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ANALYSIS OF RETINEX ALGORITHM ON DIGITAL IMAGE FROM CCTV CAMERA FOR FACE RECOGNITION

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ABSTRACT

Face recognition is a technology that has been widely applied for various purposes. The example is face recognition for the creation of identity cards, driving license or security system of a place that can recognize the face of someone.

In security system, surveillance using Closed Circuit Television (CCTV) camera generally use infrared camera which can capture images even in dark conditions. Generally, the image quality from CCTV camera is poor. This can be caused by a poor image retrieval process, such as inadequate capture distance and minimal lighting conditions so the result of image is still not optimal. One solution that can be done to overcome the lack of image quality by using the method of image enhancement.

In this research, used two retinex method that is Single Scale Retinex and Multi Scale Retinex with Principal Component Analysis face recognition method. Testing performed compared face recognition without retinex and face recognition with retinex (SSR and MSR). Testing with the same light training data conditions has the most effective conditions when the light is very dark.

Keywords: *Image, Face Recognition, Infrared, Image Enhancement, Retinex.*

1. INTRODUCTION

The use of image is one of the visual experiences that have become a part of human life today. The image has been widely used in various sides such as digital cameras, internet, gadget and other technological devices [2]. The more emerging and technological developments today, the digital image becomes an inseparable part and always continues to experience such rapid growth.

Digital image processing is growing rapidly in line with current needs. Various types of use in digital image processing include image processing for industry, monitoring system and security system with the use of CCTV camera. With the use of CCTV camera, face recognition technology is used to recognize the face of subjects captured by CCTV camera, so the subject's face can be identified in case of a situation requiring identification of the subject caught by the camera.

Face recognition works by using two data components namely test data and training data. Face recognition is done by comparing the existing face features of the image to be tested by the image contained in the system database [3]. Image with a certain size will require considerable time when processing is done by the original size of the pixel of the image. This is because all the pixel information in the image will be processed by the system.

For face recognition processing to be performed efficiently, the Principal Component Analysis (PCA) face recognition method is used. PCA works by reducing information to the image without losing main information of the image. Therefore, the processing time required is less [4].

Face recognition technology itself requires a good image quality. Some factors to consider in face recognition include image lighting quality, image noise especially on the subject's face, face pose and camera quality that produces the image itself.

One thing to note in the image is the quality of lighting. A light that tends to dark will be difficult in the process of recognizing the face of the subject. For image with minimum lighting conditions require image enhancement. Retinex is one method of image enhancement that can improve image quality in terms of lighting.

Based on previous research, retinex is believed to increase the image contrast between the information on the image and the background [5]. So, by using retinex method is expected infrared image especially image taken at location with very minimal lighting conditions can remain recognizable.

2. BASIC THEORY

2.1 Face Detection Viola Jones

Face detection is one of the important components performed before the face recognition process. Face detection viola jones classifies image based on simple feature values. In this method, the feature is used instead of pixels because the feature can encode ad-hoc domain knowledge that is difficult to learn by using limited training data.

In addition, using a feature-based operating system will do much faster when compared to pixel-based systems [7]. In this method, there are several feature types based on the number of rectangles as follows:

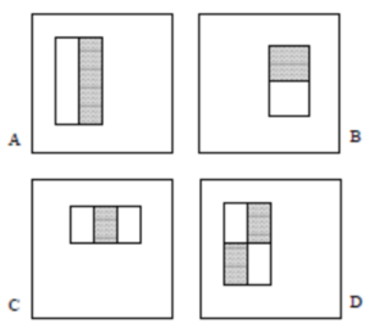

Figure 1: Feature on Viola Jones

In Figure 1, it can be seen there are 4 types of features on viola jones method. In parts a and b show that the value of the feature consists of 2 rectangular features which are the difference between the number of pixels in the two rectangular regions.

The rectangular feature of part a is shown vertically and the b section is shown horizontally. In section c there are 3 rectangular features that count the number of two rectangles on the outside minus the rectangle in the middle. In section d there are 4 rectangular features that calculate the diagonal difference in rectangles [8].

2.2 Principal Component Analysis (PCA)

2.2.1 Definition of Principal Component Analysis

Principal Component Analysis (PCA) is a method used by reducing dimensions and for feature extraction. The PCA will retain important information on the image and not retain non-critical information [6] [15].

Eigenfaces projects an image into the eigenvector that will be used for the classification of features in the image. Eigenspace projection is also known as Principal Component Analysis (PCA).

Eigenface utilizes PCA to reduce image dimension to find the best value vector for image distribution within the image space itself. This vector defines subspaces of face images and these subspaces are called face spaces. All face images accumulated in the training data are projected in the face spaces to find the weights that describe the contribution of each vector in the face space [3].

Each principal component is a representation of the linear combination of all face images contained in the training data that has been reduced by the mean image. This combination of face images is called eigenface.

Stage PCA algorithm as follows [9]:

1. Looking for eigenvalues by calculating the average value of the image using the equation as follows:

$$mean = \frac{\sum_{i=1}^{n} Xi}{n} \qquad (1)$$

In equation 1 above, the symbol Xi is the i data of the variable X. The symbol n itself refers to the amount of data available.

2. Then the normalization matrix will be calculated with the following equation:

$$A = T - mean \qquad (2)$$

3. The third stage is to find the image covariant matrix by using the equation as follows:

$$L = A' \times A \qquad (3)$$

4. Next, sort the value of eigenvalue (D) and eigenvector (V) from large to small based on the

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order of eigenvalues. Then, calculate the eigenface matrix value with equation as follows:

$$Eigenface = A \times Eigenvector \qquad (4)$$

5. Then calculate the image project from the image with equation as follows:

$$Project\ image = Eigenface^T \times A \qquad (5)$$

2.2.2 Example of Principal Component Analysis Use

This section describes the calculation of principal component analysis mathematically.

1. The first process is to find the average value of the data. In this PCA calculation example uses 2 test data.

Table 1: Sample Test Data

No.	X1	X2
1.	46	24
2.	12	38

$$mean\ X1 = \frac{46+12}{2} = 29$$

$$mean\ X2 = \frac{24+38}{2} = 31$$

2. The second step calculates the zero mean by reducing the value that is in the test data with the average value of each parameter

$$A = \begin{bmatrix} X1_1 & X2_1 \\ X1_2 & X2_2 \end{bmatrix} - \begin{bmatrix} \overline{X1} \\ \overline{X2} \end{bmatrix}$$

$$A = \begin{bmatrix} 46 & 24 \\ 12 & 38 \end{bmatrix} - \begin{bmatrix} 29 \\ 31 \end{bmatrix}$$

$$A = \begin{bmatrix} 17 & -5 \\ -19 & 7 \end{bmatrix}$$

3. The third step looks for the covariance matrix by multiplying the zero mean matrix that has been transposed with a zero-mean matrix

$$L = \begin{bmatrix} 17 & -5 \\ -19 & 7 \end{bmatrix}^T \times \begin{bmatrix} 17 & -5 \\ -19 & 7 \end{bmatrix}$$

$$L = \begin{bmatrix} 17 & -19 \\ -5 & 7 \end{bmatrix} \times \begin{bmatrix} 17 & -5 \\ -19 & 7 \end{bmatrix}$$

$$L = \begin{bmatrix} 650 & -218 \\ -218 & 24 \end{bmatrix}$$

4. The next step is Finding eigenvalues and eigenvectors.

$$det[\lambda I - L] = 0 \qquad (6)$$

$$det\left[\lambda * \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} - \begin{bmatrix} 650 & -218 \\ -218 & 24 \end{bmatrix}\right] = 0$$

$$det\left[\begin{bmatrix} \lambda & 0 \\ 0 & \lambda \end{bmatrix} - \begin{bmatrix} 650 & -218 \\ -218 & 24 \end{bmatrix}\right] = 0$$

$$det\left[\begin{bmatrix} \lambda - 650 & -218 \\ -218 & \lambda - 24 \end{bmatrix}\right] = 0$$

$$(\lambda - 650)(\lambda - 24) - (-218)(-218) = 0$$

$$\lambda^2 - 24\lambda - 650\lambda + 15600 - 47524 = 0$$

$$\lambda^2 - 674\lambda - 31924 = 0$$

To obtain the factor value of the equation system above then use the equation below as follows:

$$\lambda_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad (7)$$

$$\lambda_{1,2} = \frac{-(-674) \pm \sqrt{(-674)^2 - 4(1)(-31924)}}{2(1)}$$

$$\lambda_{1,2} = \frac{674 \pm 762.87}{2}$$

$$\lambda_1 = \frac{674 + 762.87}{2} = 718.435$$

$$\lambda_2 = \frac{674 - 762.87}{2} = -44.435$$

From the calculation result that has been done then the eigen value obtained as follows:

$$eigen\ value = \begin{bmatrix} 718.435 & 0 \\ 0 & -44.435 \end{bmatrix}$$

To obtain an eigenvector, we use the following equation:

$$(C_{11} - \lambda)u_1 + C_{12}u_2 = 0$$
$$C_{21}u_1 + (C_{22} - \lambda)u_2 = 0$$

For eigenvectors $\lambda_1 = 718.435$ then yield the following calculation:

$$(650-\lambda)u_1+(-218)u_2=0$$
$$(650-718.435)u_1+(-218)u_2=0$$
$$-68.435u_1-218u_2=0 \qquad (7)$$

$$-218u_1+(24-\lambda)u_2=0$$
$$-218u_1+(24-718.435)u_2=0$$
$$-218u_1-694.435u_2=0 \qquad (8)$$

The solution used to solve the above equation system is as follows:

$$-68.435u_1=218u_2 \qquad (9)$$
$$u_1=-3.18u_2 \qquad (10)$$

Let $u_2=a$ then the value $u_1=-3.18a$. Thus, for eigenvector in λ_1 as follows:

$$U=\begin{bmatrix}u_1\\u_2\end{bmatrix}=\begin{bmatrix}-3.18\\a\end{bmatrix}$$

Let a=1 then

$$U=\begin{bmatrix}-3.18\\1\end{bmatrix}$$

To obtain an eigenvector for $\lambda_1=718.435$ it is necessary to divide by the root of the sum of its squares.

$$U=\begin{bmatrix}\frac{-3.18}{\sqrt{(-3.18)^2+1^2}}\\\frac{1}{\sqrt{(-3.18)^2+1^2}}\end{bmatrix}$$

$$U=\begin{bmatrix}-0.954\\0.299\end{bmatrix}$$

For eigenvectors $\lambda_2=-44.435$ then generate the following calculation:

$$(650-\lambda)u_1+(-218)u_2=0$$
$$(650-(-44.435))u_1+(-218)u_2=0$$
$$694.435u_1-218u_2=0 \qquad (7)$$

$$-218u_1+(24-\lambda)u_2=0$$
$$-218u_1+(24-(-44.435))u_2=0$$
$$-218u_1+68.435u_2=0 \qquad (8)$$

The solution used to solve the above equation system is as follows:

$$694.435u_1=218u_2 \qquad (9)$$
$$u_1=0.3126u_2 \qquad (10)$$

Let $u_2=b$ then the value $u_1=0.3126b$. Thus, for eigenvector in λ_1 as follows:

$$U=\begin{bmatrix}u_1\\u_2\end{bmatrix}=\begin{bmatrix}0.3126\\b\end{bmatrix}$$

Let a=1 then

$$U=\begin{bmatrix}0.3126\\1\end{bmatrix}$$

To obtain an eigenvector for $\lambda_2=-44.435$ then it needs to be divided by the root of the sum of its squares.

$$U=\begin{bmatrix}\frac{0.3126}{\sqrt{(0.3126)^2+1^2}}\\\frac{1}{\sqrt{(0.3126)^2+1^2}}\end{bmatrix}$$

$$U=\begin{bmatrix}0.298\\0.954\end{bmatrix}$$

After calculating the eigenvectors for each λ value we can obtain the overall eigenvector as follows:

$$eigen\ vector=\begin{bmatrix}-0.954 & 0.298\\0.299 & 0.954\end{bmatrix}$$

5. The next process is to calculate the project image of the image as follows:

$$Z=\begin{bmatrix}-0.954 & 0.299\\0.298 & 0.954\end{bmatrix}\times\begin{bmatrix}17 & -5\\-19 & 7\end{bmatrix}$$

$$Z=\begin{bmatrix}-73.028 & 6.863\\-13.06 & 5.188\end{bmatrix}$$

2.3 Euclidean Distance

Euclidean distance is a classification method with its nearest neighbor that calculates the distance between two objects. Euclidean distance has equation as follows:

$$d_e=\sqrt{\sum_{k=1}^{m}\left(fd_{i,k}-k_j\right)^2} \qquad (8)$$

In equation 6 above, d_e is the euclidean distance. The $fd_{i,k}$ symbol represents the weight of the training data used. The k_j symbol represents the weights of the test data and m represents the amount of training data used in the system [10].

2.4 Retinex

The retinex method proposed by Edwin Land in 1971. Based on experiments he has done that the human visual system is able to recognize the color in different lighting conditions with a wide range. This can happen because of the color constancy.

Color constancy is the ability that seeks the color of an object seen to look the same even though the object is in different lighting conditions [12] [17]. With the color constancy then developed a method for digital image processing is retinex.

Retinex is now widely developed and produces several variants of the results of its development. The retinex variants include Single Scale Retinex (SSR) and Multi Scale Retinex (MSR).

2.4.1 Single Scale Retinex (SSR)

SSR is a dynamic version retinex that is different from the static retinex version at the beginning of its emergence using the path/mondrian system. The equation of the SSR can be defined as follows [5] [18] [19]:

$$R_{SSR}(x,y) = \log I_i(x,y) - \log[F\ (x,y) * I_i(x,y)] \quad (9)$$

In equation 7 above, $R_{SSR}(x,y)$ is the output of retinex and $I_i(x,y)$ is the image distribution in the spectral band. Where there are three spectral bands that are red, green and blue. In the above equation, the symbol * represents the convolution operator and $F\ (x,y)$ is a gaussian function [11].

$$I_R(x,y) = Ke^{\left(\frac{-r^2}{c}\right)} \qquad (10)$$

In equation 8 in level, c is a gaussian constant commonly used to represent standard deviation [3]. The small value of c gives the dynamic range compression is very good but has a color value that is not too good because the graying on the picture is a uniform color area. In contrast, on a large scale provides better color in the dynamic range compression [3].

2.4.2 Multi Scale Retinex (SSR)

Multi Scale Retinex (MSR) is the results of the development of the SSR method that has been there before. This MSR method was developed to overcome the limitations of the SSR.

SSR is already capable of performing dynamic range compression on images when used on a low scale, enabling images with very wide dynamic spacing to be compressed by strengthening the dark part of the image and weakening the bright image.

On a large scale, SSR can produce a more natural image when with a large brightness level. However, SSR cannot do both things at once. In addition, in some case the use of SSR there is a shift in color or distortion in the resulting image [12].

The MSR method can be defined by the following formula:

$$R_{MSRi} = \sum_{n=1}^{N} \omega n\{logI(x,y) - \log[F_n(x,y) * I_i(x,y)]\} \quad (11)$$

In equation 9 above, R_{MSRi} is the output of MSR which is the sum of the SSR image output. N is the number of scales used. ω_n is the weight on the scale to n. The i symbol represents the spectral band that are red, green and blue.

The symbol $F_n(x,y)$ defines ad gaussian function with equation as follows [16]:

$$F(x,y) = K \times e^{\left(-\frac{r^2}{c}\right)} \qquad (12)$$

In equation 10 above, e symbol is euler number with a value of 2,71828182846. K symbol equal as $\frac{1}{2\pi\sigma^2}$. The c symbol equal as $2\pi\sigma^2$. Where the π symbol is phi with a value of 3,14. The σ symbol is a factor value that affects retinex image changes.

2.4.3 Example of Retinex Use

This section describes the Single Scale Retinex process mathematically. The SSR calculation process is as follows:

1. The first process that needs to be done is to calculate the value of $F(x,y)$ to get the gaussian value. In this example the value of σ=5.

$$\begin{pmatrix} \frac{1}{2\pi(5)^2} \times e^{-\frac{(-1)^2+1^2}{2(5)^2}} & \frac{1}{2\pi(5)^2} \times e^{-\frac{0^2+1^2}{2(5)^2}} & \frac{1}{2\pi(5)^2} \times e^{-\frac{1^2+1^2}{2(5)^2}} \\ \frac{1}{2\pi(5)^2} \times e^{-\frac{(-1)^2+0^2}{2(5)^2}} & \frac{1}{2\pi(5)^2} \times e^{-\frac{0^2+0^2}{2(5)^2}} & \frac{1}{2\pi(5)^2} \times e^{-\frac{1^2+0^2}{2(5)^2}} \\ \frac{1}{2\pi(5)^2} \times e^{-\frac{(-1)^2+(-1)^2}{2(5)^2}} & \frac{1}{2\pi(5)^2} \times e^{-\frac{0^2+(-1)^2}{2(5)^2}} & \frac{1}{2\pi(5)^2} \times e^{-\frac{1^2+(-1)^2}{2(5)^2}} \end{pmatrix}$$

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$$\begin{pmatrix} 0.006114114613 & 0.006237627921 & 0.006114114613 \\ 0.006237627921 & 0.006363636364 & 0.006237627921 \\ 0.006114114613 & 0.006237627921 & 0.006114114613 \end{pmatrix}$$

2. The second step is to add all the elements of the gaussian value matrix that have been previously obtained. If summed, then the result should be =1. This corresponds to the equation $\iint F(x,y)dxdy = 1$.

   In the previous calculation the total value obtained is 0.055770606. When rounded the value obtained is 0.06. If the sum of ≠ 1 then needs to be recalculated using the equation as follows:

$$T(x,y) = B_{(m,n)} \times \frac{1}{Total} \quad (13)$$

$$T(1,1) = B_{(1,1)} \times \frac{1}{0.6} = 0.10190191$$

$$T(1,2) = B_{(1,2)} \times \frac{1}{0.6} = 0.103960465$$

$$T(1,3) = B_{(1,3)} \times \frac{1}{0.6} = 0.10190191$$

$$T(2,1) = B_{(2,1)} \times \frac{1}{0.6} = 0.103960465$$

$$T(2,2) = B_{(2,2)} \times \frac{1}{0.6} = 0.106060606$$

$$T(2,3) = B_{(2,3)} \times \frac{1}{0.6} = 0.103960465$$

$$T(3,1) = B_{(3,1)} \times \frac{1}{0.6} = 0.10190191$$

$$T(3,2) = B_{(3,2)} \times \frac{1}{0.6} = 0.103960465$$

$$T(3,3) = B_{(3,3)} \times \frac{1}{0.6} = 0.10190191$$

After recounting according to equation 11 then the total value obtained is 0.929510106. When rounded the total value is equal to 1.

3. The third step is to convolution the original image pixel with the gaussian kernel.

Table 2: Original Image Pixel

1	10	9	6
8	9	3	1
8	7	1	7
4	6	6	5

For gaussian kernels use the result of the count in the second step.

$$\begin{pmatrix} 0.10190191 & 0.103960465 & 0.10190191 \\ 0.103960465 & 0.106060606 & 0.103960465 \\ 0.10190191 & 0.103960465 & 0.10190191 \end{pmatrix}$$

In the calculation of this convolution using convolution type zero padding.

a. The results of the first convolution calculation as follows:

Table 3: Original Image Matrix for First Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(0 \times 0.10190191) + (0 \times 0.103960465) + (0 \times 0.10190191) + (0 \times 0.103960465) + (1 \times 0.106060606) + (10 \times 0.103960465) + (0 \times 0.10190191) + (8 \times 0.103960465) + (9 \times 0.10190191) = 2.894466166$$

b. The second convolution count results as follows:

Table 4: Original Image Matrix for Second Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(0 \times 0.10190191) + (0 \times 0.103960465) + (0 \times 0.10190191) + (1 \times 0.103960465) + (10 \times 0.106060606) + (9 \times 0.103960465) + (8 \times 0.10190191) + (9 \times 0.103960465) + (3 \times 0.10190191) = 4.156775905$$

c. The result of counting the third convolution as follows:

Table 5: Original Image Matrix for Third Convolution

0	0	0	0	0	0

0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(0 \times 0.10190191) + (0 \times 0.103960465) + (0 \times 0.10190191) + (10 \times 0.103960465) + (9 \times 0.106060606) + (6 \times 0.103960465) + (9 \times 0.10190191) + (3 \times 0.103960465) + (1 \times 0.10190191) = 12.53972248$$

d. The results of the fourth convolution calculation as follows:

Table 6: Original Image Matrix for Fourth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(0 \times 0.10190191) + (0 \times 0.103960465) + (0 \times 0.10190191) + (9 \times 0.103960465) + (6 \times 0.106060606) + (0 \times 0.103960465) + (3 \times 0.10190191) + (1 \times 0.103960465) + (0 \times 0.10190191) = 4.452105688$$

e. The results of the fifth convolutional calculation are as follows:

Table 7: Original Image Matrix for Fifth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(0 \times 0.10190191) + (1 \times 0.103960465) + (10 \times 0.10190191) + (0 \times 0.103960465) + (8 \times 0.106060606) + (9 \times 0.103960465) + (0 \times 0.10190191) + (8 \times 0.103960465) + (7 \times 0.10190191) = 5.801574764$$

f. The results of the sixth convolution count are as follows:

Table 8: Original Image Matrix for Sixth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(1 \times 0.10190191) + (10 \times 0.103960465) + (9 \times 0.10190191) + (8 \times 0.103960465) + (9 \times 0.106060606) + (3 \times 0.103960465) + (8 \times 0.10190191) + (7 \times 0.103960465) + (1 \times 0.10190191) = 5.801574764$$

g. The results of the seventh convolution count are as follows:

Table 9: Original Image Matrix for Seventh Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(10 \times 0.10190191) + (9 \times 0.103960465) + (6 \times 0.10190191) + (9 \times 0.103960465) + (3 \times 0.106060606) + (1 \times 0.103960465) + (7 \times 0.10190191) + (1 \times 0.103960465) + (7 \times 0.10190191) = 5.454448418$$

h. The results of the eighth convolution count are as follows:

Table 10: Original Image Matrix for Eighth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(9 \times 0.10190191) + (6 \times 0.103960465) + (0 \times 0.10190191) + (3 \times 0.103960465) + (1 \times 0.106060606) + (0 \times 0.103960465) + (1 \times 0.10190191) + (7 \times 0.103960465) + (0 \times 0.10190191) = 2.774037261$$

i. The results of the ninth convolution count are as follows:

Table 11: Original Image Matrix for Ninth Convolution

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0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(0 \times 0.10190191) + (8 \times 0.103960465) + (9 \times 0.10190191) + (0 \times 0.103960465) + (8 \times 0.106060606) + (7 \times 0.103960465) + (0 \times 0.10190191) + (4 \times 0.103960465) + (6 \times 0.10190191) = 4.352262333$$

j. The results of the tenth convolution count are as follows:

Table 12: Original Image Matrix for Tenth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(8 \times 0.10190191) + (9 \times 0.103960465) + (3 \times 0.10190191) + (8 \times 0.103960465) + (7 \times 0.106060606) + (1 \times 0.103960465) + (4 \times 0.10190191) + (6 \times 0.103960465) + (6 \times 0.10190191) = 5.377415512$$

k. The results of the eleventh convolution count are as follows:

Table 13: Original Image Matrix for Eleventh Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(9 \times 0.10190191) + (3 \times 0.103960465) + (1 \times 0.10190191) + (7 \times 0.103960465) + (1 \times 0.106060606) + (7 \times 0.103960465) + (6 \times 0.10190191) + (6 \times 0.103960465) + (6 \times 0.10190191) = 4.637091411$$

l. The results of the twelfth convolution count are as follows:

Table 14: Original Image Matrix for Twelfth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(3 \times 0.10190191) + (1 \times 0.103960465) + (0 \times 0.10190191) + (1 \times 0.103960465) + (7 \times 0.106060606) + (0 \times 0.103960465) + (6 \times 0.10190191) + (5 \times 0.103960465) + (0 \times 0.10190191) = 2.387264687$$

m. The results of the thirteenth convolution count are as follows:

Table 15: Original Image Matrix for Thirteenth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(0 \times 0.10190191) + (8 \times 0.103960465) + (7 \times 0.10190191) + (0 \times 0.103960465) + (6 \times 0.106060606) + (6 \times 0.103960465) + (0 \times 0.10190191) + (0 \times 0.103960465) + (0 \times 0.10190191) = 2.593002304$$

n. The results of the fourteenth convolution count are as follows:

Table 16: Original Image Matrix for Fourteenth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(8 \times 0.10190191) + (7 \times 0.103960465) + (1 \times 0.10190191) + (4 \times 0.103960465) + (6 \times 0.106060606) + (6 \times 0.103960465) + (0 \times 0.10190191) + (0 \times 0.103960465) + (0 \times 0.10190191) = 3.320808731$$

o. The results of the fifteenth convolution count are as follows:

Table 17: Original Image Matrix for Fifteenth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(7 \times 0.10190191) + (1 \times 0.103960465) + (7 \times 0.10190191) + (6 \times 0.103960465) + (6 \times 0.106060606) + (5 \times 0.103960465) + (0 \times 0.10190191) + (0 \times 0.103960465) + (0 \times 0.10190191) = 3.300223181$$

p. The results of the sixteenth convolution count are as follows:

Table 18: Original Image Matrix for Sixteenth Convolution

0	0	0	0	0	0
0	1	10	9	6	0
0	8	9	3	1	0
0	8	7	1	7	0
0	4	6	6	5	0
0	0	0	0	0	0

$$(1 \times 0.10190191) + (7 \times 0.103960465) + (7 \times 0.10190191) + (6 \times 0.103960465) + (5 \times 0.106060606) + (0 \times 0.103960465) + (0 \times 0.10190191) + (0 \times 0.103960465) + (0 \times 0.10190191) = 1.983690985$$

The convolution pixel count results between the original image pixel and the gaussian kernel as follows:

Table 19: Result of Convolution

2.894466166	4.156775905	12.53972248	2.801006406
4.452105688	5.801574764	5.454448418	2.774037261
4.352262333	5.377415512	4.637091411	2.387264687
2.593002304	3.320808731	3.300223181	1.983690985

4. The next step is to calculate the final value of SSR according to equation 7.

a. $R_{SSR}(x,y) = 1 - 2.894466166 = -1.894466166$
b. $R_{SSR}(x,y) = 10 - 4.156775905 = 5.843224095$
c. $R_{SSR}(x,y) = 9 - 12.53972248 = -3.53972248$
d. $R_{SSR}(x,y) = 6 - 2.801006406 = 2.142087211$
e. $R_{SSR}(x,y) = 8 - 4.452105688 = 3.547894312$
f. $R_{SSR}(x,y) = 9 - 5.801574764 = 3.198425236$
g. $R_{SSR}(x,y) = 3 - 5.454448418 = -2.454448418$
h. $R_{SSR}(x,y) = 1 - 2.774037261 = -1.774037261$
i. $R_{SSR}(x,y) = 8 - 4.35226233 = 3.64773767$
j. $R_{SSR}(x,y) = 7 - 5.377415512 = 1.62258448$
k. $R_{SSR}(x,y) = 1 - 4.637091411 = -3.637091411$
l. $R_{SSR}(x,y) = 7 - 2.387264687 = 4.612735313$
m. $R_{SSR}(x,y) = 4 - 2.593002304 = 1.406997696$
n. $R_{SSR}(x,y) = 6 - 3.320808731 = 2.679191269$
o. $R_{SSR}(x,y) = 6 - 3.300223181 = 2.699776819$
p. $R_{SSR}(x,y) = 5 - 1.983690985 = 3.016309015$

The results of SSR calculation can be seen in the table below as follows:

Table 20: Result of SSR

-1.894466166	5.843224095	-3.53972248	2.142087211
3.547894312	3.198425236	-2.454448418	-1.774037261
3.64773767	1.62258448	-3.637091411	4.612735313
1.406997696	2.679191269	2.699776819	3.016309015

For MSR calculations done by summing the output pixels of the SSR residing on the RGB channel to produce 3 different SSR outputs.

2.5 Peak to Signal Ratio (PSNR)

Peak to Signal Ratio (PSNR) is a method to determine image quality mathematically. The value of PSNR depend on the Mean Square Error (MSE) value of the image. If the value of PSNR is greater than the image quality will be better.

Otherwise, if the value of PSNR is smaller than the image quality will get worse. This is inversely proportional to MSE. If the value of MSE is greater than the image obtained will have poor quality and if the MSE value is smaller than the image quality will get better [14].

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The relationship between the PSNR value and the MSE value is the greater the value of PSNR the smaller the MSE value. MSE has equation as follows:

$$MSE = \frac{1}{C \times M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \left(I(i,j) - R(i,j)\right)^2 \quad (14)$$

In equation 14 above, the symbol $I(i,j)$ represents the data value in the original image pixel. The symbol $R(i,j)$ is the reconstructed image pixel. The M and N symbols represent the row and column sizes of the image. The C symbol represents the number of color components in the image. For value C=1 is used for binary image or grayscale image. For value C=3 is used for color image (RGB). For PSNR has equation as follows [13]:

$$PSNR = 10log_{10}\left(\frac{Max_I^{\,2}}{MSE}\right) \quad (15)$$

At the equation 15 the symbol $Max_I^{\,2}$ represents the maximum value of pixel in the original image I. The value of Max_I is 255 with the color component of each bit being 8 bits. The unit used on PSNR is dB (decibel) [13].

3. RESEARCH METHODS

3.1 System Overview

The system used in this final project is a system built to recognize human faces with minimal or dim lighting conditions.

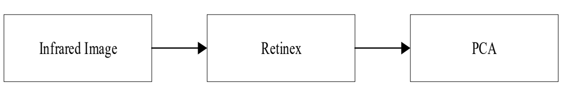

Figure 2: System Overview Diagram

In Figure 2, it is mentioned about the general description of this final project system. The system created using data in the form of infrared image. The infrared image becomes the input image that used by the system.

The information contained in the infrared image is the face of the subject to be studied for recognition by the system. The infrared image will go through image improvement process using the retinex method. Images that have been through the retinex process will go through the PCA process to recognize the face of the subject contained within the image itself.

3.2 System Design

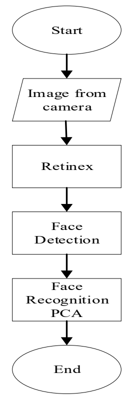

Figure 3: Flowchart System

Figure 3 shows the flowchart of the system used. The image to be tested is generated from the shots taken from the camera. Then the image will go through image improvement process using retinex method. The image of the retinex will go through the face detection process to detect the location of the subject's faces in the image. After the subject's face is found, it then goes into the PCA face recognition stage compared to the pre-entered training data set into the system.

The process of training and system testing can be seen in the diagram as follows:

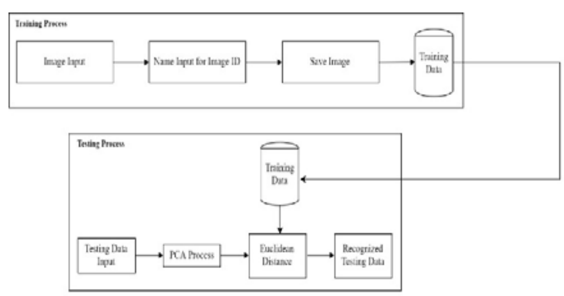

Figure 4: Diagram of Training and Testing System

In Figure 4 the data input process of training begins by inserting the image to be used as training data. Then the next process is to give the name of the trainer data which is useful as the identity of the training data entered into the system. After giving the name, the training data will be stored in the destination folder. In addition, image information such as names will be stored in the '. MAT' file.

In the process of testing on this final task is done by looking at the level of accuracy of the system in recognizing the face of the subject being tested. The

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first process to do is to input data to be tested. Then, PCA will begin the process of obtaining information on the test data.

After that, the final stage before the subject's face can be identified the system will look for similarities between test data with features that have been obtained in previous PCA process using Euclidean distance. After the Euclidean distance process then the subject face on the test data will be identified.

3.3 Training Data and Testing Data

3.3.1 Training Data

The training data used on this system is taken from a different subject with a total of 10 subjects (people). Each of the data on the subject is taken in the following conditions:

Table 21: Details of Training Data

Type of Training Data	Level of Lighting	Amount of Data
Very Dark	0 lux	15
Dimly Lit	15 lux	15
Bright	20 lux	30
Very Dark + Dimly Lit	0 lux and 15 lux	30
Mixed (Very Dark + dimly lit + bright)	0 lux, 15 lux and 20 lux	60
Very Dark with Angle Pose	0 lux	27
Amount of Training Data/subject		**177**
Total Training Data (10 Subjects)		**1770**

The data types listed in the table above refer to the light conditions of the location space of the data retrieval. In very dark room conditions, the lighting level is at 0 lux (without the aid of lighting).

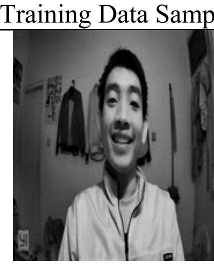
Under dimly lit conditions, the measured level of lighting is 15 lux. Room lighting combines dark lighting (without room lights) plus the use of a 5 watts yellow incandescent lamp.

In bright space conditions, the lighting level of 20 lux obtained from the lamp space of the location of data collection. The type of room light used is a white LED lamp with 10 watts of power.

To perform the measurement of the level of lighting in the location space of data retrieval using the application android "Lux Meter" is downloaded through the Play Store.

Train data retrieval is done entirely at night when the light is very minimal when compared to daylight. In addition, the camera mode used is the HD mode with the pixel size of 1280 x 720. Total training data are taken as many as 177 images for each subject. Thus, the overall training data used for this system is 1770 images.

Table 22: Training Data Sample

Type of Training Data	Training Data Sample
Very Dark	 Figure 5: Very Dark Training Data Sample
Dimly Lit	 Figure 6: Dimly Lit Training Data Sample
Bright	 Figure 7: Bright Training Data Sample

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Type of Training Data	Training Data Sample
Very Dark with Angle Pose	 Figure 8: Very Dark and Angle Pose Training Data Sample

3.3.2 Testing Data

Test data used in this final project consists of several types with various conditions. Intake of all test data is done at night using CCTV camera and infrared camera mode in dark room.

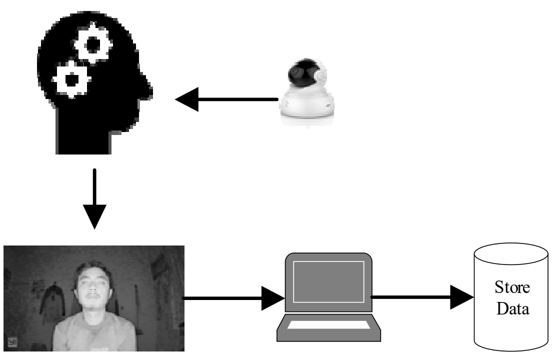

Figure 9: Test Data Retrieval Process

In Figure 9 is the process of taking the test data. Taking the test data using Yi Dome camera. Test data that has been taken then moved into the laptop for further stored into a single folder according to the type of test data used. Here are some types of test data used in this final project:

Table 23: Details of Testing Data

Type of Data	Level of Lighting	Amount of Data
Very Dark	0 lux	15
Dimly Lit	15 lux	15
Bright	20 lux	15
Very Dark distance 80 cm	0 lux	15
Very Dark distance 120 cm	0 lux	15
Very Dark distance 160 cm	0 lux	15
Total Testing Data		**102**

In the table above, there are 7 different types of test data. The test data used is taken based on 3 different conditions of room lighting and the distance between subjects with different camera positions.

As with the specifics of retrieval of data, the data type refers to the lighting conditions of the location of the test data taking place. In very dark lighting conditions, the room does not use any lighting aid at all. Thus, the value of illumination level is 0 lux. In dim lighting conditions, dark room lighting conditions with the assisted lighting of a 5 watts yellow light bulb. The level of illumination obtained in this condition is 15 lux. In bright visual lighting conditions, the room measurable level of 20 lux by using white LED lights with 10 watts of power.

In the test data is taken data type with very dark room lighting conditions (0 lux) by using the variation of the distance between the subject position with the camera. There are 3 variations of distance that is the distance of 80 cm, 120 cm and 160 cm with very dark room lighting conditions. In addition, the system will also be tested using angle data variations.

There are two variations of angle data that is used is the subject face angle of 30° and 60 ° with very dark room lighting conditions. The overall measurement at the lighting level is the same as the retrieval of test data measured using the "Lux Meter" application downloaded through the Play Store. In taking the test data, the camera mode used is the HD mode with pixel size 1280 x 720.

Total test data used to test the system of 102 images for each subject. Overall data to be tested on the face recognition system is 1020 images.

Table 24: Test Data Sample

Type of Test Data	Test Data Sample
Very Dark	 Figure 10: Very Dark Testing Data Sample
Dimly Lit	 Figure 11: Dimly Lit Testing Data Sample
Bright	 Figure 12: Bright Testing Data Sample
Very Dark with distance 80 cm	 Figure 13: Very Dark Testing Data Sample with Distance 80 cm
Very Dark with distance 120 cm	 Figure 14: Very Dark Testing Data Sample with Distance 120 cm
Very Dark with distance 160 cm	 Figure 15: Very Dark Testing Data Sample with Distance 160 cm
Very Dark with angle pose	 Figure 16: Very Dark Testing Data Sample Angle Pose

4. RESULTS AND ANALYSIS

In this research, all tests were performed in accordance with the variations of pre-determined test scenarios. Tests conducted to see the performance of the system based on the level of accuracy of the face recognition of the subject under test. Calculation of the accuracy using the equation as follows:

$$Accuration\ Rate = \frac{\sum Recognized\ Test\ Data}{\sum Testing\ Data} \times 100\% \quad (16)$$

In equation 16 is included on the calculation equation of accuracy. The level of accuracy will be calculated based on the amount of test data recognized by the system divided by the large number of test data then multiplied by 100% to get the final value of accuracy percentage. The system using MATLAB R2017a. Here's the display program that has been created.

Figure 17: Graphic User Interface Program

In figure 17 is a program view that is implemented based on system design that has been made before

4.1 First Model Test Results (Without Retinex)

The first model test scenario uses 3 different types of testing as follows:

Table 25: Test Data Specification First Model

Type of Test Data	Amount of Data
First Test (Very Dark)	150
Second Test (Dimly Lit)	150
Third Test (Bright)	150
Total Testing Data	**450**

The first test uses very dark test data. The second test uses the dimly lit test data. The third test uses bright test data. All types of testing on this model use mixed training data. The first model test is performed to see the accuracy of the system before using the retinex method. The result of the first model scenario test (without retinex) as follows:

Table 26: Test Results First Model Scenario

Type of Test Data	Recognized Test Data	Accuracy	Average Time (in seconds)
First Test (Very Dark)	96	64%	769.71
Second Test (Dimly Lit)	108	72%	768.15
Third Test (Bright)	75	50%	759.67

In table 6 is the result of testing the first model scenario without using retinex. In the first test using very dark test data obtained an accuracy rate of 64% with the introduction of 96 out of 150 data tested. The second test uses a dimly lit test data with 72% accuracy. The introduction to this test counted 108 of the 150 data tested. The third test uses bright test data with the introduction of 75 of the 150 data tested. Accuracy rate obtained by 50%. The results of the first model scenario testing can be seen in the diagram below:

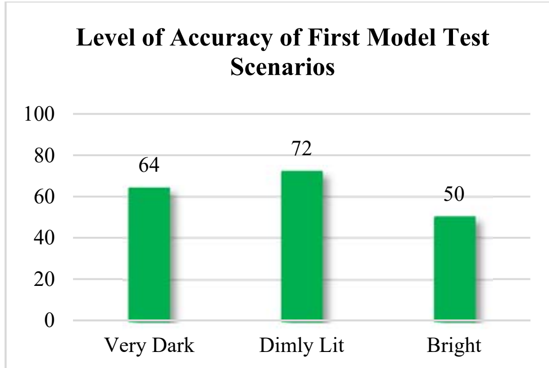

Figure 18: The First Model Test Result Diagram

Figure 18 shows the first model scenario test diagram. Based on the data that has been tested, test data with dim lighting conditions have the highest accuracy of 72%. Unlike the very dark test data that has accuracy rate of 64%. While the level of accuracy of light test data is 50%.

4.2 Second Model Test Results

The second model testing scenario uses 3 different types of testing.

Table 27: Test Data Specification Second Model

Type of Test Data	Amount of Test Data
First Test (Very Dark SSR σ=2)	150
Second Test (Very Dark SSR σ=200)	150
Third Test (Very Dark MSR $\sigma1$=2, $\sigma2$=80, $\sigma3$=220)	150
Fourth Test (Very Dark MSR $\sigma1$=4, $\sigma2$=60, $\sigma3$=200)	150
Total Test Data	**600**

The first test uses very dark SSR test data with σ=2. The second test uses very dark SSR test data with σ=200. The third test uses very dark MSR test data with values $\sigma1$=2, $\sigma2$=80 and $\sigma3$=220. The fourth test uses very dark MSR test data with values $\sigma1$=4, $\sigma2$=60 and $\sigma3$=200. The training data used in this second model scenario is mixed. A second model test was performed to compare SSR and MSR methods. The results of the second model scenario test (SSR and MSR) as follows:

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Table 28: Test Results Second Model Scenario

Type of Test	Recognized Test Data	Accuracy	Average Time (in seconds)
First Test (Very Dark SSR σ=2)	6	4%	666.09
Second Test (Very Dark SSR σ=200)	6	4%	738.46
Third Test (Very Dark MSR σ1=2, σ2=80, σ3=220)	6	4%	784.91
Fourth Test (Very Dark MSR σ1=4, σ2=60, σ3=200)	6	4%	741.49

Table 8 is the result of the second model test scenario (SSR and MSR). The first test uses very dark test data through SSR process (σ=2) system recognition level on the test data of 6 images with an accuracy level of 4%. The second test uses very dark test data with SSR (σ=200) system recognition level on the test data of 6 images of 150 test data and accuracy of 4%.

The third test data used is very dark test data with pre-processing MSR (σ1=2, σ2=80, σ3=220) can be seen that from 150 data tested system recognition level to the test data of 6 images and obtained accuracy rate of 4%. The fourth test data used is very dark test data with MSR (σ1=4, σ2=60, σ3=200) can be seen from 150 data tested its introduction of 6 and the accuracy of 4%. The results of the second model scenario test in the diagram below.

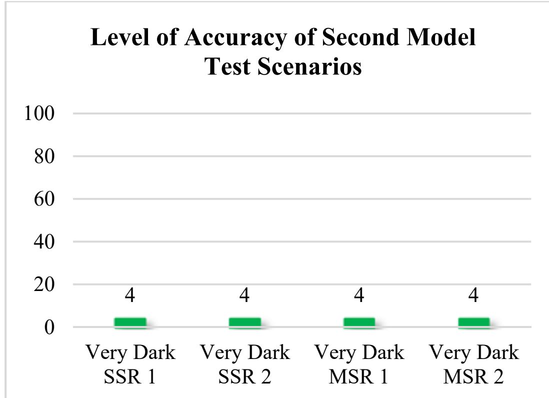

Figure 19: The Second Model Test Result Diagram

In figure 19 the diagram of the results of the second model scenario test is presented. Based on the tests on this model the accuracy of the 4 tests performed was balanced at 4%.

In terms of the value of MSE and PSNR owned by the image in the test model test data can also be seen the difference. The greater the value of MSE obtained then the image quality is worse. Conversely, the smaller the value of MSE the better the image quality. This is inversely proportional to PSNR where the greater the value of PSNR the better the image quality. While the smaller the value of PSNR the worse the image quality.

On average, images with very dark conditions that have been through the SSR process with σ = 2 have the value of MSE = 0.05050551 and the value of PSNR = 61.28197 dB. In a very dark image that has been through the SSR process with σ = 200 has the value of MSE = 0.06607653 and the value of PSNR = 59.97101 dB. In a very dark image that has gone through the process of MSR with σ1 = 2, σ2 = 80, σ3 = 220 has MSE = 0.06193037 and PSNR = 60.26539 dB. In a very dark image that has been through the process of MSR with σ1 = 4, σ2 = 60, σ3 = 200 has the value of MSE = 0.06465968 and the value of PSNR = 60.06441 dB.

4.3 Third Model Test Results

The third model test scenario uses 9 different test variations.

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Table 29: Test Data Specification Third Model

Type of Test Data	Conditions	Amount of Test Data
First Test (Very Dark MSR $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220)	The Same Light Training Data Condition	150
Second Test (Dimly Lit MSR $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220)		150
Third Test (Bright MSR $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220)		150
Fourth Test (Very Dark MSR $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220)	The Cross Light Training Data Condition	150
Fifth Test (Dimly Lit MSR $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220)		150
Sixth Test (Bright MSR $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220)		150
Seventh Test (Very Dark MSR $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220)	The Mixed Training Data Condition	150
Eighth Test (Dimly Lit MSR $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220)		150
Ninth Test (Bright MSR $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220)		150
Total Test Data		**1350**

The first test, fourth test and the seventh test using very dark MSR test data with $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220. The second test, the fifth test and the eighth test using the MSR dim data test with $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220. The third test, the sixth test and the ninth test using the MSR light test data with the values $\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220. The results of the third model scenario test as follows:

Table 30: Test Results Third Model Scenario

Type of Test	Recognized Test Data	Accuracy	Average Time (in seconds)
First Test (Very Dark MSR $\sigma 1$=2, $\sigma 2$=80, $\sigma 3$=220)	36	24%	132.3
Second Test (Dimly Lit MSR $\sigma 1$=2, $\sigma 2$=80, $\sigma 3$=220)	15	10%	134.59
Third Test (Bright MSR $\sigma 1$=2, $\sigma 2$=80, $\sigma 3$=220)	30	20%	268.67
Fourth Test (Very Dark MSR $\sigma 1$=2, $\sigma 2$=80, $\sigma 3$=220)	30	20%	275.44
Fifth Test (Dimly Lit MSR $\sigma 1$=2, $\sigma 2$=80, $\sigma 3$=220)	57	38%	278.71
Sixth Test (Bright MSR $\sigma 1$=2, $\sigma 2$=80, $\sigma 3$=220)	15	10%	280.12
Seventh Test (Very Dark MSR $\sigma 1$=2, $\sigma 2$=80, $\sigma 3$=220)	6	4%	784.91
Eight Test (Dimly Lit MSR $\sigma 1$=2, $\sigma 2$=80, $\sigma 3$=220)	29	19.3%	713.21
Ninth Test (Bright MSR $\sigma 1$=2, $\sigma 2$=80, $\sigma 3$=220)	15	10%	702.69

In Table 10, the first test uses MSR very dark test data ($\sigma 1$=2, $\sigma 2$=80 and $\sigma 3$=220). The recognition level of the test data is 36 images from 150 data tested with an accuracy of 24%.

The second test uses dim test data with MSR (σ1=2, σ2=80 and σ3=220) with bright training data. Test results from 150 data tested the recognition rate of the system to the test data is 15 images with an accuracy of 10%.

The third test used bright test data with MSR (σ1=2, σ2=80 and σ3=220) as well as very dark and dim training data. The level of recognition for 150 data tested is 30 images with an accuracy of 20%.

The fourth test uses MSR very dark test data (σ1=2, σ2=80 and σ3=220) with training data in bright condition. The test results obtained from 150 data tested the level of recognition of the system to the test data of 30 images and the accuracy of 20%.

The fifth test uses dim test data with MSR (σ1=2, σ2=80 and σ3=220) and bright training data. It can be seen from 150 data tested the level of recognition of the system against the test data of 57 images with an accuracy of 38%.

The sixth test uses the MSR light test data (σ1=2, σ2=80 and σ3=220) with very dark and dim trained data. It can be seen from 150 data tested the level of recognition of the system to the test data of 15 images with an accuracy of 10%.

The seventh test uses MSR very dark test data (σ1=2, σ2=80 and σ3=220) and bright training data. It can be seen from 150 data tested the level of recognition of the system to the test data of 6 images with an accuracy of 4%.

The eighth test uses dim data test with bright training data. Test results from 150 data tested the level of recognition of the system to the test data of 29 images with an accuracy of 19.3%.

The ninth test uses the MSR light test data (σ1 = 2, σ2 = 80 and σ3 = 220) with very dark and dim trained data. Test results from 150 data tested the level of recognition of the system to the test data of 15 images with an accuracy of 10%. The results of the third model scenario test (SSR and MSR) can be seen in the diagram below.

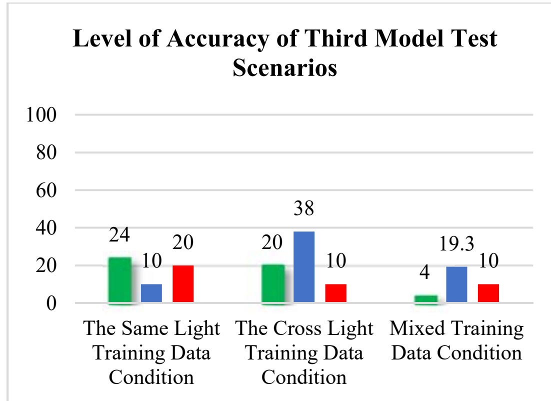

Figure 20: The Third Model Test Result Diagram

In figure 20 show the diagram of the results of the third model scenario test. Testing with the same light practice data conditions has the highest accuracy when using very dark test data with an accuracy of 24%. So, for the data conditions of light training the same very dark image becomes the most effective in the use of MSR method with (σ1 = 2, σ2 = 80 and σ3 = 220).

Testing on the condition of cross-light training data has the highest accuracy of 38% with the test data dimly. So, in cross-light training data conditions, the dim data test is the most effective in using the MSR method with (σ1 = 2, σ2 = 80 and σ3 = 220).

Testing on the condition of light training data mixed with the test data dim has the highest accuracy of 19.3%. So, in the mixed training data conditions, the dim data test is the most effective in using the MSR method with (σ1 = 2, σ2 = 80 and σ3 = 220).

In terms of the value of MSE and PSNR owned by the image in the test model test data can also be seen the difference. The greater the value of MSE obtained then the image quality is worse. Conversely, the smaller the value of MSE the better the image quality. This is inversely proportional to PSNR where the greater the value of PSNR the better the image quality. While the smaller the value of PSNR the worse the image quality.

In very dark images, on average the image that has been through the process of MSR with σ1 = 2, σ2 = 80, σ3 = 220 has the value of MSE = 0.06193037 and the value of PSNR = 60.26539 dB. As for the dimly lit condition image that has gone through the process of MSR with σ1 = 2, σ2 = 80, σ3 = 220 has the value of MSE = 0.06700035 and the value of PSNR = 59.91177 dB. In the test using the

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bright image, on average the image that has been through the process of MSR with σ1 = 2, σ2 = 80, σ3 = 220 has the value of MSE (R = 0.034536, G = 0.034591, B = 0.038087) and the value of PSNR (R = 62.82518 dB, G = 62.81145 dB, B = 62.39233 dB).

4.4 Fourth Model Test Results

Fourth model test scenario there are 3 different test variations as follows:

Table 31: Test Data Specification Fourth Model

Type of Test Data	Amount of Test Data
First Test (Distance 80 cm)	150
Second Test (Distance 120 cm)	150
Third Test (Distance 160 cm)	150
Total Test Data	**450**

The first test uses very dark test data with the distance between the camera and the subject as far as 80 cm. The second test uses very dark test data with distance of 120 cm. The third test uses very dark test data with distance of 160 cm. The training data used in this scenario is mixed training data. The results of the fourth model scenario testing as follows:

Table 32: Test Results Fourth Scenario Model

Type of Test	Recognized Test Data	Accuracy	Average Time (in seconds)
First Test (Very Dark 80 cm)	6	4%	730.78
Second Test (Very Dark 120 cm)	30	20%	735.68
Third Test (Very Dark 160 cm)	37	24.67%	521.23

In table 12 is the result of testing the fourth model scenario (distance of shooting). The first test uses very dark test data of MSR (σ1 = 2, σ2 = 80 and σ3 = 220) with distance of 80 cm. the training data used in this test is the type of mixed training data. It can be seen from 150 data tested the level of recognition of the system to the test data of 96 images with an accuracy of 64%.

In the second test using very dark test data MSR (σ1 = 2, σ2 = 80 and σ3 = 220) with distance of 120 cm and training data mixed. It can be seen from 150 data tested system recognition level to the test data of 30 images with an accuracy of 20%.

In the third test using very dark test data MSR (σ1 = 2, σ2 = 80 and σ3 = 220) with distance of 160 cm and the training data mixed. Can be seen that from 150 data tested the level of recognition of the system against the test data of 37 images with an accuracy of 24.67%. The test results of the fourth model scenario can be seen in the diagram below.

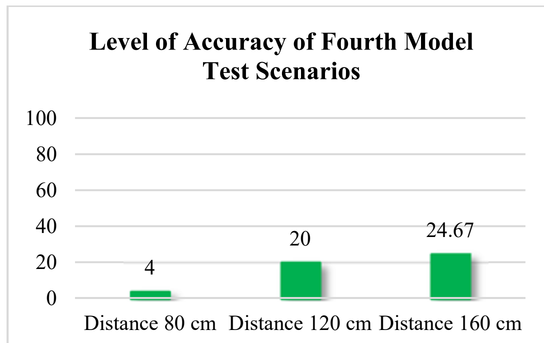

Figure 21: Test Result Fourth Model

In figure 21 the diagram of the fourth model scenario test shows the results of the fourth model scenario test. From the diagram can be seen there is an upward trend of accuracy. In the test data distance of 80 cm accuracy obtained by 4%. Then the accuracy increased to 20% on the 120 cm distance test data. In the 160 cm distance test data, the accuracy obtained is 24.67%. In this fourth model test scenario, the distance of 160 cm becomes the most effective distance when compared to the distance of 80 cm and 120 cm.

In the test data distance of 80 cm, on average the image has been through the process of MSR σ1 = 2, σ2 = 80, σ3 = 220 has the value of MSE = 0.06749937 and the value of PSNR = 59.88449 dB.

In the test data distance of 120 cm, on average already through the process of MSR σ1 = 2, σ2 = 80, σ3 = 220 has the value of MSE = 0.06740446 and the value of PSNR = 59.92222 dB.

In the distance test data 160 cm, which has been through the process of MSR with σ1 = 2, σ2 = 80, σ3 = 220 has the value of MSE = 0.06108475 and the value of PSNR = 60.36243 dB. As can be seen on the MSE and PSNR values above that the MSE value at distance of 160 cm is smaller when compared to 2 other distances of 80 cm and 120 cm.

For the PSNR the distance of 160 cm is greater than the distance of 80 cm and 120 cm. So, the smaller the value of MSE and the greater the value of PSNR on an image then the resulting image quality will be better.

4.5 Fifth Model Test Results

The fifth model test scenario testing 3 types as follows:

Table 33: Test Data Specification Fifth Model

Type of Test Data	Amount of Test Data
First Test (Angle 30°)	120
Second Test (Angle 60°)	120
Total Test Data	**390**

The first test uses very dark test data with the subject face angle of 30°. The second test uses very dark test data with a subject face angle of 60°. The training data used in this fifth model scenario is very dark exercise data plus the 30° and 60° subject face angle poses. The results of the first model scenario testing as follows:

Table 34: Test Result Fifth Scenario Model

Type of Test	Recognized Test Data	Accuracy	Average Time (in seconds)
First Test (Very Dark Angle 30°)	23	15.33%	237.61
Second Test (Very Dark Angle 60°)	13	8.67%	235.46

In table 14 is the result of testing the fifth model scenario (angle of shooting). The first test uses very dark test data of MSR ($\sigma 1 = 2$, $\sigma 2 = 80$ and $\sigma 3 = 220$) with the subject face angle of 30° and the training data used is mixed training data. Accuracy rate obtained by 4%. The second test uses very dark test data of MSR ($\sigma 1 = 2$, $\sigma 2 = 80$ and $\sigma 3 = 220$) with the subject face angle pose of 60°. The training data used is mixed training data. Test results from 150 data tested the level of recognition of the system of test data of 13 images with an accuracy of 8.67%. the results of the fifth model scenario testing can be seen in the diagram below.

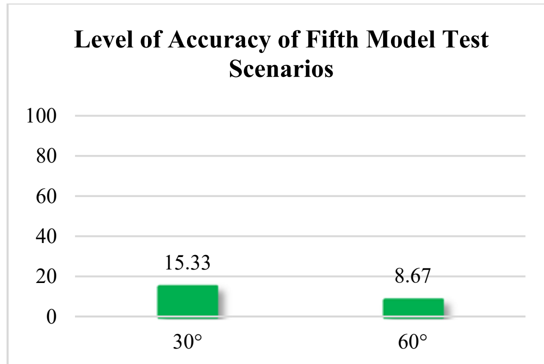

Figure 22: Test Result Fifth Model

In figure 22 show the results of the fifth model scenario test. In this test can be seen face pose testing with a 30° angle has the highest accuracy of 15.33%. For facial pose angle of 60° the obtained accuracy level of 8.67%. In this fifth model test scenario poses an angle of 30° to the most effective angle when compared to a 60° angular pose.

In very dark test data with angle of 30°, on average the image has been through the process of MSR $\sigma 1 = 2$, $\sigma 2 = 80$, $\sigma 3 = 220$ has the value of MSE = 0.06748167 and the value of PSNR = 59.88638 dB. In very dark test data with angle pose 60°, on average the image has been through the process of MSR $\sigma 1 = 2$, $\sigma 2 = 80$, $\sigma 3 = 220$ has the value of MSE = 0.07003048 and the value of PSNR = 59.72208 dB.

It can be seen from the existing MSE and PSNR values that the MSE value in the image with 30° angle poses have smaller MSE value and a larger PSNR value when compared to the angle image of 60°.

5. CONTRIBUTION

This study performs a performance test based on the level of face recognition accuracy that comes from CCTV cameras with infrared mode. If the research [19] uses face data taken from the FERET database, this study uses face data taken directly from CCTV cameras with various lighting conditions in the room, namely very dark, dim and bright. In locations around CCTV camera there are

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many objects that add variety and complexity to the images being tested.

The research [19] used PCA and LDA face recognition combined with the MSR method that had been developed to overcome the shortcomings of PCA and LDA itself. Our research uses a method of face recognition, namely PCA with two retinex methods, namely Single-Scale Retinex (SSR) and Multi-Scale Retinex (MSR). So, using this method can be seen the effectiveness of using PCA on retinex and retinex to improve image quality.

Testing in this study uses a variety of different test models with different room lighting conditions. There are 5 different types of testing models used in this study. By using different testing models, it can be seen the level of performance and effectiveness of the methods used in various test model conditions that have been carried out in this study.

This research was conducted to see the effectiveness of PCA in recognizing the faces of subjects who had gone through the retinex process. In addition, seeing the effectiveness of retinex in improving image quality. With this research it can be seen the results of the research and can be a reference for future research development.

For future research, it is necessary to use PCA face recognition methods that have been developed as well as face recognition methods outside the PCA family combined with other retinex methods. This is done to see the comparison of the results between the methods in this study and other methods. So that conclusions can be drawn about which method has the best effectiveness to be implemented in the face recognition system.

6. CONCLUSION

This research was conducted to determine the effectiveness of the PCA method on retinex (SSR and MSR) and the effectiveness of retinex on improving image quality from infrared cameras. In the study using 5 different testing models. The use of 5 different testing models is needed to be able to see the most effective accuracy results when using PCA and retinex methods (SSR and MSR) to improve the quality of infrared images.

Testing with the same light training data conditions has the most effective conditions when the light is very dark. In cross-light training data conditions, the most effective conditions are in the dim light. While using the condition of training data mixed the most effective conditions are in the dim light.

In tests that compare SSR and MSR methods using very dark conditions with each method using 2 different sigma values. This test has the same level of accuracy.

In tests with distance parameters, the most effective conditions after testing were located at distance of 160 cm. While the test with the most effective angle pose is at an angle of 30°. For system process time, the more amount of training data used then the system will take longer time to perform face recognition process.

In previous studies [19], the use of PCA and LDA was combined with the developed MSR. So that the deficiencies found in PCA and LDA can be reduced and can improve the accuracy of the subject's face recognition.

There are several factors that cause the results of testing in this study to be ineffective when using the PCA and retinex methods. PCA is a method that takes the principal component in an image. This principal component is taken as a characteristic of an image. The infrared image used in this study contained several other objects in the background of the image. So that the system cannot find the principal component of the image that is useful as important information to recognize the face of the subject to be recognized.

Based on the research that has been done, retinex algorithm and PCA is not effective enough in recognizing someone on infrared camera. This is because the retinex image on the infrared camera has a low PSNR value and PCA is difficult to select the important value of the image due to bad PSNR.

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