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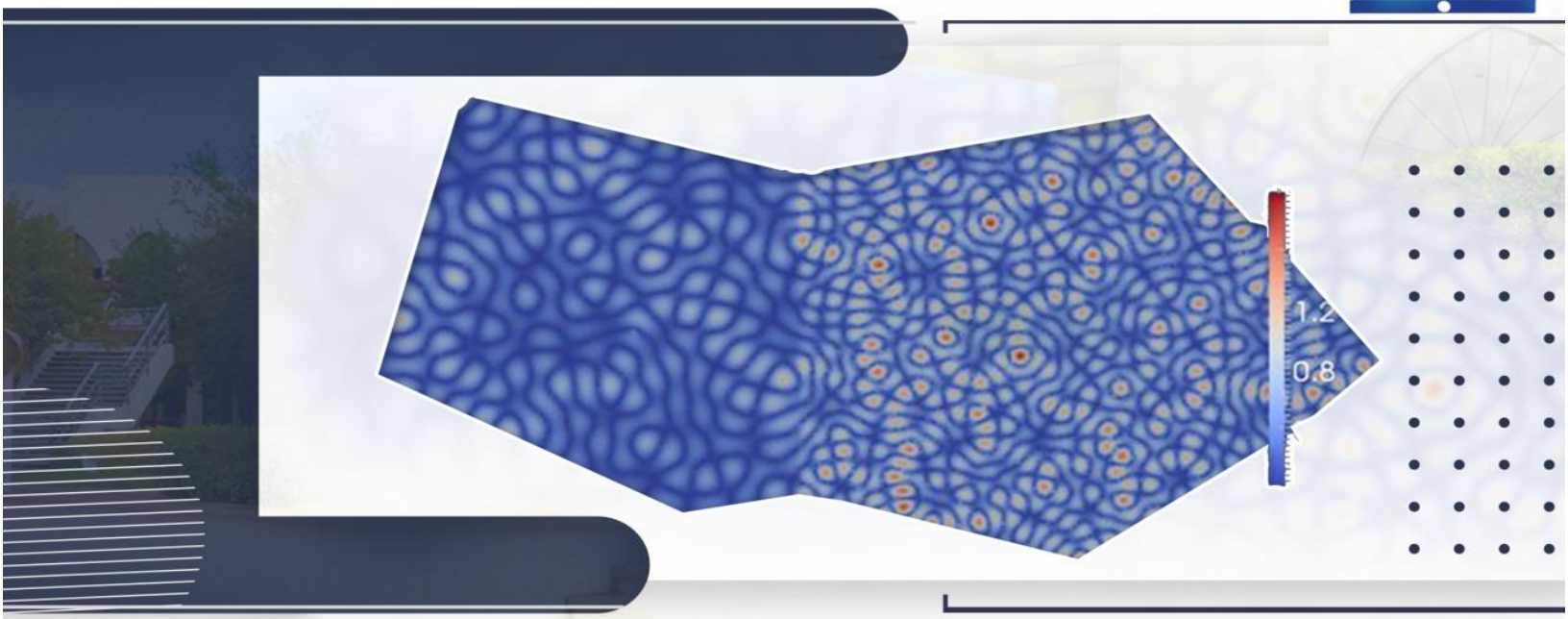

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Study of Principal Component Analysis (PCA) as a Face Recognition Method

Amina. R. Shtewi, Entisar. N. Abolkasim, Mouna. S. Jamom, and Sana. T. shrif

Computer sciences Department, Science Faculty, Gharyan University, Charyan, Libya.

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A B S T R A C T

Face recognition is a biometric technique that can be used for a variety of purposes, such as national security, access control, identity fraud, banking, and finding missing children. Faces are highly dynamic and facial features are not always easily extracted, which can lead to discarding textural information like the smoothness of faces, a hairstyle that, might contain strong identity information. In addition, brightness, scale, and facial expressions play a significant role in the face-recognizing process. Therefore, face recognition is considered as a difficult problem. To figure out this problem effective methods using databases techniques are needed. This paper describes face recognition methods and their structure. Based on Wen Yi Zhao and Rama Chellappa work the face recognition methods are divided into three groups: a holistic approach, feature-based approach, and hybrid approach, where Principal Component Analysis PCA, a holistic approach method, is presented as a mathematical technique that can assist the process of face recognition. Also, the paper shows how the PCA is used to extract facial features by removing the principal components of the available multidimensional data.

Introduction

Recently, face recognition has become a popular field of inquiry in computer vision, where a great deal of research is moving at this focal point to increase the optical ability of computing. Iris, face, fingerprints, and DNA are various human characteristics that are used in biometric systems. Face recognition can be a suitable alternative compared to other biometric techniques.

There are many approaches for face recognition in this field. Many researchers proposed algorithms to identify and recognize human beings' faces from a given database. The recent development in this field has facilitated the fast-processing capacity and high accuracy(Malakar et al., 2021)

The challenge facing of Face Recognition, is how to perform very well under hard conditions. For example, a personal variation processing system might need to process a low-quality face image which image, which has been acquired using a low-quality Personal computer camera and transferred over an IP address, or the image was captured in an uncontrolled environment with bad lighting.

In this paper, one of the most popular methods for face recognition will be presented, Principal Component Analysis (PCA), Facial recognition methods can be divided into three big groups, holistic approach, feature-based approach, and hybrid approach (Bansal et al., 2012) (Delac et al., 2005). These are described below:

Corresponding author: E-mail: aminashtewi@gmail.com

- Holistic approach or appearance-based approach (Bansal et al., 2012): which uses holistic texture features and is applied to either whole-face or specific regions in a face image uses (Delac et al., 2005). Where, each face is handled as a two-dimensional array of intensity values, which is compared to the intensity values of other facial arrays.
- Feature-based approach (A. Bansal et al., 2012): face verification is needed, which tries to verify a local feature on the face such as the nose and eyes from a given sample of that face and extracts descriptive information about them such as their widths and heights.
- Hybrid approach (Mwendwa, 2016): both face identification and face verification are used as the input to the face detection system. It can be similar to the human being's behavior to recognize the face (Mwendwa, 2016).

1 Methods of Face Recognition

To extract and recognize the human face, a variety of algorithms are used; each technique is unique, different in performance, accuracy, and effectiveness (Kumar &Kaur, 2012.) (Saini et al., 2014.)(Çarıkçı & Özen, 2012). The following are the most popular face recognition methods:

1. Principal Component Analysis (PCA).
2. The Hidden Markov method.
3. Linear discriminate analysis (LDA).
4. Neural Network method
5. Geometrical Feature Matching
6. Elastic Bunch Graph Matching (EBGM).
7. Independent Component Analysis (ICA).
8. Fisherfaces.

Most of these existing recognition methods are focused on the color-image-based (2D) appearance of faces and discard their video (3D). This leads to a poor discrimination power when dealing with variations such as illumination and makeup. Figure 1 shows the structure of general face recognition system.(Malakar et al., 2021)

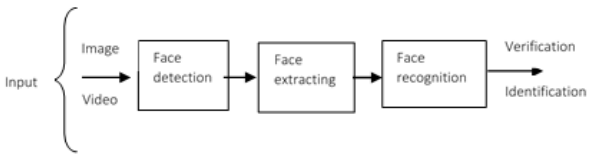

Figure (1). Structure of general face recognition system.

1.1 Principal Component Analysis Method (PCA).

PCA is also known as Karhunen-Loeve method or eigenface method. Recognition of human faces using the PCA was first done by Turk and Pentland (Batra&Goyal,2015), and many followed Kiry and Sirovich (Thakur et al., 2008). Principal Component Analysis (PCA) is a statistical method that has been used in image recognition. When there is a high correlation between observed variables, the PCA can be utilized as feature extraction in face recognition to reduce the big dimensionality of data space to lower dimensionality of feature space. The PCA is used for prediction, redundancy removal, feature extraction, and data compression (Tamimi et al., 2015). When dealing with large collections of data samples, it is a popular strategy in signal processing to lower the dimensionality of the image. By means of removing information that is not useful, and specifically decomposes the structure of the face into components, which are uncorrelated and are known as Eigenfaces (Turk & Pentland, 1991). PCA is a linear transformation that converts the data to a new coordinate system. These basis vectors represent eigenvectors of the covariance matrix of the data samples, and the coefficients for each data sample are the weights, or principal components of that data (the United States Patent Corcoran) Unlike other linear transformations, such as discrete cosine transforms (DCT) (Strang, 1999). Its basis vectors depend on the dataset. PCA can be used for reducing dimensionality in a dataset while retaining those characteristics of the dataset, that contribute most to its variance, by holding lower-order principal components and ignoring higher-order ones. Why the PCA? The principal component analysis (PCA) can be considered as one of the most important face recognition methods in the literature (Tamimi et al., 2015). Also, PCA is a very popular method. In Figure 2 below, the number of articles that have utilized the words facial recognition and PCA in their headers is shown. (Karamizadeh et al., 2013). Furthermore, the image size is unimportant for the PCA (Saini et al., 2014.).

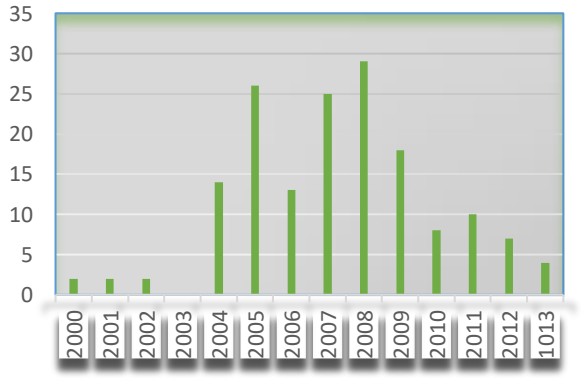

Figure (2). The number of publications utilized.

1.2 The PCA Methodology.

PCA is a mathematical technique, which acts as a dimensionality reduction technique by removing the principal components of the multidimensional data. The first principal component is the linear combination of the original dimensions, which has the highest variability. A s-dimensional vector, which is the representation of the weighted sum (feature vector) of the eigenfaces, could be used to represent each image of a face. In this method, a full front view of the face is required, otherwise, the output of recognition will not be accurate. The major benefit of this method is that it can decrease the data required to recognize the entity to 1/1000th of the existing data (Bansal & Chawla, 2013). First, all images of known faces are projected onto the face space to find sets of weights, that describe the contribution of each vector, to identify an unknown image. Then, that image is projected onto the face space as well to obtain its set of weights, by comparing a set of weights for the unknown face to sets of weights of known faces (Delac et al., 2005). Finally, the unknown face can be recognized. Figure 3 below shows the flow chart of the PCA methodology.

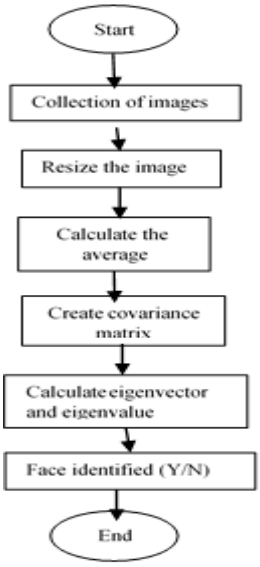

Figure (3). Flow chart of PCA methodology.

1.3 The PCA Matimatical Present.

PCA is a mathematical approach for reducing dimensionality in multi-dimensional data by extracting the primary components. The first principal component is the linear combination of the original dimensions that has the highest variability (Laltanpuia, 2018).

1. First, images with a two-dimensional N*N array must be trained. An image can be considered the basic vector of dimension N*N. Resize the image, so that a typical image of size 112x92 becomes a vector of dimension 10304 (Bansal & Chawla, 2013). If the training set of images {X1, X2, X3… XN} (Vyanza et al., 2017). The average face of the set is defined by equation (1) (Batra&Goyal, 2015):

$$\overline{X}=1\backslash N \sum_{i=1}^{n} Xi \quad (1)$$

2. Resize the images (Javed, 2013).

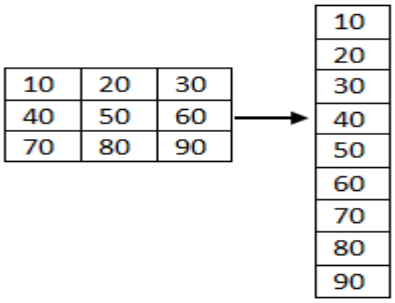

Figure 4. Resize the images

Where N is the number of sample images x is the average of the image, M is the number of images, I is the image vector.

3. The average face is calculated and subtracted from each face in the training set As given in equation (2) (Borade et al., 2016.).

$$\phi=\overline{X}i - Xi \quad , i=1,2,3,4,\ldots,N \quad (2)$$

The estimated covariance matrix (D) will be created using the results of the subtraction operation As given in equation (3) (Saha et al., 2014.) (Ejaz et al., 2019).

$$D=A^tA \quad (3)$$

Then a new matrix (B) is formed as B= [ϕ1, ϕ2, ϕ3... ϕn] (Batra&Goyal, 2015) (Abdullah, 2012).

4. The eigenvector and eigenvalue are calculated using the estimated covariance matrix. For the N-dimensional vector, there will be N eigenvalues and eigenvectors (Singh et al., 2003).
5. Finally, the eigenvalue is sorted out from high to low, then the first N eigenvectors that have large variances are chosen and removed the ones with low variance, so that could reduce the dimensionality. The eigenvector with the highest eigenvalue is the principal component of the dataset (Tamimi et al., 2015).
6. The unknown image will be compared with the training image in eigenspace and identify where the face recognition or not (Stephen et al., 2005) (Raut&Patil, 2012).

2 Principal Component Analysis' Benefits (PCA)

- Data compression is done using the low-dimensional subspace representation (Kumar &Kaur, 2012.).
- Intensity data are used directly for studying and recognizing without any type of level processing (Ameen et al., 2017) (Bansal & Chawla, 2013).
- It is very useful when you deal with a large number of variables (Deshpande & Ravishankar, 2017).
- Compared to other approaches recognition with the PCA method is simple and efficient (Kumar & Kaur, 2012.).
- Does not require any advanced knowledge of geometry or reflectance of the face (Phillips et al., 2005).
- The location and size of each face image remain similar (Singh et al., 2003).
- The method is powerful when dealing with expressions and glasses (these experiments were made only with frontal views) based on (Sharif et al., 2017).

3 Principal Component Analysis' Drawbacks (PCA).

- The size and location of each face image must remain similar (Singh et al., 2003).
- The approach is not robust when there is an extreme change in the pose as well as in the expression, disguise, and illumination.
- As it is an appearance-based method (A. Bansal et al., 2012), it is difficult to update the face databases. Therefore, learning is very time-consuming, which makes the covariance matrix difficult to solve.
- The method is very sensitive to scale (Kumar&Sehgal, 2016.).

4 Conclusions

The primary goal of this paper is to represent and review one of the popular face recognition techniques, Principal Component Analysis (PCA). The face recognition methods are derived into three groups. The paper presented the PCA functionality, method, and methodology, and reviewed its advantages and disadvantages. PCA can be used with a large dataset and it has been represented as a mathematical technique. Also, PCA is an essential approach that can be used to get clear face recognition. This is due to its technique where it passes on components where each face can be analyzed.

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