: IEEE, 2011: 17−19
4. Kotsia I, Nikolaidis N, Pitas I. Fusion of geometrical and texture information for facial expression recognition. Proceedings of the 2006 IEEE International Conference on Image Processing (ICIP'06), Oct 8−11, 2006, Atlanta, GA, USA. Piscataway, NJ, USA: IEEE, 2006: 2649−2652
5. Littlewort G, Bartlett M S, Fasel I, et al. Analysis of machine learning methods for real-time recognition of facial expressions from video. MPlab TR 2003.05. San Diego, CA, USA: Machine Perception Laboratory Institute for Neural Computation, University of California, 2003
6. Chen J, Zhao Z, Sun H, et al. Facial expression recognition based on PCA reconstruction. Proceedings of the 5th International Conference on Computer Science & Education (ICCSE'10), Aug 24−27, 2010, Hefei, China. Piscataway, NJ, USA: IEEE, 2010: 195−198
7. Ahmed F, Hossain E, Bari A S M H, et al. Compound local binary pattern for robust facial expression recognition. Proceedings of the 12th IEEE International Symposium on Computational Intelligence and Informatics (CINTI'11), Nov 21−22, 2011, Budapest, Hungary. Piscataway, NJ, USA: IEEE, 2011: 391−395
8. Viola P, Jones M J. Robust real-time face detection. International Journal of Computer Vision, 2004, 57(2): 137−154
9. Luo Y, Wu C M, Zhang Y. Facial expression recognition based on principal component analysis and support vector machine applied in intelligent wheelchair. Application Research of Computers, 2012, 29(8): 3166−3168 (in Chinese)
10. Deng J F, Yang Y, Wang G Y. An expression recognition method based on local feature fusion. Journal of Chongqing University of Posts and Telecommunications: Natural Science Edition, 2011, 23(5): 626−630 (in Chinese)

(Editor: ZHANG Ying)