Research on Face Recognition Algorithm Based on HOG Feature

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Abstract. As a common biometric recognition technology, face recognition is also an important research direction in the field of computer. Although compared with the initial research, the current research has made great progress, but there are still many difficulties in practical application. In this paper, by extracting HOG features, after introducing the detailed steps of PCA and LDA subspace feature extraction methods, dimensionality reduction feature extraction method combining PCA with LDA is applied to extract face features. This method first uses PCA to reduce the dimension of face features, and then uses LDA for linear discriminant analysis. Finally, the feature extraction methods based on PCA and LDA are tested and compared in FERET standard face database and CAS-PEAL database of Chinese Academy of Sciences.

Keywords: Face Recognition; Method Principle; HOG Algorithm; PCA; LDA

1. Introduction

Face recognition technology, which refers to the use of computer technology analysis and comparison of face recognition, is a hot research area of computer technology, including face tracking detection, automatic adjustment of image magnification, night infrared detection, automatic adjustment of exposure intensity and other technologies. Face recognition technology belongs to the biometric recognition technology, which is to distinguish the biological characteristics of the organism (generally refers to the human) itself. As early as 1966, the United States began to study automatic face recognition [1–2]; in 1990, Japan successfully developed a portrait recognition machine [3]; in
1993, the US Department of defense and the Army Research Laboratory jointly established the FERET project group [4], and established the FERET face database, which laid a solid foundation for the development of face recognition in the future [5]; since 2006, researchers have gradually begun to use deep knowledge. The deep learning network has become the most successful and widely used model [6]. In recent years, Japan has accelerated the research on video face analysis technology. In 2015, Hitachi of Japan launched a video surveillance face recognition product, mainly to accelerate the detection and recognition of facial images in videos, store the detected images, and classify the similar faces [7]. With more and more mature testing technology [8-9], face recognition technology has been widely used, in which brush face payment is a typical example.

2. Principle of Face Recognition Algorithm

Face recognition is a popular technology which uses computer to extract human facial features and verify identity based on these features. Usually, a given image is used, and then one or more faces in the tested image are determined according to the existing face database. The complete flow chart of face recognition technology is shown in Fig.1. The face image acquisition method used in this paper is through image acquisition.

![Fig.1 Schematic Diagram of Face Recognition Algorithm](image)

After inputting the tested image, face detection is carried out to determine the position of the face in the image. However, when the image is input to the computer, there will be distortion due to a large amount of noise. Therefore before feature extraction, the first step is to preprocess the image. Extract the feature only after standardize the image. Finally, face recognition is performed and the recognition result is output.

3. Face Recognition Based on HOG Algorithm

3.1. HOG Feature Extraction

HOG (histogram of oriented gradient) means directional gradient histogram, the essence of which is the statistical gradient information, and this gradient mainly exists in the edge. The process of its implementation is to obtain the pixels \((x, y)\) in the original image and gradient component in X direction and Y direction respectively. Then, the horizontal gradient and vertical gradient at the input image pixel can be calculated by using formula (1) and (2).

\[
G_x(x, y) = H(x+1, y) - H(x-1, y)
\]

(1)
\[ G_y(x, y) = H(x, y + 1) - H(x, y - 1) \]  

(2)

In the above formula, \( G_x(x, y) \) is the horizontal gradient at \((x,y)\), \( G_y(x, y) \) is the vertical gradient at \((x,y)\) and \( H(x, y) \) is the pixel value of \((x, y)\). Thus it can be seen that the gradient amplitude \( G(x, y) \) and gradient direction \( \alpha \) at the pixel \((x, y)\) are as follows:

\[ G(x, y) = \sqrt{G_x(x, y)^2 + G_y(x, y)^2} \]  

(3)

\[ \alpha = \tan^{-1}\left( \frac{G_x(x, y)}{G_y(x, y)} \right) \]  

(4)

Then the image is divided into small cells and the gradient histogram of each cell is counted to form the descriptor of each cell unit, namely HOG feature. After that, several cell units are formed into a block (e.g. 3 * 3 cell units per block), and the descriptors of each cell unit are connected in series to form the HOG feature of the block.

3.2. Principal Component Analysis

The basic idea of the Principal Component Analysis (PCA) is divided into several steps. Firstly, the covariance matrix of all samples is calculated, and then the first \( k \) eigenvectors of this covariance matrix are calculated. Secondly, the test image is projected onto each eigenvector, and the size of these \( K \) projections is formed into a new vector. Lastly, this vector is used as the subsequent recognition work. The mathematical description of PCA is as follows.

Step 1: Suppose that the length and width of image \( I \) are \( l \) and \( w \) respectively, by splicing each column of the training picture, we can get a \( P \)-dimensional vector \( T \), \( P = w * l \);

Step 2: The \( P \)-dimensional vector obtained from \( M \) Training pictures is used to form a matrix \( \left[ T_1, T_2, \cdots, T_M \right] \), where \( T_i \) represents the \( i \)-th training picture;

Step 3: Calculate the mean value of all training pictures:

\[ \mu = \frac{1}{M} \sum_{i=1}^{M} T_i \]  

(5)

Step 4: Each training sample is subtracted from the mean value to obtain the difference value \( V \):

\[ V_i = T_i - \mu \]  

(6)

Step 5: The difference matrix is constructed by combining all the difference vectors:

\[ A_{p \times m} = [V_1, V_2, \cdots, V_M] \]  

(7)

Step 6: Calculate the covariance matrix \( X \):

\[ X_{p \times p} = AA^T \]  

(8)
It can be seen from the above that the dimension of the covariance matrix is: 
\[ P \times P = (l \cdot w) \times (l \cdot w). \]

Step 7: In order to reduce the complexity of the algorithm, we define a matrix \( Y_{w \times w} = A^T A \).

Suppose that the eigenvalue and the corresponding eigenvectors of \( Y \) are denoted as \( \lambda_i > 0 \) and \( v_i \) respectively,

\[ Y v_i = \lambda_i v_i \] (9)

Then \( A^T A v_i = \lambda_i v_i \)

\[ A A^T A v_i = A \lambda_i v_i \] (10)

\[ X(A v_i) = \lambda_i (A v_i) \] (11)

Suppose \( \theta_i = A v_i \), then

\[ X \theta_i = \lambda_i \theta \] (12)

It can be seen from the above that \( \lambda_i \) and \( \theta_i \) represent the eigenvalue and eigenvector of \( X \) respectively. First, the eigenvector of \( Y \) is calculated, and then get the eigenvector of \( X \) according to the formula \( \theta_i = A v_i \);

Step 8: The projection of training samples on the eigenvector is calculated as follows, where \( r \) is the number of eigenvectors:

\[ w_k = \theta_i (T_i - \mu), k = 1, 2, \cdots, r \] (13)

Step 9: The reduced dimension vector is obtained by combining the projections:

\[ \Omega_{w \times w} = [w_1, w_2, \cdots, w_r]^T \] (14)

3.3. Linear Discriminant Analysis

Linear Discriminant Analysis (LDA) Algorithm is to maximize the spacing of class while minimizing the class dispersion:

\[ J(T) = \frac{T^T S_w T}{T^T S_T T} \] (15)
Among them, $S_b$ denotes the dispersion between classes and $S_w$ denotes the dispersion within class.

The training process of LDA is as follows.
Step 1: It can get a P-dimensional vector $T$ by splicing each column of the training picture, $P = l \times w$;
Step 2: The P-dimensional vector obtained from M Training pictures is used to form a matrix $T_{p \times M} = [T_1, T_2, \cdots, T_M]$, Where $T_i$ is the $i$-th training picture;
Step 3: Calculate the mean value of all training pictures
$$\mu = \frac{1}{M} \sum_{i=1}^{M} T_i$$
(16)
Step 4: Calculate the within class mean. Suppose the samples are divided into $c$ classes, and the number of samples in each class is $q_i$, $i = 1, 2, \cdots, c$, then
$$m_i = \frac{1}{q_i} \sum_{k=1}^{q_i} T_k$$
(17)
Step 5: Calculate the value difference vector, and make the difference between the feature vector of each training sample and the mean value of each category.
$$\Phi_i = T_i - m_i$$
(18)
Step 6: Calculate the dispersion within class. Suppose that the number of training samples belonging to class $i$ is $q_i$, the dispersion within class $S_w$ expresses as follows.
$$S_w = \sum_{i=1}^{c} \frac{1}{c} E[\Phi_i \Phi_i^T] = \sum_{i=1}^{c} \frac{1}{c} E[(T_i - m_i)(T_i - m_i)^T]$$
(19)
Step 7: Calculating dispersion between class $S_b$:
$$S_b = \sum_{i=1}^{c} \frac{1}{c} (m_i - \mu)(m_i - \mu)^T$$
(20)
In conclusion, in order to maximize $J(T)$, it is necessary to find a vector $T = W$ to make the
$$J(T) = \frac{T^T S_b T}{T^T S_w T}$$
maximum. The required vector $W$ can be obtained by equation (21).
$$S_b W = S_w \lambda_w$$
(21)
The above formula is transformed into formula (22).
It can be seen that the above formula can obtain at most \( c - 1 \) non-zero eigenvalues. After calculating each non-zero eigenvector, it can be combined to get a matrix, which is the reduced dimension matrix of linear transformation.

3.4. Dimension Reduction Method Combining PCA and LDA

In this paper, PCA and LDA are combined to reduce the dimension of face features. Firstly, PCA is used to reduce the dimension of face features to \( M \times c \) dimension. \( M \) is the number of samples and \( c \) is the number of sample categories, which makes \( S_w \) non singular. Then LDA is used for linear discriminant analysis. In this way, we can first get the linear reduced dimension matrix \( V_{P \times (M-c)} \) of PCA, and then use the training method of LDA to get the LDA transformation matrix \( W_{(M-c) \times (c-1)} \). The final transformation matrix \( Q_{P \times (c-1)} \) is obtained according to multiply \( V_{P \times (M-c)} \) by \( W_{(M-c) \times (c-1)} \). For the initial \( P \)-dimensional vector \( T \), the final reduced dimension \( c-1 \) vector can be obtained by its transposition and multiplied by \( Q_{P \times (c-1)} \).

\[
Q_{P \times (c-1)} = V_{P \times (M-c)} W_{(M-c) \times (c-1)}
\] (23)

4. Analysis of Experimental Results of Face Recognition

This paper tests and compares the feature extraction algorithms in FERET standard face database and CAS-PEAL database of Chinese Academy of Sciences.

Referring to the data in other literatures and combining with the data obtained from our own experiments, the comparison of various feature extraction algorithms is shown in Tab.1.

| Feature Extraction Method | Sample Set   |
|--------------------------|-------------|
|                          | fb(%) | fc(%) | dup1(%) | dup2(%) |
| PCA                      | 85.3  | 65.5  | 44.3    | 21.8    |
| LBP                      | 93    | 51    | 61      | 50      |
| The Algorithm in This Paper | 90.1  | 68.2  | 50.3    | 26.4    |

Tab.1 Recognition Rates of Various Face Recognition Algorithms Based on FERET test sets

In this paper, the simplified database of CAS-PEAL face database of Chinese Academy of Sciences is used, which also includes the original image set, training set and test set with a total of 6992 pictures. In this paper, three subsets of illumination change, ornament change and expression change are used for the experiment. The database example image is shown in Fig.2. The first image is a normal face; The second to fourth images are expressive faces; The fifth to sixth images are decorative faces; The seventh to eighth images are background changing faces.
Fig. 2 Example Image of CAS-PEAL Face Database

The algorithm test results of CAS-PEAL face database are shown in Tab. 2.

| Recognition Rate       | PCA(%) | LBP(%) | The Algorithm in This Paper (%) |
|------------------------|--------|--------|---------------------------------|
| Illumination Set       | 58     | 64     | 66                              |
| Decoration Collection  | 66     | 92     | 74                              |
| Expression Set         | 64     | 86     | 84                              |

Tab. 2 Recognition Rates Based on CAS-PEAL Face Database

From the experimental results of the above two databases, we can see that PCA, LBP and our algorithm can achieve better results in the case of no illumination and small change of posture expression. The main reason is that they all use global features for face recognition. Therefore, this kind of method depends on the overall gray correlation of training set and test set, and the collection ring of training samples and test samples Environment has certain requirements, but it is not suitable for uneven illumination, expression changes and local texture changes.

5. Summary and Prospect
Through the above experiments, many shortcomings are found. We realize that face recognition technology as a comprehensive hot project, not only need researchers to have a solid theoretical foundation, but also need researchers to make continuous efforts and progress to overcome various difficulties in the process. In this experiment, how to reduce the false recognition rate and how to improve the recognition rate of face recognition technology are very important work. In addition, we should improve the recognition speed on the premise of ensuring the recognition rate, and try to reduce the influence of external factors on the experimental results. In a word, with the continuous development of science and technology, face recognition is bound to reach a higher level.

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