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Face recognition method based on gabor multi-orientation fusion feature and singular value decomposition

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ABSTRACT

Traditional Gabor feature and singular value decomposition (SVD) exist the problem of high dimensionality in characterizing facial features, this paper presents a facial feature extraction method that combine the fused multi-directional Gabor features and SVD of the image, which reduce the number of feature dimensions under the premise of feature information-rich. Firstly, use performance-optimized Gabor filters whose DC component is compensated to extract the multi-scale, multi-directional characteristics of facial images, and integrate the same- scale Gabor feature in different directions as the face image local features; Then extract the SVD feature of the image as the global features of face images; Finally, combine the local features and global features to characterize the primitive face image. Experimental results on ORL face database show that the recognition rate of the proposed method is up to 98.25%. The proposed method has advantages over traditional face recognition method based on Gabor features and SVD in the recognition rate and computational efficiency.

KEYWORDS

Face recognition; Gabor; Singular value decomposition-SVD; Local features; Global features.

INTRODUCTION

Two-Dimensional Gabor[1] filter is able to capture the local structural information of images, which is similar to the visual receptive fields of the mammalian ,so it has been applied to face recognition. Gabor filter is a complex sinusoidal function modulated by a two-dimensional Gaussian function. And it corresponds a bandpass filter bank whose direction and base frequency and center frequency are adjustable. Literature [2,3] and other studies have shown that Gabor feature has good recognition performance. But Gabor features have high dimension and it can't be a real-time process. More and more researchers have proposed improved method to achieve a breakthrough in the feature extraction accuracy and computing efficiency. In the literature [4] an improved approach is proposed,which uses local Gabor filters to extract characteristics and principal component analysis to select features. But it is likely to loss the useful information. In the literature [5] another method is proposed, which fuses Gabor features and other features and achieves dimensionality reduction by feature fusion. The specific approach is to divide the integration image into sub-blocks firstly, then obtain histogram distribution of each sub-block, at last combine histograms to get features of the image. This approach preserves the image of local redundant information, while lack characterization of the overall picture, and ultimately affect the recognition effect.

A new face recognition method is proposed in this paper,which integrate local characteristics with global features based on Gabor feature and singular value feature of face image. The basic idea is: First, compensate the DC component of the Gabor filters to eliminate its sensitivity to global illumination changes. At the same time, adjust the parameters to change the scale of the Gabor filter as the center frequency is changed, to reduce local redundant information. Secondly, fuse feature of Gabor transform features of different directions in the same scale, in order to reduce the dimension of Gabor features, reduce information redundancy; extract singular value feature of the image, and make local integration feature and global singular value feature as the final feature. The method of this article retains the advantage in the local details of the image, and reduces redundancy features. So that the face recognition method has been to keep local details, as well as reducing the amount of computation.

IMPROVED GABOR FILTERS AND GABOR FEATURE FUSION

Improved gabor filters

The human visual system has different feelings to frequency and frequency alignment of the visual signal. The image on the retina is decomposed into a number of filtered images. A filtered image contains a frequency band and component image of the direction. The researchers invented the Gabor filters to describe the characteristics of the human visual system [1]. A two-dimensional Gabor filter is a Gaussian function modulated by complex sinusoidal function, usually expressed as:

$$g(x,y)=(\frac{1}{2\pi\sigma_x\sigma_y})\exp\left\{-\frac{1}{2}(\frac{x_1^2}{\sigma_x^2}+\frac{y_1^2}{\sigma_y^2})\right\}\left\{\exp(2\pi jf_0x_1)-\exp(\frac{f_0^2}{2\sigma_x\sigma_y})\right\} \quad \textbf{(1)}$$

Among them, σ_x and σ_y standard on the difference of Gaussian envelope at X and Y direction,which determines the extent of the Gaussian function, f_0 is the center frequency, θ is the rotation angle. (x,y) is the original coordinates, (x_1,y_1) is rotated coordinates. $x_1=x\cos\theta+y\sin\theta, y_1=-x\sin\theta+y\cos\theta$, $\exp(f_0^2/2\sigma_x\sigma_y)$ In the above formula is the DC component, to avoid absolute dependence of Gabor transform for image luminance.
In face recognition, how to eliminate the impact of changes in illumination and pose on face recognition performance is the key issue.

Based on the performance of Gabor filters, this paper made two improvements of Gabor filter: 1. Taking the value of the DC component into account, which is background of gray face, in order to enhance the robustness of Gabor filter to global illumination changes, thus compensate the DC component. 2. When the center frequency becomes higher,the pulse width of the filters should become narrower, thereby increasing a coefficient f_0^2/σ^2 herein, so that the telescopic scale of Gabor filter changed with center frequency. The higher the center frequency is, the smaller the telescopic scale is, and vice versa. The improved Gabor filter function is as follows:

$$g(x,y)=(\frac{f_0^2}{2\pi\sigma_x^2\sigma_y^2})\exp\left\{-\frac{1}{2}(\frac{f_0^2x_1^2}{\sigma_x^2\sigma_x^2}+\frac{f_0^2y_1^2}{\sigma_y^2\sigma_y^2})\right\}\exp(2\pi jf_0x_1) \quad \textbf{(2)}$$

The real part and the imaginary part of the improved Gabor filter at one direction is shown in Figure 1, the time domain waveform is shown in Figure 2.

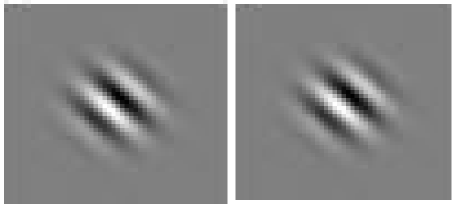
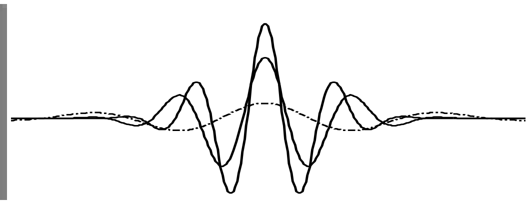

Figure 1: Real and imaginary of the filter at 0 ° direction Figure 2: Time-domain waveform

The face image is convolved with the Gabor filter, the result is the Gabor features of the image. Figure 3 is Gabon amplitude and phase characteristics of a person face image in 5 scale 8 directions. As can be seen from the figure, information in Gabor phase changes periodically as the change of spatial position, and the change of magnitude is relatively smooth and stable. Considering the computational efficiency, including most of the literature in this article, only apply Gabor amplitude information, without applying the phase information.

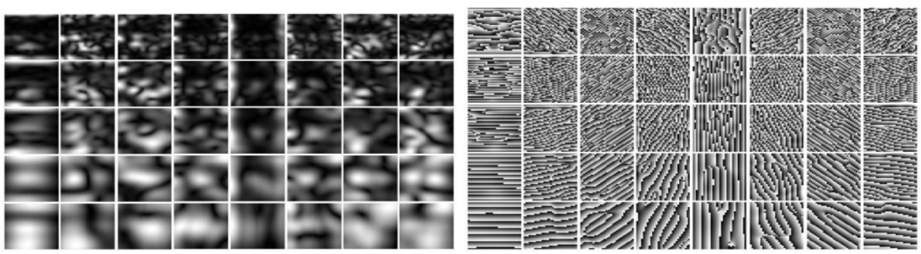

Figure 3: Amplitude and phase characteristics of 5 scale 8 direction

Gabor features and integration

By Gabor transform, each face image will be converted into 40 images in different scales and the direction and the image feature dimension was 40 times of the original image feature dimension. It not only brings redundancy feature, but also increases the computational burden. Inspired by data fusion, this article will fuse Gabor feature at eight directions on the same scale, in order to reduce data redundancy effectively between features and ensure not to lose effective information [6-8], while reducing computational time. A relatively simple fusion method is to addition and multiplication [9], this paper will add features at eight directions for each dimension and 5 scale single-direction feature. Thus, each face image is converted into the corresponding 5 images on 5 scale and 8-direction, Figure 4 shows the characteristic fused in 5 scale.

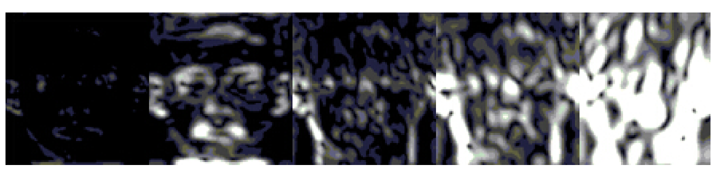

Figure 4: Integration feature in 5 scales

In Figure 4, scale is ascending from left to right, each scale image contains the original information in the appropriate scale. The characteristic dimension of fusion image is only one eighth of the original Gabor feature dimensions, but preserves all information points corresponding to 40 Gabor filters in every pixel.

SVD FEATURE EXTRACTION AND SELECTION

Studies have shown that SVD is an effective feature extraction method [10]. SVD can represent the energy information of image. It is stable and can reduce the dimension of the image. It is generally believed that the larger singular value and its corresponding singular value vector represent the image signal, and the noise is reflected in the smaller singular values and singular vectors [11]. SVD is generally used in image compression [12].

For any one face image matrix $A_{m\times n}$, there are two orthogonal matrix $U_{m\times m}$ and $V_{n\times n}$,and a diagonal matrix $D_{m\times n}$ to make $A = UDV^T$, where $D_{m\times n} = \begin{bmatrix} \Sigma_{k\times k} & 0 \\ 0 & 0 \end{bmatrix}$, $\sum_{k\times k} = diag(\sigma_1, \sigma_2, \cdots, \sigma_k)$, $U_{m\times m} = (u_1, u_2, \cdots, u_k, u_{k+1}, \cdots, u_m)$, $V_{n\times n} = (v_1, v_2, \cdots, v_k, v_{k+1}, \cdots, v_n)$, and σ_i is called the non-zero singular value of matrix, which ranges from large to small in the matrix Σ. $A = UDV^T$ is called the SVD decomposition of matrix A. Its form $A = \sum_{i=1}^{k} \sigma_i u_i v_i^T$ is the convolution of the face images of orthogonal decomposition, selecting first R generator matrix from K singular values to present he original image approximately.

Figure 5: Image represented by the first 4 SVD

SVD is a global feature of the image, the paper calculate the SVD feature vectors of the entire image directly as a feature to highlight the role of global features;

EXPERIMENT

In this paper, Gabor features and characteristics of the image SVD are joint together to characterize images. Specific methods are described as follows: the local feature vector of the image is represented as: $T_g = [T_{g1},....,T_{gn}]$, SVD feature expressed as: $T_{svd} = [T_{svd1},....,T_{svdm}]$, the combined image feature represented as: $T = [T_{g1},....,T_{gn},T_{svd1},...,T_{svdm}]$.
Dimension of Gabor feature is large, fusion features of 8-direction are only one eighth of the original image. Taking the high correlation between adjacent pixels in the Gabor features into account [13], the paper made uniformity distribution of sampling. The sampling points of the image are seen in Figure6. Do an individual experiment to test the impact on recognition rate,which brought by the number of singular values and the number of sampling points. This can be a reference as the next experiment.

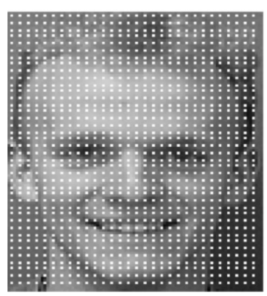

Figure 6: Image with evenly distributed sampling points

Extract Singular value feature of face image alone for face recognition, in order to determine the impact the number of features SVD have on recognition. The image is sampled at different frequencies, and extract Gabor feature of face image alone for face recognition, in order to determine the impact the number of sampling points have on recognition. when the number of singular values is 10, the recognition rate is 75.67%, when the number of sampling points is 40 * 30,recognition rate is 88.67%. In later experiments, the number of sampling points and the number of SVD features were 40 * 30 and 10.

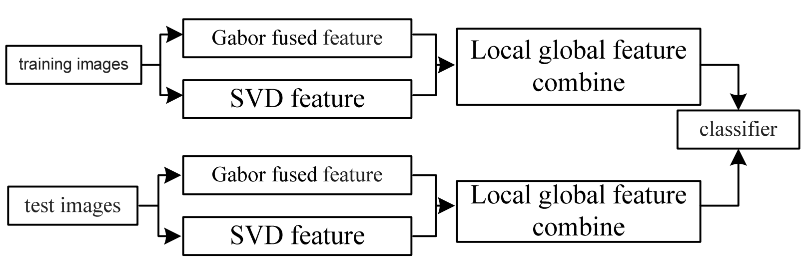

Figure7: Flow of characteristics combined algorithm

After the application of this method to get features, classify features with K-nearest neighbor [14] classification method and SVM[15] (support vector machine). This paper uses a standard ORL database, there are 40 people in the ORL database, each have10 images, the total is 400, resolution is 92 * 112, with different expressions, different positions, not to exceed 20 degrees tilt,with glasses and in different illumination.

Select five images of the same person as training images and the remaining five images as test images from the database. I.e., use 200 images as the training images, and the remaining 200 non-overlapping images as the test images.

RESULT AND DISSCUSS

In this paper, the experimental method and the traditional recognition based on Gabor feature (GF)are compared. For SVD feature,take the original face (OF), sampling face (SF), the integration of Gabor feature (IGF) in 8 direction. The results is shown in Table 1:

TABLE 1: Recognition results of different feature selection and classification methods

Feature	K-nearest neighbor	**SVM**
GF	75.89	76.91
OFGF+OF SVD	87.13	90.21
OFIGF+OF SVD	92.78	94.57
OFIGF+IGF SVD	97.21	98.25
SFGF+SF SVD	86.71	89.46
SFIGF+SF SVD	91.99	93.89
SFIGF+SFIGF SVD	96.88	98.17

1）Recognition rate combined Gabor feature with SVD feature is much higher than the traditional Gabor feature recognition rate. This shows that this improved Gabor filter gets more details and is more robust to changes in illumination. This kind of method is effective.

2）The recognition rate based on integration Gabor feature and SVD features is higher than non-fusion feature, indicating the effectiveness of integration Gabor features.

3）Sampling the original image or not have little effect on the recognition rate. However, sampling can improve computational efficiency.

4）Performance of SVM classifier is better than K-nearest neighbor classifier.

CONCLUSIONS

The traditional Gabor features are poor in characterizing global image feature, so we propose a feature extraction method based on combined Gabor direction feature and SVD characteristic, using SVM classification to achieve recognition in this paper. Experimental results show that the fusion characteristics with 8 Gabor directions reduce feature dimension, saving computation time and memory; the integration of combined Gabor features with SVD feature can extract global information and details of the image in multi-scale. The feature extraction method based on Gabor features and joint SVD feature in this article significantly improves the recognition rate.

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