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FACE RECOGNITION SYSTEM BASED ON PRINCIPAL COMPONENT ANALYSIS AND SUPPORT VECTOR MACHINE CLASSIFICATION

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Annotation. Principal component analysis is a commonly used feature extraction technology in face recognition. It can reduce the dimension of data while trying to retain the characteristics of the original data. Face images can be reduced in dimension through principal component analysis, which can effectively reduce the number of features and simplify the model. the complexity. The application of support vector machines in face recognition is based on its powerful classification ability that can effectively find decision boundaries in feature space and distinguish different categories (i.e. faces of different people). Based on the respective advantages of principal component analysis and support vector machine, this article will discuss a face recognition method based on a combination of principal component analysis and support vector machine support vector machine method, and implement the system through MATLAB.

Keywords: face recognition, principal component analysis, support vector machine, MATLAB.

Introduction. In recent years, with the rapid development of smart devices, facial recognition technology has become more and more widely used. At the same time, in the research field, various face recognition methods are emerging in endlessly. Among many methods, face recognition methods based on PCA and SVM are mainstream methods. Principal component analysis (PCA) [1], the discrete K-L transform, is the best orthogonal transform in image compression. PCA is a dimensionality reduction technique mainly used in the preprocessing stage of data. It transforms the original data into a new coordinate system through linear transformation, maximizing the variance of the data on the first few coordinate axes of the new coordinate system. Support vector machine (SVM) is a supervised learning method mainly used for classification and regression analysis. It separates different classes of data as accurately as possible by finding the best hyperplane in the feature space [2, 3].

In the process of combining PCA and SVM for image recognition, PCA is first used to reduce the dimensionality of the original high-dimensional data, extract the most important features, and then use SVM for classification. This combination takes advantage of the advantages of PCA in data preprocessing and feature extraction, and the efficiency and accuracy of SVM in high-dimensional data classification, making the entire recognition process both efficient and accurate. This paper implements a face recognition system based on PCA and SVM through MATLAB, and conducts experiments using the ORL face library. The recognition rate during training is as high as 94 %.

Main Part. In the face recognition system based on PCA and SVM, the PCA method is first used to reduce the dimensionality of the image, which not only reduces the data size but also retains key features, thereby improving the efficiency of subsequent processing. Then, the SVM model is used to train and predict the dimensionally reduced data to achieve accurate face recognition. This process effectively combines the data reduction advantages of PCA and the powerful classification capabilities of SVM, making it an ideal choice for processing high-dimensional data and identifying complex patterns. Figure 1 shows the workflow of the entire system. This system will use the ORL face database as the training set and test set. This data set contains 40 directories, each directory has 10 images, and each directory represents a different person. All images are stored in PGM format, and each image is a 92×112 pixel, 256-level grayscale image. For the images in each directory, these images were collected at different times, under different lighting conditions, with different facial expressions and facial details. In the experiment of this system, 5 images of each person will be randomly selected as training images to form a training set of images, and the remaining 5 images form a test set.

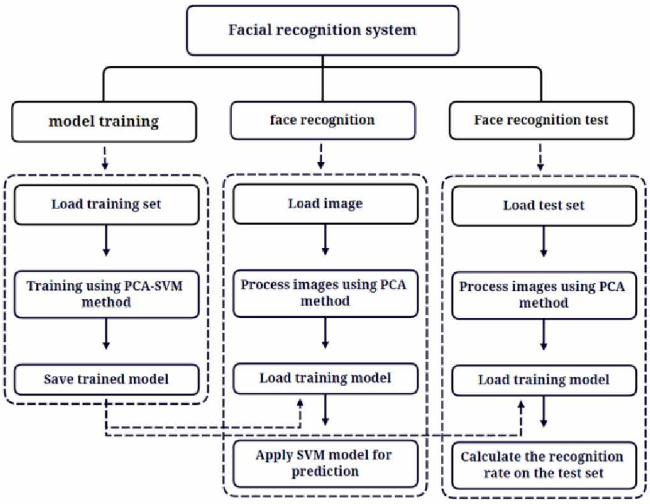

Figure 1 – PCA-SVM face recognition system workflow

The PCA method is an effective feature extraction method and is widely used in the field of pattern recognition, especially in face recognition research. By converting *mn*-dimensional two-dimensional face images into one-dimensional vectors, for example, a 92×112 image in the ORL face database can be regarded as a 10304-dimensional vector. In the high-dimensional space represented by these vectors, due to the similarity of the face structure, it can be effectively represented by a lower-dimensional subspace. This subspace is called "face space".

The main idea of PCA is to find those vectors that best describe the distribution of images in image space. These vectors can define the "face space". The length of each vector is *mn*, describes an image of mn, and is a linear combination of the original face image, called an "eigenface". For a face image of mn, connect each column to form a column vector of size $D = mn$ dimension. D is the dimension of the face image, that is, the dimension of the image space. Assume N is the number of training samples; x, represents the face vector formed by the j^{th} face image; u is the average image vector of the training samples, equation (1) represents the calculation of u, then the covariance matrix of the required samples is equation (2):

$$u = \frac{\sum_{j=1}^{N} x_j}{N}. \tag{1}$$

$$S_r = AA^T = \sum_{j=1}^{N} (x_j - u)(x_j - u)^{\mathrm{T}}. \tag{2}$$

According to the K-L transformation principle, the new coordinate system to be obtained consists of the eigenvectors corresponding to the non-zero eigenvalues of the matrix AA^{T}. The calculation amount of direct calculation is relatively large, so the singular value decomposition (SVD) theorem is used to solve the eigenvalues and eigenvectors of AA^{T}. According to the SVD theorem, let l_i ($i = 1, 2, \ldots, r$) be the r non-zero eigenvalues of the matrix AA^{T}, and v be the eigenvector of AA^{T} corresponding to 4. Since the larger the eigenvalue is, the greater the contribution of the corresponding eigenvector to image recognition is. Therefore, the eigenvalues are arranged according to size with use of equation (3):

$$p = \min_k \left(\frac{\sum_{i=1}^{k} l_i}{\sum_{i=1}^{r} l_i} \right) \geq 0.9, k \leq r. \tag{3}$$

Select the eigenvectors corresponding to the first p eigenvalues to form the dimensionally reduced eigenface subspace. Then the orthogonal normalized eigenvector u of AA^{T}. T is according to the equation (4):

$$u_i = \frac{Av_i}{\sqrt{l_i}}, i = 1, 2, ..., p. \quad (4)$$

The eigenface space is according to the equation (5):

$$W = (u_1, u_2, u_3, ..., u_p). \quad (5)$$

Project the training sample y into the "eigenface" space W to obtain a set of projection vectors Y, equation (6) represents the calculation of Y, which constitutes the training sample database for face recognition.

$$Y = W^{T} Y. \quad (6)$$

After PCA transformation and dimensionality reduction of the image, an SVM classifier needs to be used for training and testing. The working principle of the classifier is to first learn the samples, pre-discriminate the samples, and learn and classify the extracted feature vectors. After classifying the classes, the test objects can be classified and discriminated by passing the test objects through the classifier. For this system, face recognition is also realized. The classification idea of SVM is based on structured risk minimization, taking into account the minimization of training error and test error, which is specifically reflected in the selection of classification models and model parameters. It can effectively guarantee the classification accuracy in small sample problems. The key to nonlinear support vector machines is how to map from low dimensions to high dimensions. This mapping relationship is called the kernel function and theoretically needs to satisfy Mercer's theorem. This system uses the currently mainstream RBF (radial basis kernel function), which implements a support vector machine classifier based on RBF [4]. This system directly uses the libsvm toolbox for SVM classification [5]. The libsvm toolbox is a simple, easy-to-use SVM pattern recognition and regression machine software package developed by C.JLin and others at National Taiwan University. This software package uses convergence The algorithm was improved based on the performance proof results and achieved good results. libsvm implements a total of 5 types of SVM; C-SVC, u-SVC, One Class-SVC, e-SVR and v-SVR, etc.

When training SVM, the impact of kernel functions and related parameters on model performance should be considered. This article uses the default RBF kernel function. First, the cross-validation method is used to find the best parameter c (penalty factor) and parameter g (variance in RBF kernel function), and then the best parameters are used to train the model. It is worth mentioning that when the performance of the models is the same, in order to reduce the calculation time, it is preferable to choose a parameter combination with a smaller penalty factor c. This is because the larger the penalty factor c, the more support vectors will be obtained in the end, and the amount of calculation will increase. The larger the value, the trained SVM model can be directly used for face image classification. The best accuracy obtained through cross-validation during the SVM training process is 94 %. After completing the SVM classification training, we have the SVM model, and we can use the trained SVM model to test the test set.

Conclusion. The proposed system implements a face recognition system based on PCA and SVM methods through MATLAB. In experiments using the ORL face database as the training set and test set, the PCA-SVM method's face recognition achieved the best accuracy of 94 % through cross-validation during the SVM training process, and in the test on the test set The recognition rate is 85.5 %. The function implemented by this system is only the face recognition function. The complete face recognition process also includes the face detection part. If occlusion, posture transformation, etc. are involved, the recognition method may still need to be adjusted.

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СИСТЕМА РАСПОЗНАВАНИЯ ЛИЦ НА ОСНОВЕ АНАЛИЗА ГЛАВНЫХ КОМПОНЕНТОВ И МЕТОДА ОПОРНЫХ ВЕКТОРОВ

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Аннотация. Анализ главных компонентов – это широко используемая технология извлечения признаков при распознавании лиц. Она позволяет уменьшить размерность анализируемых данных при сохранении их характеристик. В частности, при использовании этого метода можно уменьшить размеры анализируемых изображений лиц и за счет этого эффективно уменьшить количество функций, необходимых для анализа, и упростить модель и сложность этого процесса. Применение метода опорных векторов в распознавании лиц основано на возможности эффективно находить с его использованием границы решений в пространстве признаков и различать разные категории (т. е. лица разных людей). В статье представлен реализованный с помощью MATLAB метод распознавания лиц, основанный на сочетании анализа главных компонентов и метода опорных векторов.

Ключевые слова: распознавание лиц, анализ главных компонент, метод опорных векторов, MATLAB.