https://dx.doi.org/10.22161/ijaers.4.2.36 *ISSN: 2349-6495(P) | 2456-1908(O)*

Real-Time Face Recognition System Using KPCA, LBP and Support Vector Machine

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Abstract**—** *With increasing security threats, Biometric systems have importance in different fields. This appears clearly exactly after the rapid development that happened in power of computing. In this paper, the Design and implementation of a real-time face recognition system are presented. In such a system, Kernel principal component analysis (KPCA) and Local binary pattern (LBP) are used as feature extraction methods with the aid of support vector machine (SVM) to work as a classifier. A comparison between traditional feature extraction methods as (PCA and LDA) and a proposal methods are performed as well as a comparison between support vector neural network and artificial neural network classifier are also implemented. Two types of experiments, On-line, and Off-line experiments are done. In the On-line experiment, a new database is created and used. While in the off-line experiment, two types of databases (ORL and YALE) are used to estimate the performance and efficiency of the system. The combinations of these methods together enhances the experimental results in compare with other methods.*

Keywords**— Face recognition, Kernel-principle component analysis, Local binary pattern, Support vector machine, linear discriminated Analysis.**

I. INTRODUCTION

The face of human provides much information that can be used in the different kinds of applications such as identification, the perception of emotional expressions, and lip-readings. The analysis of the face is considered as an essential function for many of applications such as face detection, face recognition, and face expression recognition. For this reason, face recognition has been considered as one of significant studied field through the last two decades [1-6].

Many of the systems that used are very influenced by a changing in light and noise in image; therefore face recognition isn't easy but it is a very difficult problem. Also, there are other expressions, like lighting conditions, colors and so on, that can generate several different face patterns. The separation process between the face and non-face classes is very difficult because it is nonlinear. For this reason, traditional methods such as PCA and linear discriminate analysis (LDA) are not appropriate for the task for extraction function.

Kernel-based non-linear approaches like Kernel-independent component analysis (K-ICA) and kernel PCA (k-PCA) can provide the fewest error rates compared to other methods. [7-10]. Nevertheless, these methods are usually difficult and time-consuming because they need a big amount of training samples to make decisions. K-PCA was expanded from PCA by Schölkopf et al. in 1998 [11] and there are many of K-PCA algorithms already proposed. The idea of using kernel function methods is that the kernel PCA has the ability to extract non-linear features because important information of the image may exist in the high-order relationships [12-13].

LBP has been presented to analysis face. The mainly significant features of LBP are its great tolerance against lighting change and also its computational simplicity. At first time, the LBP was developed to use various sizes of neighborhood to take features at different scales. Then, employ a small subset of the patterns to represent the texture of the images and by using this technique, the number of patterns is minimized without losing any additional information. [14].

This paper is organized as follows: In Section 2, system architecture is presented. In this section all parts of the system and the ideas of K-PCA, LBP, K-NN and SVM are given. In Section 3, the experiments are applied on two types of image database to evaluate and compared to other methods. Finally, a conclusion is introduced in Section 4.

II. SYSTEM ARCHITECTURE

The proposed face recognition system consists of five stages: face detection (localization), face preprocessing includes face alignment/normalization and light correction, feature extraction using each of K-PCA and LBP, classification using SVM and finally, feature matching using K-NN. "Fig. 1" display the five steps of proposed face recognition These steps are introduced in this section as follow:-

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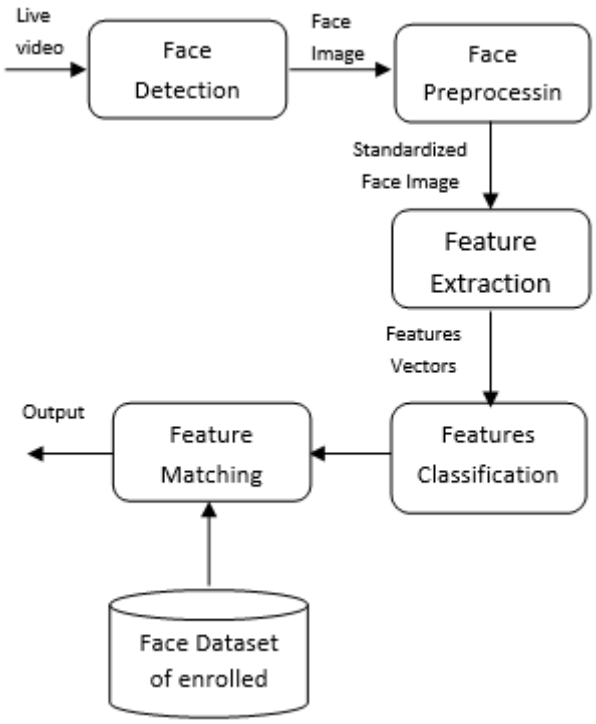

Fig.1: The five steps of proposed face recognition.

i. Face Detection

The goal of this stage is to decide the shape of the face in an image. In the case of a video input, the system must have the ability to detect the face in multiple frames. The Viola-Jones face detection algorithm [15] is a very good example of the techniques that are used to detect faces. So, in the face detection stage, this algorithm is used to detects a face in the input image.

ii. Preprocessing

The goal of this stage is to reduce the effect of lighting condition that happened during the face detection stage. It is necessary to implement preprocessing before face detection to obtain the best results. In our proposed system, two steps are applied to remove noises from the image. These two steps are:

- **Illumination gradient correction**

In this step, the best-fit value of brightness is calculated. Then, this value is subtracted from the value of all pixels in the face-image. In the face recognition, illumination gradient correction can be used to reduce the effect of shadows that appear in the image from lighting angles [16].

- **Histogram equalization**

It is considered as a one of image transformation method that can flatten the histogram of the image, and recompense the change that caused by an effect of changes in lighting or the changing in response curves of camera [17].

iii. Feature Extraction

Feature extraction stage is applied to obtain the most important feature from the face image. Without this stage, the recognition becomes very complex and it does not give good results. The KPCA and LBP methods are used to implement this function.

- **Kernel Principal component analysis**

K-PCA is extended from traditional PCA method. PCA aim is to extract feature from data through implementing an orthogonal transformation while K-PCA is developed from PCA to solve a nonlinear problem based on kernel methods by mapping the data from input space to a higher dimensional feature space and then implement PCA in feature space. This mapping is not calculated randomly but the kernel must achieve Mercer's deprive method [18].

To explain the Algorithm of K-PCA, let us consider that x1…… xN is a set of vectors and the N x N is the kernel matrix. The mapped data points are centered in feature space by using the following equation:

$$K_{ij} = K'_{ij} - \frac{1}{N}\sum_{m=1}^{N} l_{im} K'_{mj} - \frac{1}{N}\sum_{n=1}^{N} K'_{in} l_{nj} + \frac{1}{N^2}\sum_{m=1}^{N}\sum_{n=1}^{N} l_{im} K'_{mn} l_{nj} \quad (1)$$

Where l is a N x N matrix whose entries are all l's. After that, the Eigenvalue problem is solved as follows:

$$Ka = \lambda\, a \quad (2)$$

These positive Eigenvalues λj are arranged in de order (λj ≥ λj+1) and normalize the eigenvector coefficients

$$a(n).\, a(n) = 1 / \lambda n \qquad n = 1,2,3,\ldots\ldots p \quad (3)$$

The equation below can be used to obtain the n-th principal component q(n) of image xt.

$$q^{(n)} = \sum_{i=1}^{N} a_i^{(n)} k(x_i, x_t) \quad (4)$$

The amount of principal components that can be obtain using K-PCA is more than the traditional PCA because the limit for PCA is the dimensionality of the image vector while the limit of K-PCA is the number of image samples in the training set.

- **Local binary pattern**

LBP is a well-known technique employed for image representation. LBP has been commonly used in many kinds of applications because of its great tolerance against lighting changes. It was initially created by Ojala et al. [19] as gray-scale and rotation invariant texture classification method. The essence idea of LBP is that each 3x3-neighborhood in an image is threshold using the value of central pixel. After that a decimal description of the image is calculated using binary sequence. Figure 2. Explain essence idea of LBP.

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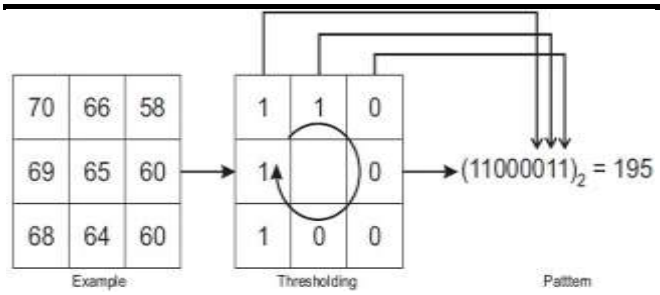

Fig.2: LBP operator: (left) the binary sequence (8 bits) and (right) the weighted threshold.

LBP is initially defined as show in question (5) [20]:

$$LBP(x_c, y_c) = \sum_{n=0}^{7} s(i_n - i_c) \cdot 2^n, \quad (5) \qquad (1)$$

Where ic refers to the central pixel value in gray level (xc, yc). The gray values of the 8 pixels s(x) that surround to the central pixel can be calculated as [21-22]:

$$s(x) = \begin{cases} 1 & \text{if } x \geq 0 \\ 0 & \text{if } x < 0. \end{cases} \quad (6)$$

iv. Classification stage

A classification is the fourth stage of this system. The goal of this stage is to classify the entire face image based on the information that obtained through the training stage. There are many classification methods that can be applied. In this system, SVMs that are considered as one of the famous classification method is used to do this job.

- **Support Vector Machines**

SVM is one of the important techniques that is used to classify features. The SVM algorithm [23] is applied to determine maximum separating hyperplane whose separate between the feature of two classes.

Let us consider that, a given group of training label is (z1; d1);.....; (zN; dN), Then the method aims to minimize the below cost function:

$$\emptyset(w, \varepsilon_i) = \frac{1}{2} w^T w + C \sum_i \varepsilon_i \quad (7)$$

But to implement that the constraints in the equation (6) must be achieved:

$$d_i(w^T z_i - b) \geq 1 - \varepsilon_i \quad i = 1,2,\dots,N$$
$$0 \leq \varepsilon_i \leq C \quad i = 1,2,\dots,N \quad (8)$$

From equation above, the parameter w refers to the weight of the vector, while b refers to the bias that calculate the perpendicular distance of the hyperplane from the origin, and ε_i refers to the group of slack variables and C refers to user-specified complexity parameter. The slack variables may lead to the opportunity that some examples will not be classified on the hyperplane. As long as there is an upper bound of the number of misclassifications degree, the type of SVM is known as the soft margin [23].

The expression of SVM decision rule is shown in the equation below:

$$g(z) = \sum_{i=1}^{N} \alpha_{o,i} d_i \, k(z_i, z) \quad i = 1, \dots\dots\dots, N \quad (9)$$

From equation above, z_i for which $\alpha_{o,i}$ is a non-zero and it known as the support vectors. These vectors are used to determine the decision hyperplane between the classes.

v. Feature Matching

It is considered as recognition process. In this stage, the feature that gets from the previous stage is matched with feature of the input image to classify the facial images according to the face in the database. The k-Nearest Neighbor (KNN) method is applied to implement this function.

- **Nearest Neighbor Classifier**

The k-NN is one of the methods that applied to classify feature by determining the nearest k neighbors in the space of feature.

To understand this method, let us consider that the point z that will be classified. This is done by take the k neighbor that has the least distances between z and all other feature points, As the follows:

$$\{d_i(z, z_{c_i i_i}), \dots\dots, d_k(z, z_{c_k i_k}\} = min_{1 \leq c \leq C, 1 \leq i \leq n_c} d(z, z_{ci}) \quad (10)$$

From equation above, nc refers to the samples in the each class. The distance computation can be describing as:

$$\sum_{c=1}^{C} n_c \quad (11)$$

There are a number of parameters can be applied with k-NN method, such as k which refers to the number of the nearest neighbors and the other parameters is the distance model. In this system, the Euclidean norm distance d(z,zci)=||z –zci|| and k equal to 1 is applied to find the class of the closest query point [25].

III. EXPERIMENTAL AND RESULTS

Two types of experiments are used to estimate the efficiency of the proposal system. The first type is an off-line experiment using YALE and ORL database and the second type is an on-line experiment using new database and it is based on live video to test.

i. Off-line Experiment

In off-line part, the first experiment is implemented based on Olivetti Research Laboratory (ORL) database [25]. The ORL database consists of 400 images for 40 persons and each person has 10 images. These images are taken under different lights, expressions, and perspectives. Figure 3 shows ten different images from ORL database. The types of these images are grayscale and their resolutions are 112 × 92 pixels. The number of images that are used as a training set is 160 (five images for each person) and the

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Residual images (240 images) are applied as the testing set.

Fig. 3: Samples of ORL Database

The second experiment is implemented based on YALE University (YALE) database [26] for. The YALE database consists of 165 images of 15 persons and each person 11 images. These images are taken under different lights, expressions, and perspectives. Figure 4 shows 10 different images for the same person. The number of images that used as training set is 60 (5 images for each person) and the remaining 105 images are applied to the testing set. Table (1) shows the recognition accuracy of the two databases.

Fig.4: Samples of Yale Database.

Table.1: The recognition accuracy of the ORL and Yale databases

No. of class	No. of training images	No. of testing images	Accuracy (%)
40	160	240	97.5 %
15	60	105	97.1428%

Finally, comparison between the proposed method and traditional methods such as PCA and LDA based on SVM classifier is also implemented as display in table (2).

Table.2: Comparison between the ORL, Yale databases and other methods results

Method	Database	Accuracy (%)
KPCA(polynomial), LBP and SVM	ORL	97.5 %
LDA – SVM [25]	ORL	96.25%
PCA- SVM [26]	ORL	91.25

ii. On-Line Experiment

In this experiment, the database created by the authors is applied to test and train. The system detects the face from live capture image, and then this face image is entered to the system. Samsung camera is used to capture image. It can capture 1080 pixel full high-definition video at 60 frames per second and 16-megapixel qualities. The database contains 176 images of 22 persons. The different images of two persons are displayed in figure 5. Eighty-eight images are selected as the training set and the remaining eighty-eight images are applied as testing set. Table (3) shows the recognition accuracy of the two databases.

Fig.5: Images of two persons from creative database

Finally, Graphics User Interface (GUI) is created to make use of the system is easy and efficient. The GUI consists of four pushbuttons: (1). Capture Image using camera, (2) Input Image from the database, (3). Recognize the face, (4). Help and (4). Exit. "Fig.6" shows the GUI that designed for the system.

Fig.6: GUI of the system

Table.3: The recognition accuracy based on creative databases

No. of class	No. of training samples	No. of testing samples	Accuracy (%)
22	88	88	96.59 %

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IV. CONCLUSION

In this research, a real-time face recognition system is presented. In such a system, K-PCA and LBP are used as feature extraction methods with the aid of SVM to work as a classifier. K-PCA is a non-linear method that developed based on PCA which is depended on the Eigenface method. K-PCA with LBP offered description of the face image that is more appropriate for recognition than traditional PCA. Each of the two experiments show that K-PCA based polynomial kernel function with LBP is better than PCA on the face recognition task when both are used with SVM classifier.

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