The Integration of PCA, FLD and Gabor Two-dimensional Wavelet Transformation using Facial Expression Feature Extraction

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ABSTRACT: *In order to improve the rate of facial expression recognition. The Gabor wavelet fusion PCA+FLD method is proposed as a new method this paper. Firstly, face image preprocessing, and then carries on the two-dimensional wavelet transform Gabor, first constructed five scale eight directional wavelet filter, through the PCA+FLD method for dimensionality reduction, and finally obtaining an optimum expression a projection subspace classifier in all the optimal subspace. The experiment proves, fusion PCA, FLD and Gabor wavelet transform two-dimensional facial expression feature extraction for classifier design, facial expression recognition rate is high.The experiment proves that the new method of Gabor wavelet fusion PCA+FLD is perfect.*

Categories and Subject Descriptors:
I.4 [Image Processing and Computer Vision]; **I.4.8 [Scene Analysis]** Object recognition; **G.1.2 [Approximation]**: Wavelets and Fractals

General Terms:
Image Processing, Facial expression, Wavelet and Fractals

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1. Introduction

Human interactions, in addition to language, facial expression is a very important means of communication. It serves as the carrier of information and voluntary or spontaneous behavior, contains many factors, can express the non-verbal information. Since the nineteen seventies, people developed a facial expression of various aspects of the study, Plutchik from strength, similarity and the 3 aspects of mood were divided, was ecstatic, vigilance, grief, fear, surprise, rage, hate, receiving 8 basic expressions. Izard from the factor analysis method is put forward to the 8 to 11 basic emotions: interest, surprise, disgust, happiness, pain, anger, fear and sadness, and shy, contempt and guilt. Ekman puts human emotions can be roughly divided into 6 types, namely, frustration, fear, joy, surprise and disgust [1]. Later Ekman and to enrich and improve the theory makes a further research on [2], thus establishing the6 basic expressions theoretical validity and feasibility. Accordingly [3], other researchers will face is divided into the 6 "*basic expressions*". Gabor wavelet can be well simulated brain cortex in single cell receptive field profiles, capture salient visual attribute. Especially the Gabor wavelet can extract the image within specific regions of the multiple scale, multi direction spatial frequency characteristics, like the microscope as enlarge face image in the eyes, nose and mouth and other local characteristic changes in the gray. Therefore, the Gabor wavelet transform is widely used in the situation of emotion.Nectarios Rose [4], Z.Zhang [5], N.Dailey [6] and ZhanYongzhao [7] are mentioned by Gabor wavelet to facial expression image filtering, with the Gabor wavelet parameter to characterize facial expression. As the neurophysiology and wavelet transformation technology development, Gabor wavelet to the progressive development of two-dimensional wavelet form. Because Gabor wavelet usually has a dimension higher weakness, in practical application needs to extract wavelet feature dimension reduction, the single Gabor wavelet transform cannot achieve good expression feature extraction, based on the PCA+FLD method based on two-dimensional Gabor wavelet transform, fusion of facial expression feature extraction classification and recognition. This paper is structured as follows: part second introduces the two-dimensional wavelet transform Gabor; third part of PCA and Fisher principle; the fourth part is based on the Gabor wavelet and PCA+FLD facial expression feature extraction. Based on the experiment, the fusion of PCA, FLD and Gabor wavelet transform two-dimensional facial expression feature extraction method for facial expression recognition rate is high. Facial feature extraction is to image data with more advanced formulation are described, which describes the image pixel data into, shape features, movement patterns, texture and other forms, during the feature extraction and compression, minimize the huge image data redundancy information data. In addition to the image processing, facial expression feature extraction of facial expression recognition research is the most important part, feature extraction directly affect the facial expression recognition rate. At present the main feature extraction methods: Based on the geometric characteristics of the facial feature extraction, based on the statistical characteristics, based on frequency and motion characteristics.

2. Overview of Gabor wavelet

In the late nineteen eighties wavelet transform gradually developed, the wavelet transform is Fourier analysis after another powerful tool of mathematics analysis, as a new mathematical tool, its history is not long. After the promotion, wavelet transform has been widely used. Wavelet transform in pattern recognition, speech recognition and synthesis of image texture analysis in image coding field wavelet transform plays a very important role. Fourier theory is that a signal can be used for a series of the cosine function is cumulative and representation, but Fourier transform only the frequency resolution without time resolution. In 1946 D.Gabor [5] found Fourier in non stationary signal aspect flaw, he according to Heisenberg in quantum uncertainty principle, discovered and proved the one-dimensional signal uncertainty principle: a simultaneous time and frequency to depict the signal characteristics affected by its bandwidth and the duration of the lower limit of the product. Then Gabor found: any can use Gauss function modulation complex sinusoidal signals can be expressed in the time domain and frequency domain combined uncertainty relations reaches the lower limit, and at the same time can in time domain and frequency domain to obtain optimum resolution, this is the first Gabor function expression.Wavelet transform multiresolution characteristics, its essence is the signal processing method, wavelet transform is applied to time frequency on the signal processing and analysis, is a window shape can change the method, but also in time domain and frequency domain can be very good expression of the local characteristics of the signal, a wavelet transform window area can be changed, which is the essence of time and frequency domain window can be changes in the parameters of change the time-frequency analysis method. Wavelet transform principle is based on a kernel function not only at the time of translation and scale expansion to obtain a series of functions, and then use this set of functions calculated to show the approximation signal and the function. The method is an effective frequency domain signal analysis method, the method can automatically adapt to the various frequency components. The method can have different time and frequency resolution, specifically in the low frequency portion can have a higher frequency resolution and lower temporal resolution, in the high frequency part is opposite with lower frequency and higher temporal resolution. FFT does not have to be time varying frequency characteristic, this has led to inadequate at the same time windows having different frequency characteristics of the case, FFT and wavelet transform does not adapt, just to make up for this inadequacy. Wavelet transform is used to obtain the signal or image of the local spectrum information does not obtain the whole information of the image processing problems, and the expression has a good local distribution characteristic, therefore using wavelet transform to process is reasonable. Because the wavelet has good localization characteristics and multiresolution processing characteristics, using wavelet multi-resolution characteristics which can extract face image edge contour portion, also can exactly describe the expression image relatively flat area. Wavelet transform in the calculation is very complex, in image processing and facial expression recognition has broad application prospects. As the neurophysiology and wavelet transformation technology development, Gabor wavelet to the progressive development of two-dimensional wavelet form. Gabor wavelet in image texture and target recognition has a special advantage, very suitable for local feature representation Wavelet transform multiresolution characteristics as a multiscale analysis method, for different scale of signal analysis and description provides a unified accurate method, wavelet transform is suitable for image processing applied to facial expression recognition, mainly because the wavelet transform has the following advantages:

(1) Wavelet transform in the frequency domain provides a complete mathematical description.

(2) Wavelet transform multiresolution characteristics, through the design of appropriate filters can effectively extract local features, the removal of different expression feature correlations between

(3) Wavelet transform by designing different kernel function can have different functions is very flexible.Compared with the basic wavelet

Gabor wavelet has unique advantages as follows:

(1) The Gabor wavelet is contains a lot of information for best time - frequency localization characteristic of wavelet.

(2) The psychology research indicated the Gabor function can be approximated by the mammalian visual simple cell receptive field model.

(3) The spatial location, spatial frequency and orientation

selective local information in the 2-D Gabor wavelet can well capture, thus is very suitable for two dimensional Gabor wavelet feature extraction of facial expression recognition.

(4) From the Gabor function real-part component is subtracted from the DC component, so that the filter image global changes in illumination is not sensitive, very beneficial to different environment image feature extraction is syndrome.

(5) The Gabor kernel function in a different direction and scale coefficients can be obtained when different orientations and scales of the Gabor filter, resulting in different direction and different size of image gray information.

(6) The amplitude of the output of the Gabor filter to change the position of influence is small, so the Gabor transform can be applied to a certain degree of image rotation and transformation has strong robustness.

3. The one-dimensional Gabor wavelet

The one-dimensional Gabor wavelet is a trigonometric function multiplied by the Gauss function, its expression as formula (1)

$$W(t, t_0, \omega) = e^{-\sigma (t - t0)^2} e^{-i\omega (t - t0)} \quad (1)$$

Through the above formula can be defined by Gabor wavelet transform formula (2):

$$C(x(t))(t_0, \omega) = \int_{-\infty}^{+\infty} x(t) W(t, t_0, \omega)\, dt \quad (2)$$

(3-8) Representation of signal in frequency the moment of time frequency information. Solution equation 3-73-8available under the (3):

$$C(x(t))(t_0, \omega) = \int_{-\infty}^{+\infty} x(t) e^{-\sigma (t - t0)^2} e^{-i\omega (t - t0)}\, dt \quad (3)$$

Which can be determined by the real and imaginary part that follows (4)

$$C(x(t))(t_0, \omega) = C_{real} + iC_{imag} \quad (4)$$

In addition to polar coordinates representation following type (5) and (6):

$$A = \sqrt{C_{real}^2 + C_{imag}^2} \quad (5)$$

$$\phi = arcta\,(C_{imag} / C_{real}) \quad (6)$$

Among them: A is the amplitude, phase angle for ϕ.

3. Two dimensional Gabor wavelet transform

Two dimensional Gabor wavelet is composed of 2D Gabor function through the scaling and rotation transformation derived a family of complex function, the formula is as follows formula (8):

$$g_{mn}(x, y) = a^{-m} g(x', y') \quad a > 1, m = 1, 2, ...M, n = 1, 2...N \quad (7)$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = a^{-m} \begin{bmatrix} \cos\theta_n & \sin\theta_n \\ -\sin\theta_n & \cos\theta_n \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad \theta_n = n\pi / N \quad (8)$$

Among them, is the scale parameter, is the rotation parameters, and the ordinary wavelet is different, Gabor wavelet is not through the moving covering the same scale space, but through the rotation generated function coverage of current scale space, the scale factor expansion can make 2D Gabor function to generate a series of complete function space. Two dimensional Gabor wavelet kernel is defined as follows

$$\psi_{u,v}(z) = \frac{\| k_{u,v} \|^2}{\sigma^2} \exp\left(-\frac{\| k_{u,v} \|^2 \| z \|^2}{2\sigma^2}\right) [\exp(ik_{u,v}\, z) - \exp(-\sigma^2/2)] \quad (9)$$

The Gabor kernel for the direction of the U, scale for V, $z = (x, y)$ for a given image coordinate function, ||•|| said operation mode. In the above formula (10), Gauss envelope function is $\exp\left(-\frac{\| k_{u,v} \|^2 \| z \|^2}{2\sigma^2}\right)$ in the above formula (10) energy spectrum is determined by the frequency, $\frac{\| k_{u,v} \|^2}{\sigma^2}$ by compensating energy spectrum. In order to make the Gauss envelope function in small local small, can add the window function of oscillation range. Because the Gauss function has a local property, the filter is a Gabor wavelet, used to extract the coordinates Z near the feature information. $\exp(ik_{u,v} z)$ By cosine function (real) and sine function (imaginary) composed of oscillating functions. As the DC component, $\exp(-\sigma^2/2)$ is provided by Gauss function radius decision, the function of limiting the size of Gabor wavelet filter, in order to make the overall brightness information is not sensitive, filter need to ignore DC component function influence. The method has the advantages of while maintaining spatial relation information [4] and to describe the spatial frequency structure. In addtion $k_{u,v} = \begin{pmatrix} k_v \cos\varphi_u \\ k_v \sin\varphi \end{pmatrix}$. The formula the left represents the center frequency of the filter, $kv = k_{max} / f^v$, $\varphi u = \pi u/8$, k_{max} Represents the maximum frequency, in the frequency domain, kernel space factor is f Filter of direction selectivity is decision by φ_u. The center frequency of the filter $k_{u,v}$ can be used to describe the value of different Gabor wavelet to multiple directions and multiple dimensions of response. The different value $k_{u,v}$ can be obtained for a family of Gabor filter. The present case selects 40 different Gabor wavelet function is enough, for this set of five scales in eight directions (even if the V value of $0,1,2,3,4U$ value is: 0, 1, 2, 3, 4, 5, 6, 7, five) and $k_{max} = \pi / 2$, $\sigma = 2\pi$ $f = \sqrt{2}$ thus obtained scale eight direction Gabor wavelet kernel function family.Based on two-dimensional wavelet transform Gabor facial expression image transformation : set the image gray value $f(x, y)$, with a two-dimensional Gabor wavelet kernel $\psi_{u,v}(z)$ and $f(x, y)$ convolution, convolution formula is as follows (10):

$$Q_{u,v}(x, y) = I(x, y) * \psi_{u,v}(x, y) \qquad (10)$$

Where * is convolution factor, corresponding to the scale and direction of the convolution image. In the actual facial expression feature extraction, because the Gabor response amplitude reflects the image local feature energy spectrum information, therefore uses the Gabo output amplitude to express the characteristics of. The facial expression image $f(x, y)$ and 40 Gabor filters do a convolution of the response amplitude output, can be found in Gabor filter output energy is mainly concentrated in the eyebrows, eyes, nose and mouth with local features and strong position. In order to obtain the coordinates (x, y) of the wavelet characteristic value $f(x, y)$, can put with five scale eight directional wavelet amplitude combined. In order to obtain the whole image Gabor feature vector, can be further put all positions (x, y) Gabor feature combination. In which the entire image Gabor feature vector for: $X = (O_{0,0}, O_{0,1},.., O_{4,7})^T$.

4. PCA and Fisher profile

4.1 PCA

PCA (principal component analysis) [6] is a mathematical transform method, it is given to a group of related variables through linear transform into another set of irrelevant variables, these new variables according to the variance in descending order. Pattern recognition has many methods, including linear mapping method of principal component analysis (PCA) to occupy an important position, in the multi-dimensional pattern space, the PCA method according to the sample point distribution, and to the sample points in space to the maximum variance direction as the benchmark discriminant vector, and in order to extract the data features and data compression. According to probability theory and statistics characteristics of know. A variance of a random variable is larger, it contains more effective information, when the variance of a random variable is zero, the variable to a constant does not contain any useful information [8].Componential analysis is a mathematical transform method, it is given to a group of related variables through linear transform into another set of irrelevant variables, these new variables according to the variance in descending order. In the mathematical transformation to maintain the total variance invariant variables, the first variable has the largest variance, known as the first principal component, second variable times greatly, and the first variable is not related, known as the second principal components, followed by analogy. PCA in image processing are also known as K-L transform, the feature extraction method is unsupervised linear method, the method in the minimum mean square error sense can achieve data compression optimal transformation [7]. Because each principal component is linearly independent, so the method is applied to eliminate the image feature correlation calculation. According to the variance of order is according to the corresponding characteristic values of the order from big to small each principal component. Contains a noise component has the following characteristics: the corresponding variance is very small, the other is its corresponding mathematical quantum characteristic value is smaller, the eigenvector analysis of these noise components are excluded, so as to achieve the aim of reducing dimension. Usually discriminant analysis plane by before a few larger main component variance.

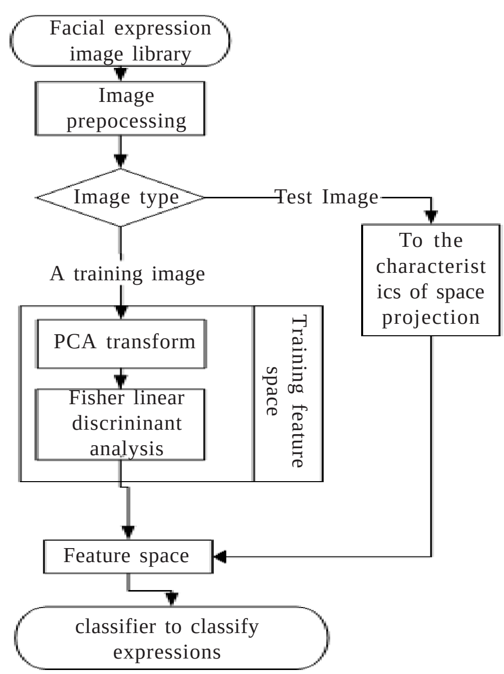
In facial expression recognition using principal component analysis to certain steps of feature space training, specific as follows: for a given number of training samples for N facial expression training set, to make the MXM of each image line by line into a vector, i value,$0, 1, 2, ..., N$.

4.2 Fisher

Fisher (linear discriminant analysis) basic principles Fisher linear discriminant analysis basic principle is: to find an optimal discriminant vector space, the projection to the sample space can maximizes between-class scatter and within-class scatter ratio, therefore, use FLD to get the expression features better representation of the original data is more suitable for classification [7].

5. Fusion of Two-dimensional Gabor wavelet and PCA+FLD Facial Expression Feature Extraction

In this paper, PCA+FLD method based on two-dimensional Gabor wavelet transform, fusion of facial expression feature extraction classification and recognition. To ensure that the PCA subspace of samples within the within class scatter matrix is nonsingular and based on the use of FLD further feature dimension reduction. The FLD subspace is below the test image classification based, all the facial expression recognition to this subspace in. Flowchart of algorithm is as follows flowchart 1:



Flowchart 1. Algorithm of fusion of PCA, FLD and Two-dimensional Gabor wavelet transform

Specific training and recognition process is as follows: N (C class) after pretreatment of the face image by Gabor wavelet transform and a preliminary sample after the training sample set: $\{x_1, x_2,..., x_N\}$ In which $x_i = (O^{(\rho)}_{0,0}, O^{(\rho)}_{0,1},.., O^{(\rho)}_{4,7})^T$ All images mean: $\mu = \frac{1}{N}\sum_{i=1}^{N} x_i$. For each training sample and the center of the face image: $x'_i = x_i - \mu$, $i = 1, 2,..., N$, Set $A = [x'_1, x'_2,..., x'_N]$, Solving the covariance matrix $S = AA^T$ Get the characteristic value and the characteristic vector, Due to the high dimensionality of the matrix $S = A^TA$, first described previously for singular value decomposition theorem of eigenvalue and eigenvector, then we can obtain the transformation matrix.

$W_{pca} = (v'_1, v'_2,..., v'_m)$, v'_i, $i = 1, 2,...m$ and m is the largest eigenvalue of the corresponding feature vectors. In order to ensure the rear Fisher linear discriminant analysis of the within class scatter matrix S_w is reversible. Selection $m \leq N - C$, m on the other hand also cannot be less than the number of categories C expression. The training sample set all the projection $\{x_1, x_2,..., x_N\}$ to the m dimension space, i.e.:

$$y_i = W^T_{pca}(x_i - \mu)\ i = 1, 2,... N, \qquad (11)$$

So we have obtained through PCA dimensionality reduction of the feature vector $\{y_1, y_2,..., y_N\}$ When the image is mapped to the m dimensional feature space, the space expression image samples the within class scatter matrix S_W can be guaranteed to be nonsingular. This can be in the feature space of Fisher linear discriminant analysis. Implementation procedure is as follows, in the m dimension feature space, Implementation procedure is as follows, in m dimensional feature space, set x_{ij} as the I class J expression sample, N_i as a class I expression in the number of images, $i = 1, 2,...C$ and $\sum_{i=1}^{C} N_i$ Calculated for each image within class average face

$$m_i = \frac{1}{N}\sum_{j=1}^{N} x_{ij}, \ i = 1, 2,..., C \qquad (12)$$

General face image value:

$$m_i = \frac{1}{N}\sum_{i=1}^{C}\sum_{i=1}^{N_i} x_{ij} \qquad (13)$$

M calculate dimensional feature space of all facial image samples of between-class scatter matrix S_B and the within class scatter matrix S_W. The last to get PCA to FLD characteristic space transformation matrix: $W_{fld} = [w_1, w_2,..., w_k]$, w_i, $i = 1, 2,...,k$ With the first k largest eigenvalues of the corresponding feature vector. Select $k \leq C - 1$, the m dimension in the feature space of the feature vector $\{y_1, y_2,..., y_N\}$ is projected to K dimension space: $z_i = W^T_{fld}\, y_i$ $i = 1, 2,..., N$. In the space sample between-class scatter and within-class scatter the maximum ratio, and is more favorable for the classification. $k = C - 1$, select $C = 7$, In this thesis, getting the 6 dimensional vector. This feature dimension reducing data quantity is significantly reduced in favor of table please real-time recognition. The use of Gabor wavelet expression feature extraction, and uses PCA+FLD method to Gabor feature dimension reduction method can be described as: firstly, using PCA methods Gabor features are mapped to a lower dimensional space, then the space in the application of FLD method on feature further dimensionality reduction, and get more discriminative feature vector. We can see the total transformation matrix: $W_{opt} = W_{pca}\ W_{fld}$. After sampling Gabor features X through type is mapped to the optimal expression projection subspace:

$$z = W^T_{opt}(x - u) = W^T_{fld} W^T_{pca}(x - u) \qquad (14)$$

Finally the test image and the training sample images are projected into the space, and can then select a classifier to classify .

6. Experimental results and analysis

The subject of the use of Japanese women face expression database (Japanese Female Facial Express Database, JAFEE) as an expression database for facial expression recognition experiment. The database consists of 213 face images, each image is 256 x 256 gray image. Total includes seven expression . Part of the facial expression image as follows: from left to right are: angry, disgust, fear, joy, sadness, surprise, and neutral expressions. In order to facilitate the following classification of the results of the seven kinds of expressions according to the following categories were numbered:

Expression	Angry	Hate	Fear	Happy	Neutral	Sad	surprised
Type ID	1	2	3	4	5	6	7

Table 1. Facial expression category identifier

Figure 1. Expression in part of the sample image database

The topics were the original gray image with PCA and FLD training space, expression recognition results are shown in table 3.6.1, use the Gabor: feature extraction combined with PCA + FLD method for dimension reduction of recognition results as shown in table: 3.6.2: one of: recognition rate (Recognition rate) R. The average recognition rate is recorded as AR.

From table 2 can see, correct identification of the image number 205, error 5, recognition rate is 97.6% from the table 3, this method correctly identified 195, error 15, recognition rate is 92.9%. 3.6.2 can be seen from the table, this method correctly identified 204, error 6, recognition rate is 97.1. From the above experimental recognition result analysis by use of the fusion of Gabor and PCA + FLD method for the identification of better.

Out / in	1	2	3	4	5	6	7	R	AR
1	30	0	0	0	0	0	0	100%	97.6%
2	0	29	1	0	0	0	0	96.7%	
3	0	0	28	0	0	0	2	93.3%	
4	0	0	0	30	0	0	0	100%	
5	0	0	0	0	30	0	0	100%	
6	1	0	0	0	0	29	0	96.7%	
7	1	0	0	0	0	0	29	96.7%	

Table 2. Related expression recognition experimental results

Out / in	1	2	3	4	5	6	7	R	AR
1	24	5	0	1	0	1	0	80%	76.3%
2	4	19	1	0	2	3	0	65.5%	
3	3	4	20	0	1	1	3	62.5%	
4	1	1	1	26	0	0	2	83.9%	
5	1	0	0	5	23	0	1	76.7%	
6	1	1	5	0	0	22	1	73.3%	
7	0	0	0	0	2	0	27	93%1	

Table 3. Irrelevant expression recognition experimental results

7. Conclusion

This paper mainly discusses the expression feature extraction problems should be paid attention to and the main feature extraction algorithm, in the relevant academic research technical analysis of Gabor wavelet theory. PCA and Fisher linear discriminant analysis theory, in the above method to separate application and facial feature extraction the shortcomings and its advantages is proposed on the basis of the integration of Gabor and PCA+FLD algorithm. Mainly on the pretreated gray-scale image Gabor wavelet transform feature extraction, based on the PCA+FLD methods used for dimensionality reduction, to achieve smaller feature space, on the basis of experiment, this paper put forward to verify the fusion algorithm expression extraction identification effect is better.

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