RESEARCH PAPER

Facial Expression Identification System Using fisher linear discriminant analysis and K-Nearest Neighbor Methods.

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A B S T R A C T:
Facial expression system has become an important and effective research area in many fields such as cognitive processes, medical care and interaction between man and computer. A facial expressions recognition system using each of FLDA with K-nearest neighbors (K-NN) classifier is introduced in this research. The system is applied to recognize various basic facial expressions such as happy, neutral, angry, disgust, sad, fear and surprise, in the Karolinska Directed Emotional Faces (KDEF) and Japanese Female Facial Expressions (JAFFE) database. The experimental results on JAFFE database proved that the proposed method is robust with good accuracy compared to other approaches. The accuracy rate of the system achieved 95.09% and 94% when the proposed method was tested.

KEYWORDS: Face Expression, Expression Recognition, Fisher Linear Discriminant Analysis, K-Nearest Neighbors.

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1. INTRODUCTION:

One of the goals of intelligent systems is to create systems that have the ability to effectively interact with humans in many ways. Many systems have been developed that carry out human facial expressions recognition to understand, interact, and recognize human emotions. However, the realization of the balance between speed and accuracy of each method in these systems is a challenging task (Chakraborty et al., 2017). Depending on the purpose of the system each system tries to use a methodology that reaches a level of accuracy and speed that is needed by the system.

In general, most of facial expression systems contain three stages (preprocessing, feature extraction, and classification). In the feature extraction stage, the significant features of the face will be extracted to represent facial expressions (Abdullah et al., 2018).

There are two kinds of methods that can be implemented in this stage. The first type of method is used to extract the geometric features of the face while the second method is used to extract the appearance features (Sadeghi et al., 2013).

Geometric features methods aim to extract the shape and location of face component such as mouth, nose, eyes and eyebrow. However, using these kinds of methods in real time systems is very difficult because it needs more computational power but they are more robust compared to the appearance features methods. On the other hand, appearance features methods such as PCA principal component analysis (PCA) (George et
al., 2017), linear discriminant analysis (LDA) (Otrosi-Shahreza, 2017), Gabor wavelet transform (Abdulrahman et al., 2014), they aim to extract significant features either whole-face or specific regions of the face image.

Classification stage is another important stage of face expression’s recognition system. Many algorithms have been proposed in order to classify the features of the face. At first, binary classification was introduced such as support vector machines (SVM) (Senthikumar et al., 2017), and then a number of enhancement methods were introduced to obtain robustness and low computational cost (Burges et al., 1997).

The remainder of this paper is organized as follows. Section two provides description of the design of the proposed system including the mathematical description of the proposed methods such as fisher linear discriminant analysis and K-Nearest Neighbors method. Section three introduces the experiment results. Finally, the conclusions are presented in Section four.

2. SYSTEM DESIGN

The proposed system consists of three main stages. The first stage is preprocessing. In this stage some of preprocessing methods such as (Adjust the intensity of the image and, remove the noise and enhance the contrast of the face image) are applied to enhance the face image. In the second step, fisher linear discriminant analysis as a feature extraction method is applied to extract the unique features of the face image. Finally, K-Nearest Neighbors is used to classify the extract features to give the nearest classification of the input image. Figure 1 shows the description of the steps of the proposed system:

![Figure (1): The design of the Proposed System](image)

2.1. Preprocessing

Illumination is one of the important parameters that affect the quality of the image and the recognition rate. There are many preprocessing methods that can be applied to solve this problem and improve the quality of the input image and increase the recognition rate of the system. In this system, to enhance the contrast of the image, histogram equalization method was used in addition to Low Pass Filter to minimize the high frequency information. These two methods make the extract of the features from the image in the next stage easier and more effective.

2.2. Fisher Linear Discriminant Analysis

FLDA is a modification of Eigenfaces; therefore, it is based on Principal Components Analysis in its calculation. The main update to this method takes into consideration classes because Eigenfaces does not find the variation among the two images from different classes during the training part. Each of the images was affected by the total average. FLDA uses the Linear Discriminant Analysis method to find the variation among different classes. It is aimed to minimize the variation within a class compared to the variation between classes. For that not only the total average of faces is used, but the average per class will also be an essential operation. The average is calculated according to the following equations (Atasoy et al., 2015):

\[
\Psi_{c_i} = \frac{1}{q_i} \sum_{k=1}^{q_i} \mathbf{r}_k
\]

(1)

Where \( C_i \) represents the class \( i \) and \( q_i \) represents the number of images in the class \( C \). The average is also subtracted from each vector as in Eigentaces, but this time the average of the corresponding class is used.

\[
\Phi_l = \mathbf{r}_l - \Psi_{c_l}
\]

(2)

Then the scatter matrices are calculated. The Intra-class scatter matrix represented by \( S_w \) can be computed with the following equation:

\[
S_w = \sum_{l=1}^{c} \sum_{\mathbf{r}_k \in C_l} (\mathbf{r}_k - \Psi_{c_l})(\mathbf{r}_k - \Psi_{c_l})^T
\]

(3)

The Inter-class scatter matrix is represented by \( S_b \) which is computed using the following equation:
\[ s_b = \sum_{i=1}^{c} q_i (\Psi_i - \Psi)(\Psi_i - \Psi)^T \]  

(4)

The next formula is applied to get the total scatter matrix \( S_r \).

\[ s_r = \sum_{i=1}^{M} (\Gamma_i - \Psi)(\Gamma_i - \Psi)^T \]  

(5)

After that, the aim is to find a projection of \( W \) which maximizes Fisher's optimization criteria.

\[ W_{opt} = \arg \max_w \frac{|w^T s_b w|}{|w^T s_w w|} \]  

(6)

Finally, the eigenvectors are found as follows:

\[ s_b w_i = \lambda_i s_w w_i, i = 1, 2, ..., m \]  

(7)

Then the process is the same as Principal Components Analysis, the projection of the training image will be compared to the projection of a test image, and the class of the image which has the smallest distance will be the prediction of the algorithm.

\[ \text{dist}(x, y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \]  

(8)

Based on the equation (1), the smallest difference is selected and the input facial image is given the label of nearest neighbor class.

### 2.3. Implementation

The proposed system was implemented by developing a software application on a PC using MATLAB which allows us to program a code to process the input which are the images and also design a GUI in order to interact with the system. The system then will report the output to the user.

### 3. RESULTS AND DISCUSSION

MATLAB version 16th was used to implement the recognition system. All the experiments were simulated and implemented on a personal computer with 2.6MHz Core i5 CPU and 4 GB of memory running under Windows 7 64-bit operating system. A database called JAFFE (Dailey et al., 2010) (Japanese Female Facial Expressions) is a good example to evaluate the performance of this system by using it as a training set. This database is free and available on the Internet for academic and research purposes.

The database contains 213 images for 7 facial expressions (six basic facial expressions in addition to one neutral) are contained in this database and it is posed by 10 Japanese female models (Fig. 2).

These images are taken with a white homogeneous background in different lighting conditions. The size of each image is \((256 \times 256)\) pixels with 256 available gray levels per pixel and the accuracy rate of recognition reached up to \(95.9\%\). While, The KDEF (Goeleven et al., 2008) database consists of 239 colored images for 7 face expressions (one neutral pose and six different expressions) capture under different homogeneous background with different lighting conditions.

2.3 K-Nearest Neighbor

It is one of the famous and simple methods that is applied for classification and regression. It is applied to classify the extracted features based on closest training examples in the feature space. This method depends on Euclidian distance rule to calculate the similarity among the weight of the input facial image and the weights of the training data set. The Euclidean distance measuring is shown in equation below (Eyupoglu, 2016):
The database consists of 17 females and 17 males. The size of each image was (256 x 256) pixel. The accuracy rate of recognition reached up to 94%.

Table 1: Result accuracy by database

| Seq. | Database | Number of Images | Accuracy |
|------|----------|------------------|----------|
| 1    | KDEF     | 239              | 94%      |
| 2    | JAFFE    | 213              | 95.09%   |

In order to check the performance of our system in compare to other systems, a comparison was done to similar systems mentioned in (Shih et al., 2008). The comparison results are explained in Table 2 below.

Table 1: Comparison of results

| #    | Method          | Database | Accuracy | Reference |
|------|-----------------|----------|----------|-----------|
| 1    | Our proposed method | JAFFE    | 95.09%   | FRANK Y. SHIH, PATRICK S. P. WANG |
| 2    | 2D-LDA          | JAFFE    | 94.13%   |           |

As shown above that the proposed system in this research performed better than the other system and this can be due to the methods used.

A major disadvantage of this system is that some of the data used is non-linear and the methods described use linear descriptive analysis. A solution for this problem could be by using a Kernel method which allows to process non-linear data.

4. CONCLUSIONS

A facial expressions recognition system using each of FLDA with K-nearest neighbors (K-NN) classifier is proposed in this research. The system performance is computed by Extensive experiments conducted on databases called KDEF and JAFFE. The experimental results showed that the proposed system can work in different conditions such as facial details, different lighting exposure and facial expressions.

The results showed that the system has a high recognition rate with the accuracy up to 95.09% in JAFFE and 94 % in the KDEF database. In future work, a method like SVM (Support Vector Machine) or convolutional neural network (CNN) could be used to enhance the process of classification. Another method to enhance the lightening may be performed so as to improve the accuracy rate of the recognition. In the future the described method in this research could be improved by using some non-linear feature extraction methods and this will improve performance.

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