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Integration of PCA and Euclidean Distance Methods for Human Face Recognition Image Processing

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ABSTRACT

The purpose of this study is to combine the PCA method and Euclidean Distance weighting to detect faces in images for face recognition, and to determine the level of accuracy in face recognition. This study begins with detecting the face part in the image. The original RGB image is converted into the YCbCr colour model, and then skin colour pixel segmentation is performed on the components according to the specified threshold. The results of the segmentation image are subjected to morphological opening (erosion) to remove noise. Furthermore, labelling and cropping of the image, identified as a face, are carried out. After the face part is detected, the next process involves feature extraction using PCA (principal component analysis), which reduces a 2-dimensional image type to 1 dimension, normalizes the image, calculates the matrix, determines the eigenvalues and eigenvectors, and calculates the image weight. Then, the Euclidean distance method is used for classification by finding the minimum distance between the weight of the test image and the weight of the training image. In this study, the PCA method used reduces the facial features, which originally had a matrix size of 34 × 20400, to a matrix size of 34 × 200. The matrix is a selected component because it has a significant influence on the database. The level of accuracy of facial recognition in this study was 95%, as it was able to identify faces even when the faces had expressions. The primary objective of this study is to detect the similarity between a person's face and that of the same person, as well as similar individuals.

Keywords: Image Processing; Face Recognition; Principal Component Analysis; Euclidean Distance.

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I. INTRODUCTION

Image processing and computer vision are advancements in the field of computer science that enable the creation of systems closely resembling the human visual system. Image processing is a type of technology used to solve problems related to images processing. In image processing, existing images are modified to enhance their processing. At the same time, computer vision has the primary goal of making a useful decision about real physical objects obtained from devices or sensors. The application of image processing and computer vision is currently widely used in companies and institutions to enhance data-driven security systems that utilize body characteristics or behaviour, known as biometric technology. Digital image processing is a method of capturing and processing images that is non-destructive (non-intrusive), where the data retrieval process is carried out with the help of a special image capture tool and then processed using software with an image processing algorithm [1].

Biometric technology is an approach that identifies a person based on their unique physical characteristics and biological properties. There are several developments in biometric technology approaches, including facial recognition, fingerprint recognition, palm geometry, iris recognition, and handwriting recognition. One of the most interesting biometric techniques is an application that can detect and identify facial patterns. Facial scanning in biometric systems is a technology used to recognize or verify a person's identity based on the unique characteristics of each person's face, such as shape, distance between facial parts (eyes, nose, mouth), and the overall contour of the face [2].

Face recognition is one of the most developed applications in computer vision and pattern recognition. Its primary goal is to recognize human faces from images or videos using a pre-stored database of faces. The development of a facial recognition system is a significant issue because the human face is too complex, making it difficult to develop an ideal algorithm. Face recognition is a method of personal identification based on geometric or statistical features extracted from human facial images. Extra-personal and intra-personal variability factors influence the facial recognition process. Extra-personal variability factors are factors that

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arise during the facial recognition process carried out on different faces due to racial and genetic factors. Applications of facial recognition can be applied in the field of security (security systems) such as room access permits, location surveillance and so on.

Others have conducted several previous studies discussing facial image processing or facial recognition. Research [3] designed a face recognition system using the Principal Component Analysis-Genetic Algorithm (PCA-GA) algorithm for smart home door security. The PCA-GA algorithm can recognize faces with an accuracy of 90%, which is built using Raspberry Pi processing. Research [4] discusses Face Recognition Based on Genetic Algorithm. Research [5] conducted a study on face recognition and motion detection on 45 videos from CCTV. The method used for motion detection is Accumulative Difference Images (ADI), and face detection is Haar Cascade Classifier (HCC) with Speeded-Up Robust Features (SURF) and PCA feature extraction. Then, research by [6] examined face recognition by comparing facial sketches using the PCA method as feature extraction and calculating the distance between the test image and the training image using Euclidean distancee. Research by [7] discusses the use of a face recognition system for server room security, utilizing a Raspberry Pi. The face recognition method used is Triangle Face, which calculates the distance between features such as eyes, nose, mouth, height, and width of the face.

Furthermore, research from [8] discusses the application of facial recognition using the HCC method to detect faces and the Local Binary Pattern Histogram (LBPH) method to recognize faces. LBPH is not a machine learning algorithm, but rather an image matching process that involves comparing the histogram values of the extracted images. The results of this study indicate that LBPH can effectively recognize faces in streaming videos by comparing them with a stored image database.

Facial recognition techniques, which are used to identify a person's face, are currently widely applied in various fields, including security. The combination of security systems with machine learning produces smart devices that can operate automatically, leveraging the widespread application of machine learning in security [9]. Face recognition involves several essential stages to ensure accurate recognition results, including data acquisition, pre-processing, data representation, and decision-making. Data acquisition encompasses all processes related to capturing facial images for facial recognition, including the use of digital cameras and scanners. Pre-processing involves adjusting the facial image to meet the requirements for the following process. Pre-processing can be performed through various processes, such as gray scaling, face detection, cropping, resizing, and other operations that can condition the facial image. Data representation is generally a representation of features extracted and selected from facial images to reduce data dimensionality. Decision making is the stage where classification is carried out by measuring the similarity between the test data and the data representation in the database, using methods such as Euclidean distance, the distance between two vectors, and correlation coefficients, among others. Face detection is an important initial stage in a face recognition system. The goal of face detection is to identify all areas present in an image, distinguishing between face and non-face areas.

Generally, facial image recognition systems are categorized into two types: feature-based systems and image-based systems. In feature-based systems, features are extracted from facial image components, such as eyes, nose, and mouth, and then the relationship between these features is modelled geometrically. Meanwhile, the image-based system utilizes raw information from image pixels, which is then represented in a specific method, one of which is Principal Component Analysis (PCA). Eigenface is a method used to transform and reduce the dimensions of an image. Eigenface utilizes the Principal Component Analysis (PCA) method, a mathematical approach for representing an object, extracting its characteristics, and reducing the object by transforming it through linear transformations using eigenvalues and eigenvectors.

Principal Component Analysis (PCA) is one of the most widely used methods for dimensionality reduction in facial recognition systems. PCA is also known as Eigenfaces in the context of facial images. The advantage of this method is that PCA can extract the main features of facial images by reducing the number of variables without losing important information. Compared to other methods, such as k-NN, which work directly on the original dimensions, PCA simplifies the data into a more computationally efficient form. This research aims to detect faces in images based on the YCbCr colour model, analyze principal components and Euclidean distance for face recognition, and determine the level of accuracy in recognizing faces using the Euclidean Distance method.

II. METHOD

This method section explains the research procedures, analysis processes, and depiction of image processing flow diagrams for human face recognition.

A. Face Detection

Face detection is the process of recognizing the shape of a human face in an image by matching existing facial features, such as curvature and texture, with digital images stored in a database. Face recognition is a computer vision technology in the field of biometrics that enables the recognition of a person from a digital image or video, and is an actively researched topic [10][11][12]. Face recognition is a component of a more comprehensive biometric technology that can be utilized in scenarios involving multiple individuals simultaneously, such as in missing persons searches or wanted lists [13].

This study uses the YCbCr colour model method for facial image segmentation. The YCbCr colour model is known for its ability to separate components containing skin colour from other colour components. Images that have been separated into skin colour components and other components are subjected to mathematical morphology to remove noise. After the facial part is obtained, it is then cropped, and the image is transformed back to the RGB colour model.

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B. *Convert RGB Image to Grayscale Image*

Converting an RGB image to a grayscale image with 256 levels of gray. This can be done by eliminating the hue and saturation information while maintaining the luminance level, resulting in a black-and-white $M \times N$ matrix in 256 levels of gray. This is done because a black-and-white image simplifies the calculation process.

C. *Resize*

Resize is changing the pixel size of an image. Each image resulting from face detection cropping has a different pixel size, so it is necessary to standardize the image size using the Nearest Neighbour (NN) Interpolation method. Nearest neighbour interpolation is an image interpolation algorithm that utilizes pixel replication techniques to produce smooth results. Each image is reduced in resolution to 120 x 170 pixels. Reducing the size of an image means displaying it with a smaller number of pixels, achieved through a pixel sampling process with a reduced pixel density.

D. *Pattern Recognition*

The pattern recognition stage utilizes the eigenface algorithm, which employs Principal Component Analysis (PCA) to reduce the image dimension and identify vectors that maximize the distribution of facial images in the input image space. At this stage, the process in the facial recognition system will be analyzed. This analysis aims to examine and describe the processes in the facial recognition system. The pattern recognition stage utilizes the eigenface algorithm, which employs Principal Component Analysis (PCA) to reduce the image dimension and identify vectors that maximize the distribution of facial images in the input image space. At this stage, the process in the facial recognition system will be analyzed. This analysis aims to examine and describe the processes in the facial recognition system. The facial recognition process consists of two distinct phases: the training phase and the recognition phase.

E. *Classification*

Classification is performed to identify homogeneous regions that belong to a specific class. The classification results are regions that have been assigned a specific class label. In the pattern recognition process, distance calculations will be carried out using the Euclidean distance method. Distance measurement is performed by comparing the similarity of two image feature vectors between training and testing sets. The smaller the distance, the more similar the two vectors that are matched/compared. Conversely, the greater the distance, the more different the two vectors that are matched/compared. The test image that has undergone the classification and decision-making process will be identified as a specific facial pattern.

F. *Flow Diagram*

This study aims to identify facial images based on the stored database. Fig.1 is an overall flow diagram of the facial recognition system.

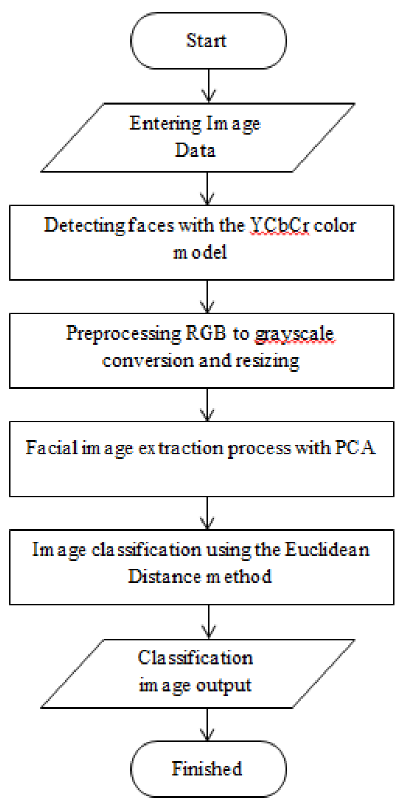

Fig.1. Facial Recognition Flowchart

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G. Flowchart Of Face Detection Based on YCbCr Colour Model

The first step in the research is face detection in RGB images. Face detection aims to determine the facial region in the input image. Fig.2 shows the flowchart of face detection using a skin detector based on the YCbCr colour model.

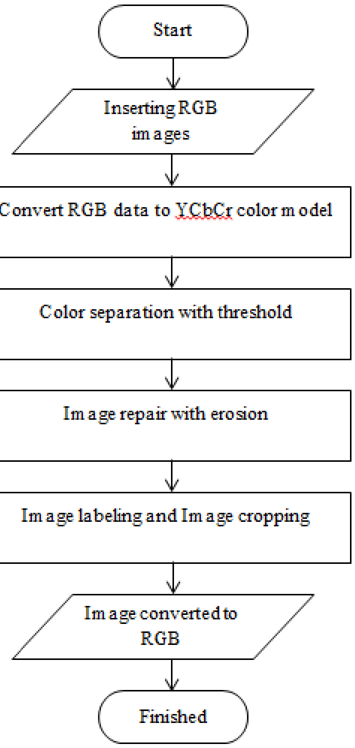

Fig.2.Face detection flowchart

H. Extraction Flow Diagram Using Principal Component Analysis Method

Feature extraction aims to obtain the characteristics of each image in the database using principal component analysis. Fig.3 is a flowchart of feature extraction.

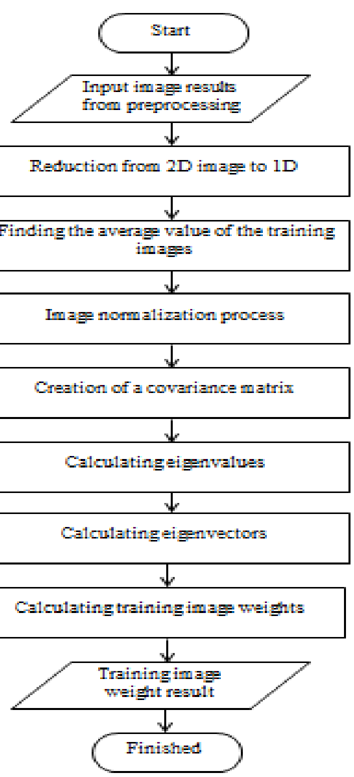

Fig.3. Feature Extraction Flowchart

I. Flowchart Of Facial Identification Based on Distance with Euclidean Distance Method

Face identification aims to recognize the test image against the stored database by comparing the weight of the test image with the weights of the database images. Fig.4 shows the flow diagram of face identification using the Euclidean distance method.

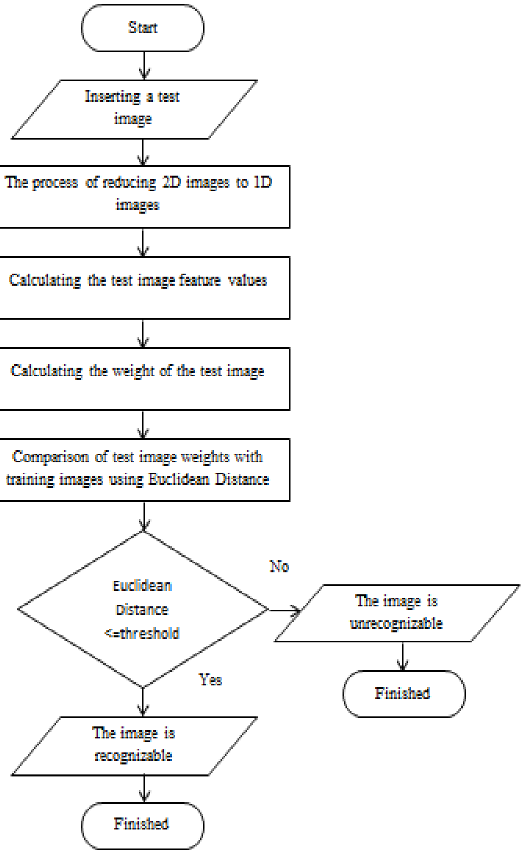

Fig.4. Facial identification flowchart

III. RESULT AND DISCUSSION

In this study, a system was developed to recognize faces using the Principal Component Analysis (PCA) method. To detect faces, the skin detection method was employed by determining the ranges of Y, Cb, and Cr.

A. Facial Image Detection

In this study, a skin colour segmentation method is employed to detect facial images. Skin colour segmentation is the process of separating objects (foreground), namely skin, from the background. This method separates RGB values into luminance and chrominance values. The RGB colour space in the original image still contains light effects that alter skin colour characteristics, so it needs to be converted into a chromatic colour form. Chromatic colours are also known as original colours, which are not influenced by lighting. To reduce the lighting effects, the YCbCr color model is used because in this color model all lighting effects are in the Y component, this color model consists of 3 components shown in Fig. 5, namely: Y has a luminance value (level of brightness), Cb has a Chrominance Blue value (level of bluishness) and Cr has a Chrominance Red value (level of redness).

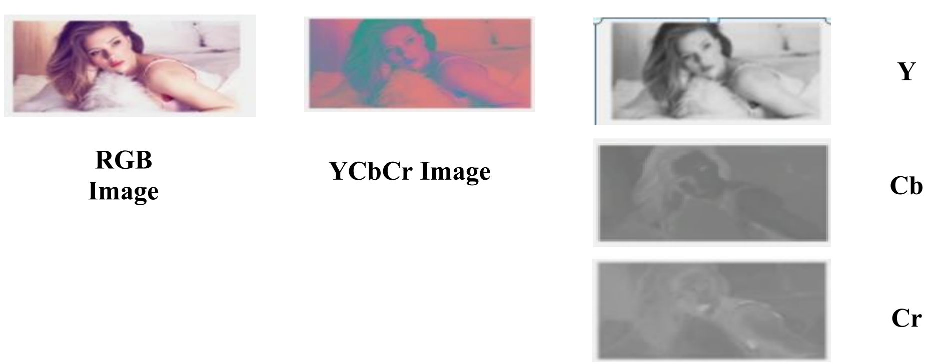

Fig. 5. YCbCr Image Components

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Skin colour segmentation is only performed on the chrominance components blue (Cb) and chrominance red (Cr) because the Y (luminance) component contains lighting and is therefore ignored. The most representative Cb and Cr ranges for skin colour maps using Equation (1).

$$77 \leq \mathrm{Cb} \leq 127 \text{ and } 133 \leq \mathrm{Cr} \leq 173 \quad (1)$$

The process of detecting skin by separating skin and non-skin is called the binary image process. Fig. 6 shows the possible colours. Fig. 6 shows the possible skin colours, categorized as white (1), and non-skin colours, categorized as black (0). Fig.7 shows the distribution graph of possible skin colours in the image samples.

Fig. 6. Skin likelihood image

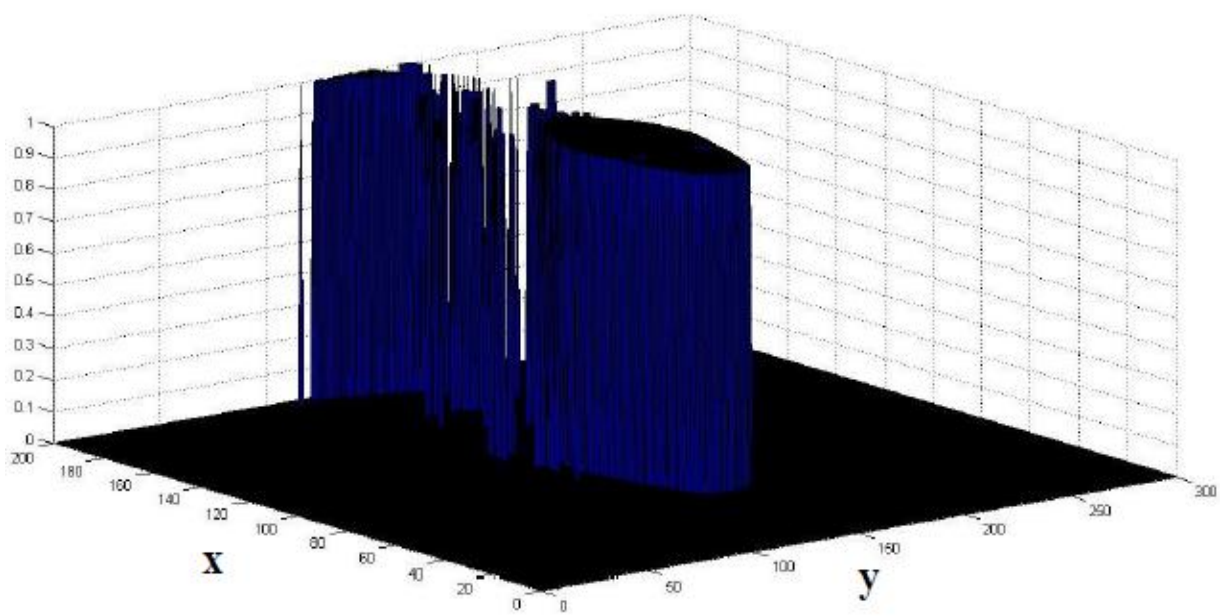

Fig.7. Example Of A Graph of The Distribution Of Skin Probability on An Image Sample.

Fig. 6 shows the result of skin possibility segmentation, indicating that the detected area does not necessarily match the skin. It can only be concluded that the detected area has the same colour as the skin tone. Therefore, image improvement is needed with morphological techniques. Morphological techniques aim to improve segmentation results by combining background points with part of the object. The morphological technique used in this study is the opening technique. The opening technique is an erosion process followed by dilation; the effect is the disappearance of small objects and the smoothing of large object boundaries without significantly altering the object area. The opening technique utilizes an element or kernel structure in the form of a 5 × 5 square matrix, as shown in Figure 8.

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$$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

(a) erosion image

(b) dilation image

Fig.8. Opening Morphology

The erosion image in Fig.8 (a) shows the object edge shrinking or eroding because the white object point (1) adjacent to the black background point (0) becomes a black background point (0). On the other hand, the dilation image in Fig.8 (b) shows the object becoming wider because the black background point (0) adjacent to the white object point (1) becomes a white object point (1). Fig.8 (b) is the result of the opening morphology, where the pixels in the image are represented as shown in Fig.9.

0	0	1	1	1	1	0	0
0	1	1	1	1	1	1	0
0	1	1	0	1	0	1	0
0	1	1	1	1	1	1	0
0	0	1	1	1	1	0	0
0	0	0	1	1	0	0	0
0	0	0	0	0	0	0	0
0	1	1	1	0	0	0	0
0	1	1	0	0	0	0	0

Fig. 9. Opening Morphological Image Representation

In determining the facial region, labelling is needed, which aims to exemplify several areas of pixels that are not interconnected. Labelling utilizes the Connected Component Labelling (CCL) method with a 4-neighbour connectivity configuration; label checking is performed only on the two closest neighbours, namely the top, bottom, right, and left. Fig.10, when labelled with 4 connectivity, yields results similar to those. There are two labels, labelled "1" and "2", corresponding to the column order. A group of labels is called a hole. Of the two holes, there must be one hole which is the facial area. After analysis, there is one label hole that has a high and wide ratio. The area is wider than that of other holes.

0	0	1	1	1	1	0	0
0	1	1	1	1	1	1	0
0	1	1	0	1	0	1	0
0	1	1	1	1	1	1	0
0	0	1	1	1	1	0	0
0	0	0	1	1	0	0	0
0	0	0	0	0	0	0	0
0	2	2	2	0	0	0	0
0	2	2	0	0	0	0	0

Fig.10. Labelling 4 Connectivity

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B. Principal Component Analysis

This facial recognition algorithm utilizes training images consisting of 5 individuals, each with 7 facial images, resulting in a total of 35 training images. In the test image, each individual consists of 4 facial images and 2 images from the database, resulting in a total of 22 facial images for the test data. Each facial image is 120x170 pixels in size and has a gray level of 256 (grayscale). Some of the processes that occur include: Dimension reduction, finding the average of training images, image normalization and creating a covariance matrix.

1) Dimensionality Reduction

This dimension reduction aims to simplify the next process, namely, finding the average value of the row. This dimension reduction aims to simplify the next process, namely, finding the average row value. The dimension reduction of 2D images to 1D is carried out on all training images. The next step is to combine them into a Γ matrix (augmentation) as exemplified in Table I. In this study, there are 35 training images with a resolution of 120 x 170 pixels each, resulting in an augmentation matrix size of 35 x 20480.

TABLE I
TRAINING DATA IMAGE AUGMENTATION MATRIX

Image 1	Image 2	Image 3	Image 4	Image 5	Image 6	Image7	Image …	Image 32	Image 33	Image 44	Image 35
183	209	211	206	197	192	211	-	211	211	211	211
183	206	210	210	210	187	210	-	210	210	210	210
183	205	209	190	209	210	209	-	209	209	209	209
183	207	212	211	212	211	212	-	212	212	212	212
183	208	212	212	212	211	212	-	212	212	212	212
183	205	213	208	213	212	210	-	213	213	213	213
183	205	213	213	211	212	211	-	213	212	210	213
181	204	213	208	212	213	211	-	213	214	212	213
181	204	212	208	210	213	212	-	212	212	213	212
181	207	212	212	211	214	213	-	212	212	211	212
182	207	210	210	211	214	213	-	210	210	211	210
182	208	211	211	211	214	214	-	211	211	211	211
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
173	115	88	130	200	120	143	-	88	88	100	121
182	120	90	216	156	201	119	-	187	145	90	90
190	122	100	100	211	210	100	-	100	110	111	120

2) Finding The Average Of Training Images

Determine the average image (Ψ) in the row direction by summing all training images and dividing them by the total number of images.

3) Image Normalization

The next process is to subtract each facial image Γk from the average Ψ or $\Phi k = \Gamma k - \Psi$ (deviation from the average) to obtain a vector Φ_k with $k = 1, 2, 3, \ldots, 35$. From each vector Φ_k, a matrix A can be formed with Equation (2).

$$[\varphi_1\ \varphi_2\ \varphi_3 \ldots . \varphi_{35} = A] \quad (2)$$

4) Creating A Covariance Matrix

The Covariance Matrix is obtained by multiplying the transpose of matrix A by matrix A. The principal components of a dataset are the eigenvectors of the covariance matrix. The covariance matrix is used to obtain the face space (eigenspace) of the main features of each facial sample. In this study, the covariance matrix formed is a 35 × 35 symmetric square matrix, as shown in Table II.

TABLE II
COVARIANCE MATRIX

Image 1	Image 2	Image 3	Image 4	Image 5	Image 6	Image 7	Image …	Image 32	Image 33	Image 34	Image 35
0,7274	0,2314	0,7274	0,2314	0,5423	0,7274	0,7274	0,7274	0,3274	0,7274	0,7274	0,7274
0,6234	0,5423	0,6642	0,5423	0,7756	0,6274	0,6074	0,6674	0,4274	0,4474	0,8774	0,2754
0,7704	0,7721	0,7274	0,7231	0,2354	0,7464	0,5664	0,5374	0,4574	0,2374	0,5474	0,6274
0,6214	0,7270	0,7112	0,6170	0,6534	0,5644	0,2754	0,4074	0,6674	0,3574	0,2474	0,4474
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
0,6642	0,7231	0,2314	0,6674	0,6074	0,7274	0,5423	0,2754	0,4074	0,4574	0,7274	0,5664
0,7274	0,6170	0,5423	0,5374	0,5664	0,7274	0,7756	0,5374	0,7274	0,6674	0,7274	0,2754

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C. Testing Phase

The process of testing facial images in this study involved comparing the distance between the weight of the testing image and the weights of each training image in the facial space. This process is carried out by determining the minimum distance using the Euclidean distance.

$$\epsilon^2 = \|\Omega\_test - \Omega_{train}\|2 \quad (3)$$

After the minimum distance is found, the distance will be compared with the threshold value (θ) as an indication of whether the test image is recognized or not. If the minimum distance of the test image is smaller than the threshold (θ), then the image is recognized as one of the training images, and the training image will be displayed. However, if the minimum distance of the test image is greater than the threshold (θ), then the test image will be considered unrecognized, and the string "Unrecognized Image" is displayed. In this study, two tests were carried out.

This first test contains images using different accessories and facial expressions from the training image database. The first step after inputting the test image is to calculate its features by subtracting the average of the training image from the pixels of the test image. The next step is to calculate the weight of the test image by multiplying the features of the test image by the selected eigenface. Fig. 11 shows the weight of the test image. Then the weight of the testing image is compared with each column of the training image weight matrix using Euclidean distance. Fig. 12 shows that the minimum Euclidean distance on the test image sample is 5.0821 × 10 ^5. Since the minimum Euclidean distance is smaller than the threshold value of 7.4446 × 10^5, the test image sample is recognized as similar to the training image. The second test was conducted using images that were not in the database. In this second test, 22 samples were used, and the test data are presented in Table III, along with the accuracy result in Equation (4).

$$Accuracy\ (\%) = \frac{correct\ amount}{total\ amount} x\ 100 = \frac{21}{22} x100 = 95{,}45\% \quad (4)$$

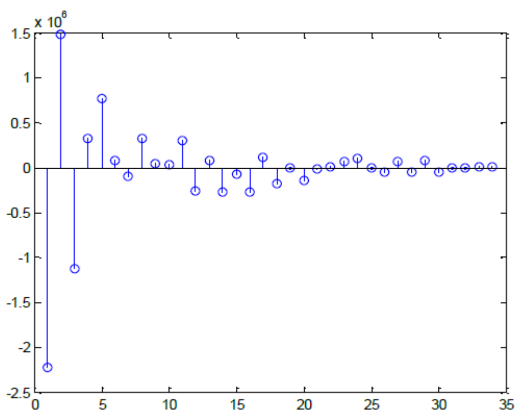

Fig. 11. Test Image Sample Weight

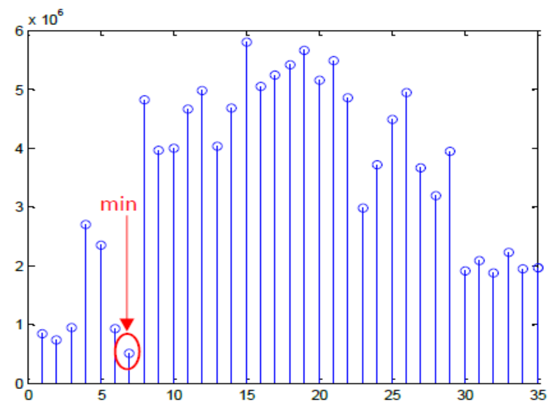

Fig. 12. Euclidean Distance of Test Image Sample

TABLE III
SECOND TEST RESULTS

Test Image	Recognizable Image	Minimum Euclidean Distance	Truth value
1	YES	1.4201	1
2	YES	1.4097	1
3	YES	2.9994	1
4	YES	5.0821	1
5	YES	1.2715	1
6	YES	1.4336	1
7	YES	1.0709	1
8	YES	2.6791	1
9	YES	0.7500	1
10	YES	5.0485	1
11	YES	4.2729	1
12	YES	7.3989	1
13	YES	1.3375	1
14	YES	2.7716	1
15	YES	1.0704	1
16	YES	7.2350	0
17	YES	3.2886	1
18	YES	2.4593	1
19	YES	7.3797	1
20	YES	3.2886	1
21	NO	7,5330	1
22	NO	14,132	1

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IV. CONCLUSION

Face detection in images using the skin detection method consists of five stages, namely transforming RGB images to the YCbCr colour model. The Principal Component Analysis (PCA) method used can handle a large amount of data and is capable of handling complex data dimensions, allowing for the creation of eigenspace or eigenfaces. In this study, the PCA method reduces the facial features, whose original matrix size is 34 × 20400, to a matrix size of 34 × 200. This matrix is a selected component because it has a significant influence on the database, with an accuracy value reaching 95%. Face matching is done by calculating the minimum distance between the characteristic values of the pixels of the test image and the training image using the Euclidean distance. PCA works by eliminating components that have low variance, thus reducing noise from the data. This makes the facial recognition system more stable against variations in lighting, facial expressions, or head positions. However, PCA also has weaknesses, namely that it is less robust to rotation-tilted faces, requires large datasets and high computation, and is Ineffective for noise or complex expressions.

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