Enhanced Facial Expression Recognition using 2DPCA Principal component Analysis and Gabor Wavelets.

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Abstract — Face plays significant role in social communication. This is a window to human personality, emotions and thoughts. According to the psychological research, nonverbal part is the most informative channel in social communication. Verbal part contributes about 7% of the message, vocal-34% and facial expression about 55%. Due to that, the face is a subject of study in many areas of science such as psychology, behavioural science, medicine and finally computer science. We propose an algorithm for facial expression recognition, which can classify the given image into one of the seven basic facial expression categories (Happiness, Sadness, Fear, Surprise, Anger, Disgust and neutral). The goal of this project is to design and implement the facial expression recognition system. The 2DPCA algorithm can be easily implemented in any programming language on a digital computer. 2DPCA algorithm is found to be very accurate and more effective. Our program has been tested using JAFFE Database who contains images of 10 women with 213 different facial expressions. Each image has a 256*256 pixel resolution; available at http://www.kasrl.org/jaffe.html using 113 images randomly selected for training and 100 images for testing, without any overlapping; we obtain a recognition rate equal to 94.22%.

Keywords: facial, expression, recognition, Matlab, JAFFE, 2DPCA (2D Principal Component Analysis), SVM.

I-INTRODUCTION:

Facial expression recognition continue to attract researchers from image processing, pattern recognition, and machine learning, computer vision, neural networks, computer graphics, and psychology. Face detection and facial expression recognition system from image is a popular topic in biometrics research [5]. In identification problems, the input to the system is an unknown face, and the system reports back the determined identity from a database of known individuals, whereas in verification problems, the system needs to confirm or reject the claimed identity of the input face. The solution to the problem involves segmentation of faces (face detection) from cluttered scenes, feature extraction from the face regions, recognition or verification. Robust and reliable face representation is crucial for the effective performance of face recognition system and still a challenging problem [4].

Several state of the art biometric techniques have been developed in recent years, which use a variety of human characteristics for identification and recognition. These include fingerprint, signature, iris, retina, hand, voice and facial recognition. Each biometric trait has its strengths and weakness, and the choice of a specific trait depends upon the requirements of the application [9]. Face recognition plays an important part in human activities. The way we interact with other people is firmly based on our ability to recognise them. Faces consist of the same elements (nose, mouth, eyes, etc.) and recognition of individuals happens when we discriminate between the same basic configurations. Each individual must therefore be distinguishable from others because of the way the basic element configuration varies, as pointed out by Young and Bruce [8]. The description of relational features is useful to discriminate between different people, and also to determine different kinds of facial behaviour or expression for the same person. Various efforts were made to develop a system able to distinguish and model different types of facial expression [3]. Automatic recognition of facial expression can be an important component of natural human-machine interfaces. Although humans recognise facial expression virtually without effort or delay, reliable expression recognition by machine is still a challenge. We propose an algorithm of facial expression recognition, which can classify the given image into one of the seven basic facial expression categories (Happiness, Sadness, Fear, Surprise, Anger, Disgust and Neutral). 2D Principal Component Analysis (2DPCA) is used for dimensionality reduction in input data while retaining those characteristics of the data set that contribute most to its variance. The extracted feature vectors in the reduced space are used with SVM for Classification.

This code has been tested using the JAFFE database, available at http://kasrl.org/JAFFE.html.

The remainder of the paper is organized as follows: next section describes Gabor wavelet. Section III describes the concept of PCA and its 2D extension. Data Set and Representation is given in section IV. And Face classifier using SVM approach is described in section V. Recorded experimental results are presented and discussed in section VI. Finally, a global conclusion is given in section VII.

2-GABOR WAVELET:

Among various wavelet bases, Gabor functions provide the optimal resolution in both the time (spatial) and frequency domains, and the Gabor wavelet transform seems to be the optimal basis to extract local features for several reasons [2]:

Biological motivation: The simple cells of the visual cortex of mammalian brains are best modeled as a family of self-similar 2D Gabor wavelets.

Mathematical and empirical motivation: Gabor wavelet transform has both the multi-resolution and multi-orientation properties and are optimal for measuring local spatial frequencies. Besides, it has been found to yield distortion tolerance space for pattern recognition tasks.

Based on these advantages of Gabor wavelet transform, it has been used in many image analysis applications, and this report focus it's applications on face recognition, texture classification, facial expression classification, and some other excellent researches.

Fundamentals of Gabor wavelet transform

The Fourier transform has been the most commonly used tool for analyzing frequency properties of a given signal, while after transformation, the information about time is lost and it's hard to tell where a certain frequency occurs. To solve this problem, we can use kinds of time-frequency analysis techniques learned from the course [6] to represent a 1-D signal in time and frequency simultaneously. There is always uncertainty between the time and the frequency resolution of the window function used in this analysis since it is well know that when the time duration get larger, the bandwidth becomes smaller. Several ways have been proposed to find the uncertainty bound, and the most common one is the multiple of the standard deviations on time and frequency domain:

$$\sigma_t^2 = \frac{\int t^2 |x(t)|^2 dt}{\int |x(t)|^2 dt}, \sigma_f^2 = \frac{\int f^2 |X(f)|^2 df}{\int |X(f)|^2 df}$$

$$\sigma_t \times \sigma_f \geq \frac{1}{4\pi} \tag{1}$$

Among all kinds of window functions, the Gabor function is proved to achieve the lower bound and performs the best analytical resolution in the joint domain [7].

In practical cases, the Gabor wavelet is used as the discrete wavelet transform with either continuous or discrete input signal, while there is an intrinsic disadvantage of the Gabor wavelets which makes this discrete case beyond the discrete wavelet constraints: the 1-D and 2-D Gabor wavelets do not have orthonormal bases. If a set of wavelets has orthonormal bases, the inverse transform could be easily reconstructed by a linear superposition, and we say this wavelet transform provides a complete representation. The non-orthonormal wavelets could provide a complete representation only when they form a frame [1]. The concepts of the frame is beyond the scope of this report because it's too theoretical, while in most of the applications, we don't really care about these non-orthonormal properties if the Gabor wavelets are used for "feature extractions". When extracting features for pattern recognition, retrieval, or computer vision purpose, the transformed coefficients are used for distance measure or compressed representation but not for reconstruction, so the orthogonal constraint could be omitted.

Through the 2D DWT processing, the input images are decomposed into low frequency images by applying wavelet transform and ignored the high-frequency components, the processed images kept the main characteristic of the original image and reduce the dimensions of data for extraction.
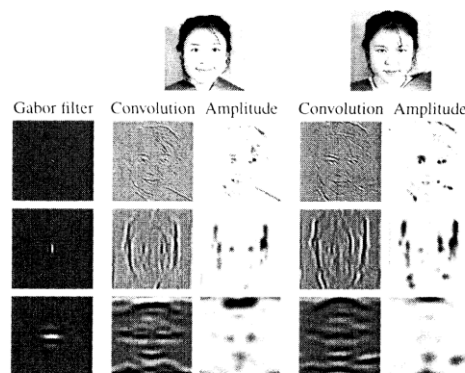

Fig.1: Gabor Wavelet representation.

3- 2DPRINCIPAL COMPONENT ANALYSIS (2DPCA):

A straightforward image projection technique, called two-dimensional principal component analysis (2DPCA), is developed for image feature extraction. As opposed to conventional PCA, 2DPCA is based on 2D matrices rather than 1D vectors. That is, the image matrix does not need to be previously transformed into a vector. Instead, an image covariance matrix can be constructed directly using the original image matrices. As a result, the 2DPCA has two important advantages over the PCA. First, the size of covariance matrix using the 2DPCA is much smaller, so it is easier to evaluate the covariance matrix accurately. Second, the 2DPCA computes the corresponding eigenvector more

quickly than that of the PCA, so less operation time is required [11]. In the 2DPCA model, the mean matrix, which is generally estimated by the class sample averages of all training samples, is used to character the total scatter matrix, so the average of training samples plays a critical role in the construction of the total scatter matrix and finally affects the projection directions of the 2DPCA.

3.1 Algorithm For 2DPCA Algorithm:

Training Input: Finger spelling training images Output: Finger spelling image features, eigenvector matrix, feature matrix. Method:

a) Applying pre-processing techniques to the training images.

b) Obtain the average image A of all training samples:

c) Estimate the image covariance (scatter) matrix G:

d) Compute d orthonormal vectors X1;X2; : : : ;Xd corresponding to the d largest eigenvalues of G. X1;X2; : : : :;Xd construct a d dimensional projection subspace. Yang et al. have showed that X1;X2; : : : ;Xd are the d optimal projection axes, such that when projecting the sample images on each axis Xi, the total scatter of the projected images is maximum.

e) Project A1; : : : ;AM on each vector X1; : : : ;Xd to obtain the principal component vectors: Training ends [10].

Following is the algorithm designed for recognition.

Algorithm: Recognition

a) Apply the respective pre-processing technique on B

b) When a testing image with 2D intensity matrix B arrives, compute the principal component vectors of the new image: YBi = BXi; i = 1; : : : : ; d

c) Compute the Euclidean distance between (YB1 ; : : : : ; YBd) and (Yj1 ; : : : : ; Yjd) (j = 1; : : : ;M): Where || YiB − Yij ||2 is the Euclidean distance between YiB and Yij

d) Use dist(B;Aj) (j = 1; : : : ;M) and a threshold value to decide the label of the testing image.

Recognition ends.

4-DATA SET REPRESENTATION:

The database we use in our experiments contains 213 images of female facial expressions. The head is almost in frontal pose. Original images have been rescaled and cropped such that the eyes are roughly at the same position with a distance of 80 pixels in the final images (resolution: 256pixels*256pixels) the number of images corresponding to each of the 7 categories of expression (Neutral, Happiness, Sadness, Surprise, Anger, disgust and Fear) is roughly the same. A few of them are shown in fig.2 [3]
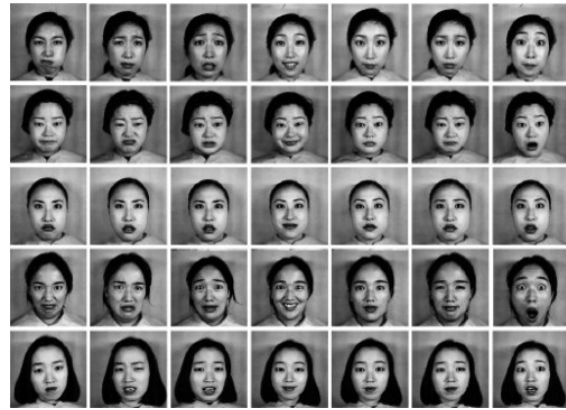

Fig.2: facial expression database: examples.

A facial expression recognition system is a computer application, which automatically identifies a person from an image database or video. The general steps used are, Image Acquisition –Face images are normally acquired by scanning a digital photography as by using cameras to capture live picture of a person. Segmentation or face detection –Segmentation is the process which detects the location of a face in the acquired image, feature selection –Both the studies use Principal Components Analysis PCA), which is commonly referred to as the Eigen face method. In our study, for a given set of training face images, feature vectors of faces are extracted through 2-D wavelet at appropriate LL sub band. The reduced image data is then set to the 2D-PCA process for finding the principal component and reducing the dimensional space of the image, which is stored into the library. For a given testing face image, feature vector is extracted through appropriate 2-D wavelet decomposition. The features are extracted using 2D-PCA and faces can be classified by SVM.

5. FACES CLASSIFIER USING SVM APPROACH

Support Vector Machines (SVM) is a two-class classification method that finds the optimal decision hyper-plane based on the concept of structural risk minimization [9].

Support vector machines (SVM) are supervised learning models with associated learning algorithms that analyze data and recognize patterns, used for classification and regression analysis. The basic SVM takes a set of input data and predicts, for each given input, which of two possible classes forms the output, making it a non-probabilistic binary linear classifier. As the dimensions of face image data is very large, although the satisfactory recognition rate can be obtained, but the processing time need so long as the large dimensions.

Based on the analysis above, we proposed a integrated method which is combined with 2D DWT, 2D PCA and SVM approach for facial expression recognition. At first stage, the original images are decomposed into low frequency images by applying wavelets transform, the high-frequency components were ignored, while the low-frequency components which contains the primary information can be

obtained. And then 2D PCA algorithm is used to deal with feature extraction. After generating feature vector, distance classifier and SVM are used for classification stage. We used "one-against-all" SVM multi-classification for recognizing face, and n SVM classifiers should be trained.

6- RESULTS:

In this project, we have made a facial expression recognition system that can detect the facial expressions like happy, sad, angry, disgust, surprise and fear. All the image from the JAFFE (Japanese female facial expression) database contains images of 10 women with 213 different facial expressions. Each image has a 256*256 pixel resolution. The number of images corresponding to each of seven categories of expression (neutral, happiness, sad, surprise, anger, disgust, and fear) is almost the same.

At each epoch, the 213 training images were randomly divided into two groups. The first group, containing roughly 40% of the 213 images, was used to train the SVM. The second group, containing the other 60% of the images, was used to evaluation the updated system.

Firstly, we used 2D-DWT for extracting the low frequency component and reducing the dimension of original image; secondly, 2D-PCA is used for extracting face features from low frequency component and to realize further dimension reduction; and then in recognition stage, One-Against-All decomposition SVM algorithm based on RBF is used for classifying faces feature.

Before using 2D DWT for decomposing the images, two crucial problems should be ensured, that are wavelet basis and decomposition level. By experiments research, db4 wavelets is selected for decomposing original images, and we do 1 level 2D DWT on JAFFE face database and 2 levels on JAFFE face database, these processing can reduce the dimensions of image and save the important information of face efficiently. For SVM classifier, we choose RBF kernel function and Kernel parameter γ is written as 0.015 for better performance.

Table 1 summarizes the recognition rates of various facial expressions.

Facial expression	Recognition rate using 2DPCA (%)	Recognition rate using PCA (%)
Happy	48.25	45
Disgust	69.24	66
Neutral	89	79
Sad	75.41	72
Anger	91	89
Surprise	89	88
fear	93.63	91.51

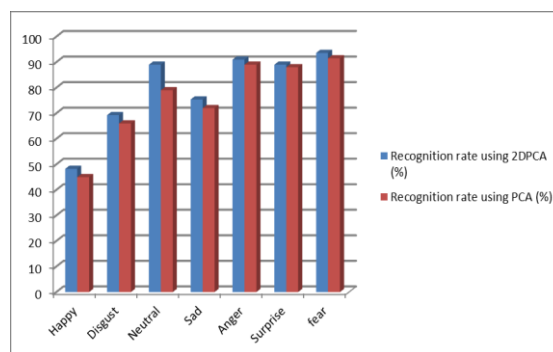TABLE1: THE RECOGNITION RATES OF VARIOUS FACIAL EXPRESSIONS.

Fig.3 : Bar Graph showing recognition rates of various facial expressions.

The results are shown as Table 2.

From Table 2, we can find that on JAFFE face database, when the number of training samples is 6, the recognition rate is 96.6%, it is better than SVM and 2DPCA as 0.5% and 6.4% respectively; when the number of training samples is 10, the face recognition rate is 98.8%, and it is similar to SVM algorithm, but it is much better than 2DPCA.

Through the results table below, we can find that it will take a short time by using 2D PCA for facial expression recognition, but the recognition rate is not well. Using SVM could get an effect recognition rate but it will take a long time. The results show that the algorithm we proposed has a more sufficient accuracy rate and reduce training and testing time.

TABLE 2: EXPERIMENTAL RESULTS ON JAFFE DATABASE

Algorithm	Training images	Testing images	Training time (s)	Testing time(s)	Recognition time (s)
2DPCA	10	6	1.36	2.12	80.5
SVM	10	6	56.52	39.45	92.3
Proposed method	10	6	10.39	8.25	94.5
2DPCA	15	5	1.83	1.12	96.6
SVM	15	5	72.32	23.76	99.1
Proposed method	15	5	12.84	4.12	98.8

7-CONCLUSION:

In this paper, an integrated algorithm for facial expression recognition is proposed based on the respective advantages of wavelets transform (WT), 2D Principle Component Analysis (PCA) for image feature extraction and representation. 2DPCA has many advantages over conventional PCA (Eigen faces). In the first place, since 2DPCA is based on the image matrix, it is simpler and more straightforward to use for image feature extraction. Second, 2DPCA is better than PCA in terms of recognition accuracy in all experiments. Although this trend seems to be consistent for different databases and conditions, in some experiments the differences in performance were not statistically significant. Third, 2DPCA is computationally more efficient than PCA and it can improve the speed of image feature extraction significantly. However, it should be pointed out that 2DPCA-based image representation was not as efficient as PCA in terms of storage requirements,

since 2DPCA requires more coefficients for image representation than PCA [4], and Support Vector Machines (SVM). 2D DWT is used as a pre-processing tool, which improves the recognition performance significantly. This improvement includes a substantial reduction in error rate and processing time of obtaining 2D PCA orthonormal basis representation. The extracted features are combined with SVM classifier for recognition. The results from our methods outperformed significantly.

In this project, the particular method using 2D principal component analysis for facial expression recognition was initially started with 10 training images and 15 testing images from each class of expression. After that, the same procedure was repeated by increasing the number of training images and the number of testing images from each class of expression.

In future, we will develop a work for the real time system that can be utilized in any sensitive area and surveillance system. Also the facial expression analysis is the useful for the security, gaming, intelligent tutoring system and human behaviour recognition.

REFERENCES

[1] Bouzned kh, N.Zermi, (2013). "Use of NLPCA for Sensors Fault Detection and Localization Applied at WTP", Journal of E -Technology Volume 4 Number 3 August 2013.

[2] Chellappa, R., Wilson, C. L., & Sirohey, S. (1995). "Human and machine recognition of faces: A survey". Proceedings of the IEEE, 83, 705-740.

[3] Ekman, P., & Friesen, W. V. (1977). "Manual for the Facial Action Coding System". Palo Alto, CA: Consulting Psychologists Press.

[4] Lyons, M., Akamatsu, S., Kamachi, M., & Gyoba, J. (1998). "Coding facial expressions with gabor wavelets". Proceedings of the Third IEEE International Conference on Automatic Face and Gesture Recognition, IEEE Computer Society, 200-205.

[5] Pantic, M. & Rothkrantz, J. M. (2000) "Automatic analysis of facial expressions: The state of the art." IEEE Transactions on Pattern Analysis and Machine Intelligence, 22(12), 1424-1445.

[6] Samal, A., & Iyengar, P. (1992). "Automatic recognition and analysis of human faces and facial expressions: A survey". Pattern Recognition, 25, 65-77.

[7] Willis, J.,Todorov, A. (2006). "First impressions: Making up your mind after a 100-ms exposure to a face". Psychological Science, 17, 592-598.

[8] Young and Bruce (1999). "Feature-based facial expression recognition: Sensitivity analysis and experiments with a multilayer perceptron." International Journal of Pattern Recognition and Artificial Intelligence, 13(6), 893-911.

[9] N.Zermi, ramdani.m " Facial expression recognition using Principal component analysis and artificial neural network" world symposium on computer networks and information security 2014, International Conference on digital Image Processing (ICDIP'2014) 13-15 juin 2014 hammamet Tunisia p51.

[10] N.Zermi,ramdani.m " Human facial expression recognition based on two dimensional Principal component analysis 2DPCA" world symposium on computer networks and information security 2014 International conference on soft computing, artificial Intelligence and Applications (ICSCAIA'2014), 13-15 juin 2014 hammamet Tunisia p44.

[11] M.Saaidia, N.Zermi, Ramdani.m "facial expression recognition using neural network trained with Zernike moments" IEEE 4th, International conference on artificial intelligence and application in engineering and technology (ICAIET2014) KOTA KUNABALU , SABAH , MALAYSIA 2014