Accuracy enhancement in face recognition using 1D-PCA &
2D-PCA based on multilevel reverse-biorthogonal wavelet
transform with KNN classifier

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Abstract. Face recognition is a physical biometric technique that allows computers to recognize
human faces. Currently, face recognition is widely used in the authentication security system.
Accuracy improvement in face recognition can be made by doing image decomposition using
multi-level reverse biorthogonal wavelets. Composed image features will be extracted using 1D-
PCA and 2D-PCA. Face classification was carried out by using the K-Nearest Neighbor
algorithm. Furthermore, the face recognition accuracy results using and without the wavelet
decomposition will be compared. This research used 565 images in which 400 face images are
obtained from the AT&T database, and 400 face images are obtained from the YALE database.
This study revealed that the highest accuracy in face recognition using AT&T is 98.75% which
obtained by 60% training images and 40% testing images, while in face recognition using YALE
highest accuracy is obtained on face recognition using 90% training images and 90% testing
images with 100% accuracy.

1. Introduction
Plastics waste is one of the crucial environmental problems in this modern era. Plastics have become an
A facial recognition system that is a technology capable of identifying or verifying a person from a
digital image or a video frame from a video. Face recognition in computers adopts human learning
ability. With the learning concept approach, a computer program can learn the characteristics of different
faces then interpret them into knowledge. Face recognition has several advantages, such as its security,
which is relatively difficult to embodied [1], and its speed is faster than biological methods such as
signature biometrics of DNA [2].

There are three face recognition steps, namely face detection, feature extraction, and classification
[3]. Face detection is used to detect a face in an image. This process will remove features that are not
needed in a face pattern and eliminate some parts on an image that don’t have a face shape pattern.
Feature extraction is used to obtain important information on the face, such as eyes, nose, eyebrows, and
mouth in the face. The last process is face recognition classification, which is the process of grouping
classes face on the image's origin.

The principal Component Analysis algorithm is a very popular feature extraction algorithm in face
recognition. PCA algorithm can be used to process the image of a person's face so the system will
automatically recognize a person's face through its main features such as eyes, nose, lips, eyebrows as
identity. The system will identify this identity of the person's face image as a variety of training images stored in the database. PCA is a good method for the analysis of data. PCA algorithm also has the disadvantage of requiring the data to be scalar and large training and testing to obtain an accurate accuracy [4].

Discrete Wavelet Transform is a multi-level localization decomposition technique which very useful for image compression and image analysis. Discrete Wavelet Transform convolution is done by applying a low-pass filter (H) to get a global signal and high-pass filter (G) to obtain a detailed signal. This decomposition process will reduce the image Eigenface's size without losing the important feature of the image.

The application of three-level Daubechies wavelet transform for image decomposition before feature extraction using PCA can improve the accuracy of face recognition by an average of 1% using wavelet decomposition 3 levels Daubechies2 and 3% using wavelet decomposition 3 level Daubechies1 on four datasets that face94, face95, face96 and face self [5]. Daubechies wavelet transform is a kind of orthogonal wavelet suitable for compression and noise removal on voice signals. But Daubechies wavelet transform is not too good for image processing because it makes overlapping windows which cause signal changes significantly.

Biorthogonal wavelet feature extraction results proved better than orthogonal wavelet [6]. Biorthogonal wavelet edge detection can improve the X-ray images' accuracy with the number of edges on bior 1.3 at 222,964 points and 229,276 points using bior 2.4. This value is higher than the orthogonal wavelet for edge detection, 16,296 points using the Haar wavelet, 16,182 using dB 3 wavelet, and 16,467 using sym 2 wavelet. The higher accuracy of edge detection can improve the accuracy of feature extraction in face recognition.

In Melanoma image classification, reverse biorthogonal wavelet proved to be better than orthogonal wavelet [7]. This research applies various types of image wavelet decomposition Melonema images, such as rbio3.1, rbio 2.2, rbio1.5, rbio 4.4, 1.5 bior, bior 1.1, and coiflet 1. A decomposed image is used as input in the classification of the ensemble learning. After the experiment using 3 Melonema images with different resolutions, the result shows that rbio3.1 wavelet transform is better than the other.

The last step in face recognition is classification. K-Nearest Neighbor (KNN) algorithm is a very simple algorithm for classification but it works very well [8]. KNN is good for face classification. Face recognition using 1D-PCA feature extraction and KNN classifier gives 89.38% accuracy, while the face recognition using 2D-PCA feature extraction and KNN classifier gives 96.88% accuracy[9].

Based on the description, this research goals to improve the accuracy of face recognition using the AT & T "The Database of Face" and YALE dataset. Before the feature extraction, the image will be decompressed using a multi-level reverse biorthogonal wavelet transform. After decomposition is done, feature extraction will be done using 1D-PCA and 2D-PCA. This is the background of researchers in conducting the study, entitled “Accuracy Enhancement In Face Recognition Using 1D-PCA & 2D-PCA Based On Multilevel Reverse-Biorthogonal Wavelet Transform With KNN Classifier”.

2. Methods

The accuracy enhancement is done by applying two-level Reverse-Biorthogonal Wavelet Transform decomposition in preprocessing steps. Wavelet decomposition is highly efficient and flexible to decompose the image into four sub-bands. The first band that is LL is an approximated compressed of the original facial image. The bands LH and HL record the edges along with horizontal and vertical directions respectively. While the HH band records the diagonal edges of the image. This is the first level decomposition. Further 2-level decomposition can be conducted on the LL sub-band. In this paper, we preferred the Reverse-Biorthogonal Transform for the transformation of an image into the 2-level wavelets as shown in Figure 1.
After extracting the data by using Reverse-Biorthogonal Wavelet, the PCA is applied to retrieve the principal component for recognition purposes. Here, we applied two types of PCA, one-dimensional principal component analysis and two-dimensional principal component analysis. Furthermore, structure information will be lost during processing. The Eigenfaces vector as considered as the vector for constructing the covariance matrix. Here, the pixel information of each image is used to construct the Eigenvector. This Eigenvector information is used to select the Principal Component having a higher Eigenvalue. Each image location contributes to each Eigenvector so that we can display the Eigenvector as a sort of face. Each face image can be represented exactly in terms of a linear combination of the Eigenfaces. The number of possible Eigenfaces is equal to the number of the face image in the training set. The faces can also be approximated by using the best Eigenface, those that have the largest Eigenvalues, and which therefore account for most variance between the set of face images.

Then we applying the KNN classification method to classify the image. The k-nearest neighbor algorithm is the simplest classifier of all machine learning algorithms. In this classifier, the image is classified by a majority vote of its neighbors. In the KNN classifier, the Euclidean distance between the testing image feature and each training image feature is determined to form a distance matrix. The summation value of the distance matrix is estimated and sorted in increasing order. The first K elements are selected and the majority class value is determined for classifying the image accurately.

3. Results and discussion

This research used AT & T "Face of Database" and the YALE Face database. AT & T "The Database of Face" (formerly ORL database) is a database that contains a series of face images taken between April 1992 and April 1994 in a laboratory. 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 [9]. The files are in BMP format with each image size is 92x112 pixels with 21 gray levels per pixel. A sample image of the face of AT & T "The Database of Face" can be seen in Figure 2.

The YALE face database contains an image of 15 subjects with 11 images for each subject so the total is 165 images [10]. The YALE face database is stored in GIF format with a size of 6.4 MB. The accessories used are glasses. Face images taken with different brightness and accessories (glasses/ no glasses). Samples YALE face database facial image can be seen in Figure 3.
All of the face images will be divided into training data and testing data. This data division is done manually by defining it at the start of the program. Testing is done by 68 times trial with AT & T as much as 33 times and YALE as much as 36 times. Experiments carried out by changing the number of training images from the smallest value from 1 to the largest value which is the total image-1. Every experiment will have facial recognition with 4 different methods, are 1D-PCA + KNN, Wavelet + 1D-PCA + KNN, 2D-PCA + KNN, and Wavelet + 2D-PCA + KNN.

Implementation of wavelet decomposition on the image of AT & T is proven to increase the accuracy of face recognition using Principal Component Analysis feature extraction on both, 1D-PCA & 2D-PCA and KNN classification. The results of the accuracy of facial recognition on AT & T's image can be seen in Table 1.

| Ratio Training : Testing | 1D-PCA+KNN | Wavelet+1D-PCA+KNN | 2D-PCA+KNN | Wavelet+2D-PCA+KNN |
|-------------------------|------------|-------------------|------------|-------------------|
| 1:9                     | 64.444     | 68.611            | 74.444     | 81.944            |
| 2:8                     | 73.438     | 79.063            | 84.375     | 92.857            |
| 3:7                     | 75.357     | 77.143            | 88.571     | 94.500            |
| 4:6                     | 81.250     | 81.667            | 91.667     | 96.250            |
| 5:5                     | 84.000     | 86.500            | 92.500     | 98.750            |
| 6:4                     | 94.375     | 94.375            | 96.250     | 99.750            |
| 7:3                     | 94.167     | 94.000            | 95.833     | 97.500            |
| 8:2                     | 95.000     | 95.000            | 95.000     | 97.500            |
| 9:1                     | 92.500     | 95.000            | 95.000     | 97.500            |

Implementation of wavelet decomposition on YALE image can improve the accuracy of face recognition using 1D-PCA & 2D-PCA and KNN classification but only in a small amount of training. Face recognition accuracy on the YALE image can be seen in Table 2.

| Ratio Training : Testing | 1D-PCA+KNN | Wavelet+1D-PCA+KNN | 2D-PCA+KNN | Wavelet+2D-PCA+KNN |
|-------------------------|------------|-------------------|------------|-------------------|
| 1:10                    | 48.667     | 50.000            | 54.667     | 56.000            |
| 2:9                     | 54.074     | 56.296            | 68.148     | 67.407            |
| 3:8                     | 74.167     | 74.167            | 81.667     | 80.000            |
| 4:7                     | 79.047     | 80.000            | 89.524     | 89.523            |
| 5:6                     | 83.333     | 83.333            | 88.889     | 90.000            |
| 6:5                     | 81.333     | 81.333            | 86.667     | 86.667            |
| 7:4                     | 93.333     | 93.333            | 96.667     | 96.667            |
| 8:3                     | 93.333     | 93.333            | 97.778     | 97.778            |
| 9:2                     | 90.000     | 90.000            | 96.667     | 96.667            |
| 10:1                    | 93.333     | 93.333            | 100.000    | 100.000           |

Although it does not provide a significant accuracy improvement, wavelet decomposition is given an advantage to the other point of the storage memory. Wavelet decomposition can reduce the size of the original image matrix 243x320x165 be 72x91x165. This contributes to decreasing the required storage memory. A comparison of size before and after the reverse biorthogonal wavelet decomposition can be seen in Table 3.

| Dataset | Original Size | Size After Decomposition |
|---------|---------------|--------------------------|
| AT&T    | 92×112×400    | 39×34×400                |
| YALE    | 243×320×165   | 72×91×165                |
The accuracy in face recognition with this proposed method is compared with the results of the previous experiment on the same dataset. The results of the face recognition accuracy compared with previous studies are presented in Table 4.

| Dataset | Ratio | Method | Accuracy  |
|---------|-------|--------|-----------|
| AT&T    | 8:2   | IKLDA + PNN [11] | 97.22%    |
|         |       | Proposed Method  | 97.5%     |
|         | 5:5   | (MF, GF, HE)-PCA-multiSVMs [12] | 91.6% |
|         |       | Proposed Method  | 94.5%     |
|         | 6:4   | RSA+SHA256+LBP [13] | 97.5%   |
|         |       | 2D-PCA + KNN [9]  | 96.88%    |
|         |       | Weight Sum Rule [14] | 98%    |
|         |       | Proposed Method  | 98.75%    |
| YALE    | 8:3   | IKLDA + PNN [11] | 83.80%    |
|         |       | Proposed Method  | 97.77%    |

The disadvantages of these proposed methods are not good to process the small-sized image after the cropping by the face detection process. Cropping will make the image has fewer pixels so the decomposition process will produce only white images only. Besides, the greater the training images are processed will cause an increase in accuracy is less and less. This is because more and more knowledge is already defined as a reference to the results of face recognition. The larger the mass of black carbon the larger the number of oxygen.

4. Conclusion
The implementation of decomposition using multi-level reverse biorthogonal wavelet able to improve the accuracy of facial recognition on the image of AT & T and YALE. The results of the highest accuracy in experiments using AT & T was 98.75% in the proportion of 60% training images and 40% testing images, while the YALE reach 100% in the proportion of 90% training images and 10% testing images. Besides, the size of the matrix is also fewer than the original size so we can save more storage.

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