



Comparison of PCA and 2DPCA Accuracy with K-Nearest Neighbor Classification in Face Image Recognition

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Abstract

Face recognition is a special pattern recognition for faces that compare input image with data in database. The image has a variety and has large dimensions, so that dimension reduction is needed, one of them is Principal Component Analysis (PCA) method. Dimensional transformation on image causes vector space dimension of image become large. At present, a feature extraction technique called Two-Dimensional Principal Component Analysis (2DPCA) is proposed to overcome weakness of PCA. Classification process in 2DPCA using K-Nearest Neighbor (KNN) method by counting euclidean distance. In PCA method, face matrix is changed into one-dimensional matrix to get covariance matrix. While in 2DPCA, covariance matrix is directly obtained from face image matrix. In this research, we conducted 4 trials with different amount of training data and testing data, where data is taken from AT&T database. In 4 time testing, accuracy of 2DPCA+KNN method is higher than PCA+KNN method. Highest accuracy of 2DPCA+KNN method was obtained in 4th test with 96.88%. while the highest accuracy of PCA+KNN method was obtained in 4th test with 89.38%. More images used as training data compared to testing data, then the accuracy value tends to be greater.

Keywords: Face Recognition, Feature Extraction, PCA, 2DPCA, K-Nearest Neighbor.

1. INTRODUCTION

The rapid development of information technology has made a lot changes to human life [1]. Development of information and technology computers can solve problems that occur in society [2]. Improvement of computer technology and telecommunications help many peoples to get a lot of work to done quickly, accurately, and efficiently [3]. Development of digital image processing is increasingly widespread, one of them is pattern recognition in digital imagery. Pattern is defined entities and can be identified through their features. More special features obtained, more precise of recognition this method can do. The characteristics of identification results will be used to distinguish a pattern from other patterns.

Every human being is created with a different physical form and appearance that make humans can be distinguished from one another. On technology information, uniqueness of physical shape of human face can be used as input into a system of identification, authentication or security systems. In information technology, uniqueness physical shape from human face can be made as input to a system of identification, authentication or system security. Face is one of the body parts that usually used to distinguish or recognize someone. Face recognition system is a three-step process, contains face detection, feature extraction and face recognition [4]. Face detection is initial process that must be done on input image to detect presence of facial images in image input. The face detection process will be carried out together in the extraction feature process. It's because in face detection process, feature extraction is required in input image that will detect whether the input image is image that contains facial fetures or not. Face recognition itself is a process identification based on face images stored in database.

Two things that really influence in face recognition process is feature extraction and classification method [5]. Feature extraction can be researched by taking some part of image that can show the characteristics of image, for example color, image paterrn, diameter, etc [6]. The charateristics of extraction results then used as a parameter/input value to distinguish between one image to another at classification stage. The image has a variety and has large of dimensions, so that dimension reduction is needed, one of them is Principal Component Analysis (PCA) method. PCA method or Eigenfaces is the most widely used method in recognition human face [7]. PCA method also has a weakness, this method has the scalar characteristic and also requires extensive data for training data and testing data in order to get accuracy [8]. With the dimensional transformation in image, causes vector space dimension of image become large. Nowadays, a feature extraction technique called Two-Dimensional Principal Component Analysis (2DPCA) is proposed to overcome weakness of PCA. 2DPCA has better computing time performance than PCA because covariance matrix is directly obtained from face image matrix and it is not necessary to transform matrix into one-dimensional vectors like on PCA method [9].

In face recognition, classification process is as important as feature extraction. After important facial features are generated in the extraction features, these features will later be used for classification process. K-Nearest Neighbor works better and more efficient than other existing methods due to it's reduced error rate [10]. K-Nearest Neighbor is algorithms that are very simple to recognize but work extremely well in practice [11]. Based on the description, the purpose of this study is to applying combination of Principal Component Analysis (PCA) and Two-Dimensional Principal Component Analysis (2DPCA) with K-Nearest Neighbor (KNN) to do a comporative analysis the accuracy of performance this method.

2. METHODS

2.1. Principal Component Analysis (PCA) Algorithm

The PCA method is a statical technique that is useful in fields such as face recognition, image compression, and general techniques to find patterns in high dimensional data [7]. The PCA procedure is basically aims to simplify the variables observed in a way shrink/reduce its dimensions [12]. The following are the extraction steps traits with PCA [13]:

1. Make the same image $N \times N$ on face image I .
2. Read each training face image, $I = (I_1, I_2, I_3, \dots, I_i)$.
3. Change the dimensions of face image to vector size $1 \times N^2$ and symbolize each image I_i as vector r_i .

4. Calculate the average matrix

$$\Psi = \frac{1}{M} \sum_{i=1}^M r_i \quad (1)$$

5. Substract each face image matrix by its average

$$\Phi = r_i - \Psi \quad (2)$$

6. Calculating covariance matrix

$$C = \Phi \Phi^T \quad (3)$$

$$\text{Where } \Phi = \begin{bmatrix} \Phi_1 \\ \Phi_2 \\ \dots \\ \Phi_M \end{bmatrix}$$

Because the size of the matrix is too large, look for the covariance matrix be:

$$C = A^T A \quad (4)$$

7. Calculating eigenvalue and eigenvector

$$C u_i = \lambda u_i \quad (5)$$

$$\text{Eigenvalue } (\lambda) = \text{Det} (C - \lambda I)$$

$$\text{Eigenvector } (u_i) = (C - \lambda I) u_i$$

8. Calculating eigenface (μ)

$$\mu = \sum_{i=1}^M v_i Q_i \quad (6)$$

2.2. Two-Dimensional Principal Component Analysis (2DPCA) Algorithm

By calculation, 2DPCA has better computing time performance compared to PCA because covariance matrix in 2DPCA is directly obtained from the face image matrix [9]. The 2DPCA method has two important advantages over the PCA method. First, it's easier to evaluate the covariance matrix accurately. Second, we don't need a lot of times to determine the appropriate eigenvector [14].

The feature extraction with 2DPCA is explained by this following steps [5]:

Steps 1

The face image database contains a set of M training images $A_j = [A_1, A_2, \dots, A_m]$ ($j = 1, 2, \dots, M$) with the image dimension (92×112) projected 2-dimensional matrix.

Step 2

The next step is the calculation of the average matrix:

$$\hat{A} = \frac{1}{M} \sum_{i=1}^M y \quad (7)$$

Where : M = image amount, Y = image matrix, \hat{A} = average.

Step 3

Then calculate the difference matrix of each image A_j with \bar{A} :

$$\bar{A} = A_j - \hat{A} \tag{8}$$

Step 4

The covariance matrix can be calculated from the set of training images:

$$G_t = \frac{1}{M} \sum_{j=1}^M \bar{A}^T \bar{A}$$

Or can be written,

$$G_t = \frac{1}{M} \sum_{j=1}^M (A_j - \hat{A})^T (A_j - \hat{A}) \tag{9}$$

where:

G_t = Covariance matrix

M = image amount

j = 1, 2, 3, ..., n

A_j = Face image matrix

\bar{A} = Difference matrix

\bar{A}^T = Tranpose Difference Matrix

The covariance matrix will get a square matrix with a size of 92 x 92.

Step 5

Determine the eigenvalue and eigenvector are used the Singular Value Decomposition (SVD) method.

$$A\vec{V} = \lambda\vec{V} \tag{10}$$

where :

A = Square matrix (nxn)

\vec{V} = Eigenvector

λ = Skalar/Eigenvalue

Eigenvalue is always correspondence with changes in eigenvector, then the eigenvector is projected according to the eigenvalue starting from the largest $\lambda_1 > \lambda_2 > \lambda_3 > \dots > \lambda_n$.

2.3. K-Nearest Neighbor (KNN) Algorithm

KNN classification works by comparing the distance between training data with testing data. When there's input on testing data, KNN will looks for closest distance (euclidean distance) testing data of known training data. The euclidean distance matrix is used to determine the proximity of the points data/distance between data in K-Nearest Neighbor [15]. The following function are used to search for euclidean distance [16]:

$$d_i = \sqrt{\sum_{i=1}^p (x_{2i} - x_{1i})^2} \tag{11}$$

declaration:

x_1 = training data

x_2 = testing data

i = data variabel

d_i = distance

p = data dimension

3. RESULT AND DISCUSSION

3.1 Face Image Database Components

In this study, the application of methods is done by using MATLAB R2015a. Face data taken from AT&T “The Database of Face” (previously called ORL database). There are 40 subjects or classes where each class consists of 10 face images so that the total amount of data is 400 images face. This entire face image will be divided into training data and testing data. The images are taken with a dark background and upright position and facing forward (with tolerance for some changes to the taking of the face angle). These files are in the format of PGM and size of each image is 92x112 pixels with grey levels 21 for each pixels. Samples of AT&T’s face image can be seen in Figure 1.



Figure 1. Samples of AT&T’s Face Image

In detail the data distribution in this study can be seen in Table 1.

Table 1. Distribution of Training Data and Testing Data

| Percentage Training Data | Percentage Testing Data | Amount of Training Data | Amount of Testing Data | All Data |
|--------------------------|-------------------------|-------------------------|------------------------|------------|
| 30% | 70% | 120 images | 280 images | 400 images |
| 40% | 60% | 160 images | 240 images | 400 images |
| 50% | 50% | 200 images | 200 images | 400 images |
| 60% | 40% | 240 images | 160 images | 400 images |

3.2 Testing of the Face Recognition System

The testing process is done by 4 times in each combination method. This test is carried out to determine the accuracy of the combination method used. Explanation of the testing process will be explained by this following.

3.2.1 Data Partition

Data distribution is done manually by dividing data into two part, training data and testing data. Training data will be used as experimental material and testing

data is used as data for testing. The distribution of training data and testing data can be seen in Table 1.

3.2.2 Input Test Image

After specifying the database and divide data, next step is testing. Testing is done on all test image contained in the database. At this stage, user enters the test image to system.

3.2.3 Feature Extraction

Feature extraction stage is done by changing the face image into face matrix. In PCA method, face matrix converted into one-dimensional matrix first to get covariance matrix. While in 2DPCA method, covariance matrix directly obtained from face image matrix and there is no need to transform matrix into one-dimensional vectors. The last stage of feature calculation extraction looks for eigenfaces from each face. To get eigenfaces, PCA and 2DPCA do calculations covariance matrix of training face images. The face image feature extraction process can be seen in Figure 2.

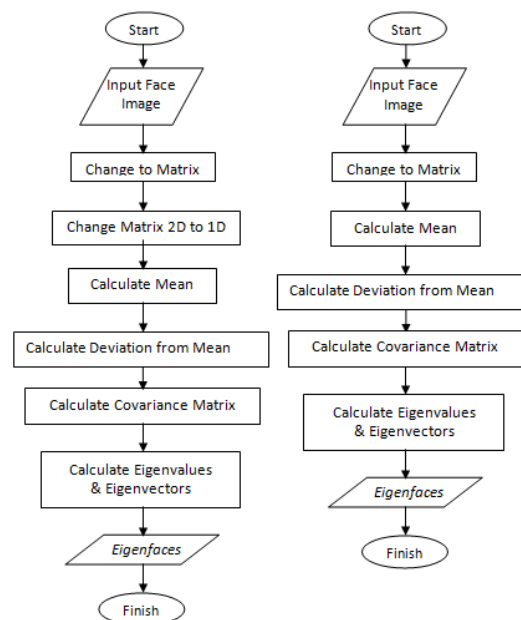


Figure 2. Flowchart of Feature Extraction Process (a) PCA method, (b) 2DPCA method

3.2.4 Classification

Classification is a matching process of image testing classes and training image. K-Nearest Neighbor (KNN) used as a method in this study, first step in this classification is finding eigenface value from training image. Second, calculate the euclidean distance between training image and testing image. Classes that

have smallest euclidean distance are considered as classes that have many similarities with testing images. Flowchart of K- Nearest Neighbor classification can be seen in Figure 3.

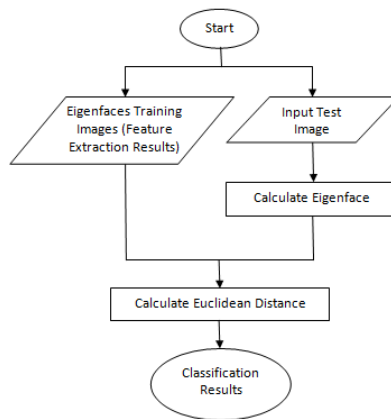


Figure 3. Flowchart of K-Nearest Neighbor Classification

3.2.5 Calculation Accuracy

Accuracy calculation process is used to find out level of accuracy system in recognizing face image classes. Confusion matrix provides decisions obtained in training and testing, confusion matrix give an assessment of the performance of classification based on the object correctly or wrong.

3.3 Analysis of Test Results

In this study, author conducted experiment 4 times with different amount training data and testing data to determine of accuracy from combination methods. The database consist of 40 subjects or classes with each class consists of 10 images. Face images are taken differently both in terms of time, lighting, facial expressions (opening/closing eyes, smiling/no smile) and facial details (wearing glasses/not wearing glasses). All images are taken with a dark background and upright position and facing forward (with tolerance for some changes to the taking of the face angle). The test results can be seen in Table 2.

Table 2. Test Result

| No | Amount of Data | Accuracy Results | |
|----|----------------------------------------|------------------|-----------|
| | | PCA+KNN | 2DPCA+KNN |
| 1 | 120 training images, 280 testing image | 72,86% | 84,64% |
| 2 | 160 training images, 240 testing image | 76,25% | 88,33% |
| 3 | 200 training images, 200 testing image | 77% | 91% |
| 4 | 240 training images, 160 testing image | 89,38% | 96,88% |

Face recognition system is tested by using data from AT&T “The Database of Face” (previously called ORL database). There are 40 subjects or classes where each class consists of 10 face images so that the total amount of 400 face images.

This whole face image will be divide into training data and testing data as in Table 1. These files are in the format of PGM and size of each image is 92x112 pixels with grey levels 21 for each pixels. The results of facial feature extraction are represented to face matrix. In PCA method, face matrix is converted into one-dimensional matrix to get covariance matrix. While in 2DPCA method, covariance matrix is directly obtained from face image matrix and not necessary transformation matrix into one-dimensional vectors. Last stage from fitur extraction is calculate eigenfaces from each face image. Result weight value eigenfaces is used to recognize test images by looking for distance weight values from testing image with training image. The smallest distance weight value is a representation of training image that similiar to test face image. The last stage of the classification process is calculation accuracy, accuracy calculation using confusion matrix. Calculation accuracy is used to evaluating success method by calculating percentage accuracy of combination methods.

Based on Table 2 shows that the accuracy results obtained using 2DPCA+KNN method is higher than accuracy results of PCA+KNN method. Test result using PCA+KNN method obtained the highest accuracy value at 4th test amounting to 89.38% with 2240 training images and 160 test images. And the lowest accuracy from PCA+KNN method occurred in the first test amounting to 72.86% with 120 training images and 280 test images. While result testing with 2DPCA+KNN method obtained the highest accuracy value in 4th test of 96.88% with 240 training images and 160 test images. And the lowest accuracy from 2DPCA+KNN occurred in first test amounting to 84.64% with 120 training images and 280 images test.

4. CONCLUSION

Based from results of the research and discussions that have been conducted, show that 2DPCA+KNN method has higher accuracy more than PCA+KNN method for face recognition. Based on 4 times testing with difference in amount of training data and testing data, highest accuracy results were obtained from combination of 2DPCA+KNN method in 4th test amounting to 96.88%. the 4th test consists of 240 training images and 160 test images, from 160 training images there are 155 images that can be classified correctly. More images used as training data then value of accuracy tends to be more big. This is evidenced by value of accuracy obtained from 4 times testing has increased when amount of training data is increasing. The accuracy of 2DPCA+KNN method is superior compared to PCA+KNN method.

5. REFERENCES

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