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Neural Network Algorithm for Biometric Analysis of Human Retina Image

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ABSTRACT

Identity recognition is an important process because many systems require a valid user identity for security and access control. Identity recognition such as passwords, signatures, id cards have some weaknesses that are they can be duplicated, stolen, forgotten, and even lost. Identity recognition using biometric techniques is known to be more reliable. Biometric technique is a recognition and classification technique that uses human behavior and physical atributes. In this research, a non-realtime simulation system is designed to identify a person by biometric of retina image. The system can identify one's identity through pattern of retinal blood vessels. The processes of this system divided into two stages that are training stages and testing stage. The identification process begins with prepocessing retinal photo. Biometric features extracted by using Discrete Orthonormal S Transform (DOST). Biometric classification by using Adaptive Resonance Theory 2 (ART 2) with unsupervised learning process that can recall previously learned patterns . The results obtained from this study showed 65% of accuracy for the right retina image and 50% of accuracy for the left retina image. Computing time is about 6 seconds. Further development is needed to improve the accuracy of the system as a security and access control systems.

Keywords: biometrics, retina image, DOST, and ART 2

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1. INTRODUCTION

Identity recognition is an important process because many systems require a valid user as access control especially for systems that store confidential data or other valuable data. Identification techniques which are still widely used are password, PIN, signature, key, and card. All of them have many weaknesses like being disappeared, being forgotten, and can be duplicated. Therefore a reliable identification techniques is needed to improve security and access control. One of the reliable technique is biometrics-based techniques (J.A. Unar,dkk 2014) .

Biometrics is science and technology of individual identification by using the unique physiological or behavioral characteristics (J.A Unar,dkk,2014). The examples of biometric-based physiological characteristics include iris, ear, fingerprint, hand geometry, knuckle, hand lines, vein, face, voice, retina, smell, and DNA. The examples of biometric-based behaviors are signature, gait, accent and keystokes dynamics. All kinds of biometrics are unique, but the most secure is retina because retinal blood vessels are not easy to imitate and more stable due to its internal location and it is protected from the various layers that are unaffected by the exposure of outside environment . This new personal identification base don retinal image needs to be developed utilizing variety of methods to obtain the best one (Jain, Anil, et al.2002).

The purpose of this research is to implement the Discrete Orthonormal S-Transform (DOST) as feature extraction method and Adaptive Resonance Theory 2 as identification method on a system simulation to recognize individual by his/her retinal blood vessel images. Furthermore, the performance of the system is measured by accuracy parameter such as FAR, FRR and computation time. In this research, the effect of parameters, alpha and rho, are observed by iterating the system using ART 2 methods to find the optimal combination of parameters (Shasikala, K.P. and K.B. Raja. 2012) .

2. METHOD
2.1. Identification Method.
Retina biometrics is individual identification technique by using retinal blood vessel. Biometrics concepts are (Adiguna. 2006.):
1.Universal: everybody has the characteristic.
2.Unique: no one has the same characteristics.
3.Permanent: the characteristic can't be damaged or changed.
4.Collectable: the characteristic can be measured quantitatively.

In 1935, two ophthalmologists, Drs. Carleton Simon and Isodore Goldstein, concluded that each eye has unique patterns. In 1950, Dr Paul Menara said that blood vessel pattern will not be the same even for identical twins. Hence, retina biometric is considered to be the most secure biometric (. Figure 1 showed typical retina image and blood vessel extraction used in this study (Beuter,et al. 2020).

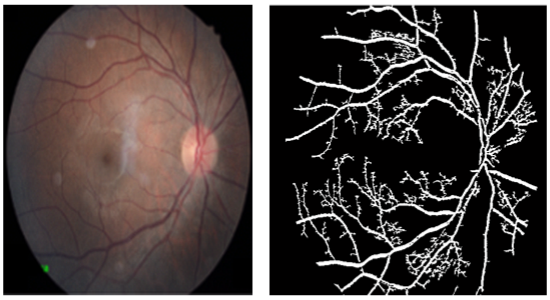

Fig 1. Retina image a) right retina b) retinal blood vessel image

Digital image is presented by light intensity function where x and y value is spatial coordinate and the intensity value at any point is given by red, green and blue values. Digital image is stored in a matrix. Rows and columns represent a point at the image and pixel represents color level (Drabycz, Sylvia, etal..2022).

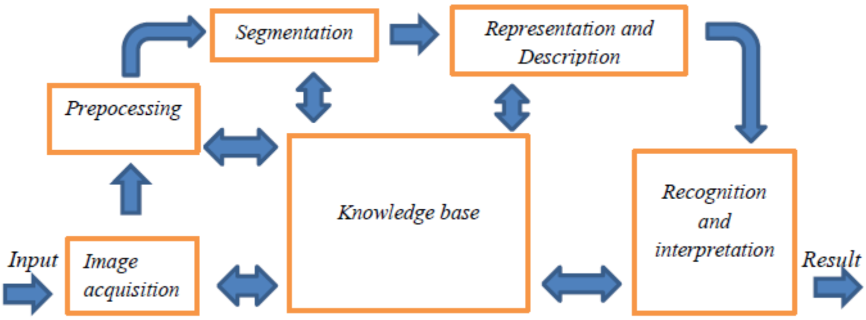

Fig 2. Basic step digital image processing (Shasikala, K.P. and K.B. Raja.)

Basic processing of digital image pattern recognition (Wang, Yu-Hsiang. 2021) include:
1. Image acquisition: a process to get the image.
2. Preprocessing: a process to improve the quality of image according to the needs, eliminate noise, and get the region of interest.
3. Segmentation: a process to take part of image containing the important information only. This is one of the most important proccess because it affects the the system successfulness.
4. Representation and Description : a process to represent and decrypt the characteristics inherent in the objects using feature extraction (M. Oravec, dkk 2014) Discrete Orthonormal S Transform is used in this research.
5. Identification and Interpretation: a proccess to classify the images based on similar characteristics. Similar characteristics is classified into one group. Classification is the final proccess. Adaptive Resonance Theory 2 is used in this research.

Pattern recognition is the process activity of making decisions by information patterns based on similarity of characteristics. There are three methods used in pattern recognition (Munir and Renaldi. 2004.):

1. Statistical Approach, a pattern recognition technique using statistics for its classification algorithm.
2. Syntactic Approach, a pattern recognition technique that refers to structural.
3. Neural Approach, a pattern recognition technique using artificial neural network algorithms in the classification process

2.2 Discrete Orthonormal S Transform (DOST) (Gurney, K. 2007)

DOST is a parameter extraction method by using an orthogonal set. To calculate DOST of 2D image, 2D-FT image is partitioned, multiplied by the square root partition points to reconstruct the spectrum, and restored by inverse FT. The calculation formula is as follows.

$$S[x',y',v_x,v_y] = \frac{1}{\sqrt{2^{p_x+p_y-2}}} \sum_{m=-2^{p_x-2}}^{2^{p_x-2}-1} \sum_{n=-2^{y-2}}^{2^{p_y-2}-1} H[m+v_x, n+v_y] e^{2\pi i(\frac{mx'}{2^{p_x-1}}+\frac{ny'}{2^{p_y-1}})} \quad (1)$$

Where $v_x = -2^{p_x-1} + 2^{p_x-2}$ and $v_y = 2^{p_y-1} + 2^{p_y-2}$ act as horizontal and vertical "voice" frequency.

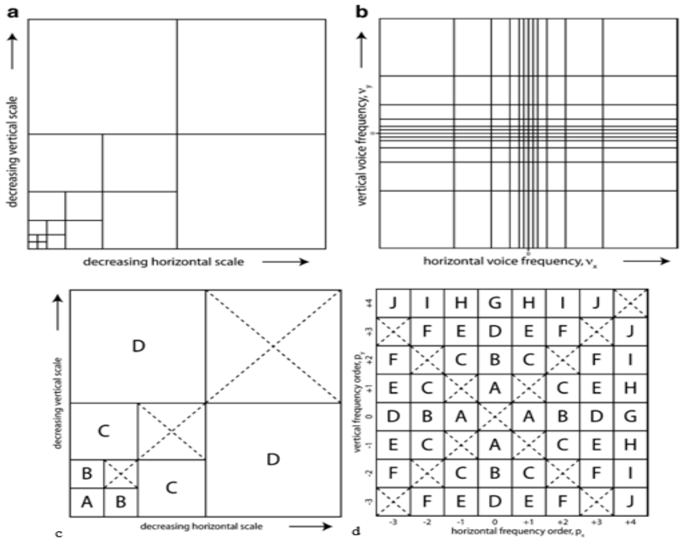

Fig 3. Feature Extraction (a) order 6 DWT partition (b) order 6 DOST partition (c) wavelet decomposition (d) DOST local frequency

To calculate the voice image $S[x,y,v_{0x},v_{0y}]$ which consists of inverse of FFT, spectrum is partitioned and shifted into zero. To reverse the spectral partitions and reconstruct the image spectrum, $2^{p_x-1}x2^{p_y-1}$ of FFT inverse is applied to each voice order.

$$H[m,n] = \sqrt{2^{p_x+p_y-2}} \sum_{m=-2^{p_x-2}}^{2^{p_x-2}-1} \sum_{n=-2^{p_y-2}}^{2^{p_y-2}-1} S[m-v_x, n-v_y] e^{-2\pi i(\frac{mx\prime'}{2^{p_x-1}}+\frac{ny\prime'}{2^{p_y-1}})} \quad (2)$$

Then the image is restored by using FT inverse formula as follows.

$$h[x,y] = \frac{1}{N^2} \sum_{m=-N/2}^{N/2-1} \sum_{n=-N/2}^{N/2-1} H[m,n] e^{2\pi i(mx+ny)/N} \quad (3)$$

DWT and DOST concept are the same but the information given is different. DWT provides horizontal, vertical, and diagonal "detail" coefficient for each order, while DOST provides horizontal and vertical components only. Figure 3 showed the partition used in this study (Hikmah dkk. 2008).

2.3 Adaptive Resonance Theory 2 (ART 2)

A neural network is an information computing system that the output is not programmed but comes from the learning process. The main characteristic of JST is its ability to participate in learning. The learning process aims to improve the network and connection weights. Learning process by neural network is divided into 3 parts:

1. Supervised learning, the network is given a target that must be achieved. ANN is trained to obtain results that are as similar as possible to the target.
2. Unsupervised learning, the network is provided with basic knowledge (network parameters) and then required to organize itself to form similar input vectors.
3. Combination (Hybrid), this type is a combination of supervised learning and unsupervised learning.

ART is one of neural network algorithms with unsupervised learning mode. ART uses competitive mode that can learn new things but still remember what they have learned previously. Two types of ART which are commonly used are ART1 and ART2. The difference between both of them is the input characteristic. ART 1 is a binary input while the second one ia analog input.

ART 2 architecture consist of F1 layer as input layer, F2 layer as output layer, and similarity of the pattern control system. F1 layer consists of six sublayers. The sublayers are w, x, u, v, p, and q. Input vector normalization proccess and suppress irrelevant noise input occur at F1 layer, while competition and 'finding the winner' process occur at F2 layer. Weights of winner will be updated if the resonance has been reached.

F1 activation update process in each sublayer is formulated as follows.

$$w_i = s_i + au_i \quad (4)$$

$$x_i = \frac{w_i}{e + \| w \|} \quad (5)$$

$$v_i = f(x_i) + bf(q_i) \quad (6)$$

$$u_i = \frac{v_i}{e + \| v \|} \quad (7)$$

$$q_i = \frac{p_i}{e + \| p \|} \quad (8)$$

$$p_i == u_i + dt_{ji} \quad (9)$$

$$r_i = \frac{u_i + cp_i}{e + \| u \| + \| cp \|} \quad (10)$$

The reset condition checking is done by the equation as follows.

$$\rho / (e + \| r \|) \quad (11)$$

If the result is greater than 1 then the reset and node do not compete again. Winners weights are updated by using the following equation. Figure 4 showed the ART2 diagram.

$$t_{ji} = \alpha du_i + (1 + \alpha d(d-1))t_{ji} \quad (12)$$

$$b_{ij} = \alpha du_i + (1 + \alpha d(d-1))b_{ij} \quad (13)$$

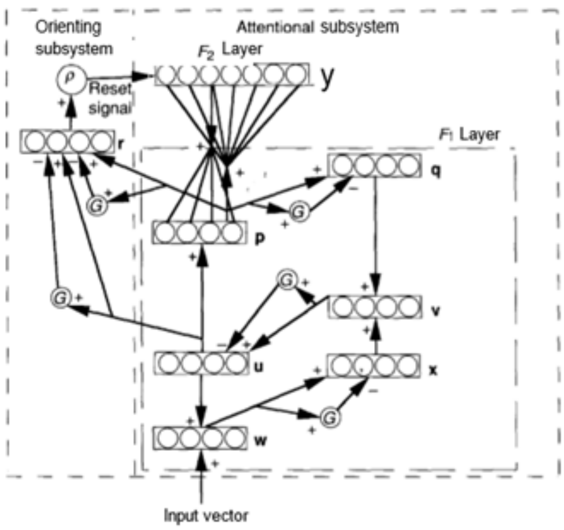

Fig 4. ART 2 Structure [10]

The parameters for ART 2 are a, b, c, d, e, α,θ,ρ,Bu,Td [1].
a, b are fixed weights in layer F1. Setting a= 0 or b = 0 results in instability in the network. Standard value a=b=10.
c is the fixed weight used to test the reset condition. A small value of c provides a wider effective range for the parameter ρ. Standard value c= 0.1.
d is the activation of the winning unit F2. The value d varies between 0 and 1 and satisfies the inequality: $cd1-d\leq1$. Standard value d=0.9.
e is a parameter used to prevent division by zero when the normalization vector is zero.
α Learning rate is a parameter to determine learning speed.
θ is a noise suppression parameter. Its value ranges from $0\leq\theta\leq1\sqrt{m}$
ρ Vigilance parameter is a parameter that determines how many cells will be formed.
m number of F1 layer nodes correspond to many vectors resulting from feature extraction
n Number of output nodes of layer F2
Bu is a weight preventing the possibility of a new winner being selected during resonance as the weight changes. A larger value encourages the network to create more clusters. $bij(0)=1(1-d)\sqrt{m}$
Td is a weight that ensures that no reset will occur for the first pattern placed in the cluster. The value for initialization must be small. $tji(0)=0$.

2.4 System Performance

The system accuracy is calculated using the following equation (McAndrew, Alasdair. 2004).:

1. False Accept Rate or False Match Rate (FAR or FMR), which measures the number of system identifies test data incorrectly. For example, A is recognized as B, B is recognized as A, C which is not in the database but is recognized as A or B. A good system if the FAR value is low.
2. False Rejection Rate or False Non-Match Rate (FRR or FNMR), which measures the number of system fails to identify test data that is actually in the database. For example, A or B is in the database but is not recognized at all. A good system if the FRR is low.

Correct Recognition Ratio or Accuracy (CRR or ACC) is a measure of how capable the system recognizing correctly. For example, A is known as A, B is known as B, C is not known. A good system if the CRR value is high.

Table 1. System Performance Criteria

Performance Parameter	Value	Criteria
FAR	< 0.3 %	Very High
	0.3% - 1%	High
	1% - 5%	Midlle
	>5%	Low
FRR	< 1%	Very High
	1% - 3%	High
	3% - 7%	Midlle
	>7%	Low

3. Main System Diagram

The main system on this research is showed in Figure 5.

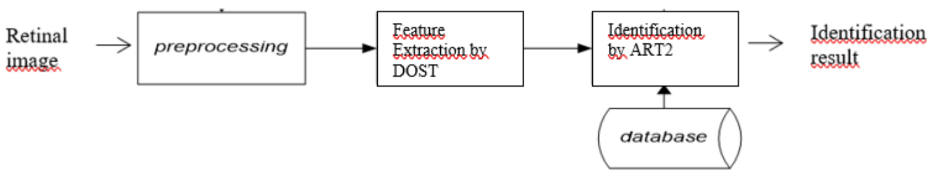

Fig 5. Block Diagram of the Main System

3.1 Preprocessing and Region of Interest Selection

The aim of this process is to get the retinal optic disk. Preprocessing step:

a) Greyscale red layer
   the RGB image is converted into a red layer greyscale image because in this layer the optical disk has the highest color intensity. This step makes the next step easier.
b) Gaussian Filters
   The objective of this process is to remove the image noise so that it does not interfere with the feature extraction process. Noise may occur during the acquisition process. The kernel used is 5x5 because at this size the resulting image is not too blurry. Sigma is worth 0.8. Sigma is a parameter for Gaussian ability to detect edges. The greater the sigma value, the more defined the edge must be to be detected.
c) Sharpening
   Sharpening is to make the image sharper so that the output of blood vessel segmentation are better. alpha parameter equal to 1. Alpha is a parameter to control the laplacian.
d) Optic Disk
   This step is to get the optical disk.
e) Cropping
   The cropping objective is to make the optical disk image size is uniform. The image size is standardized to 128x128. This uniformity very necessary in the feature extraction process.
f) Green *Greyscale* layer
   The image is convert to a green layer greyscale image. In the green layer, the blood vessels look optimal.
g) Bottom-Hat Transformation
   Furthermore, blood vessels can be produced using a morphological transformation process. The transformation used is bottom-hat. This transformation principle removes objects according to the structure elements in the bottom hat that do not correspond to the object to be removed

Preprocessing block diagram and typical retinal vessel segmentation image are shown in Figure 6 and Figure 7.

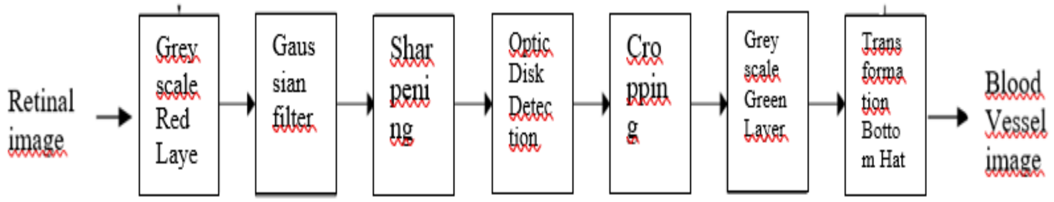

Fig 6. Preprocessing Block Diagram

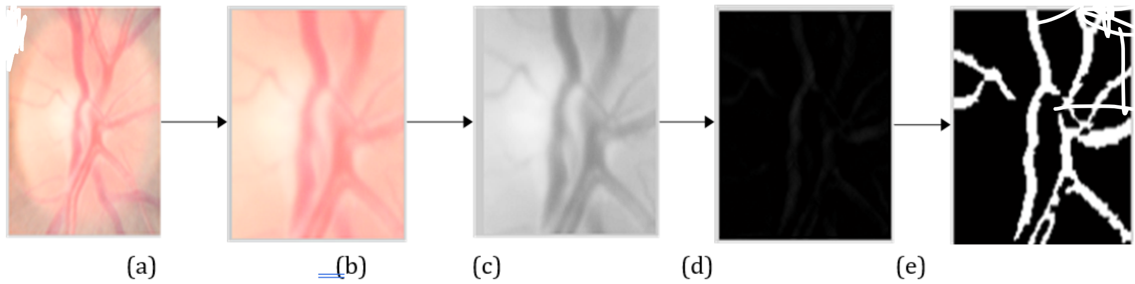

Fig 7. *Region of Interest* (a) OD cropped (b) OD cropped 128x128 pixel (c) red layer image (d) Bottom Hat result image (e) Retinal blood vessel

3. 2 Feature Extraction

DOST works at the frequency domain and in this research DOST was implemented on a two-dimensional image. Extraction product is a complex number and the absolute value was used in this research. DOST invariant wavelet coefficient is calculated by taking the average of the same amount of horizontal and vertical frequency value for each order and not including the "diagonal" DOST element in which px equals py. By combining the horizontal and vertical frequency information, invariant domain of whole picture can be obtained. The 1x10 matrix is resulted from 4th order feature extraction process.

3.3 Identification

There are two layers in ART 2 method (See Figure 4). The normalization proccess and suppressing irrelevant noise input occurs at F1 layer. The proccess at F1 layer stops if sublayer value doesn't change. The number of input nodes in F1 layer depends on the number of extraction process results vector. In this research, the number of input nodes is 10.

Proccess at F2 layer determines the winner and updates the weights of winner. The number of output nodes depends on the results reset. If there is reset in every node, it will form a new node to a new weight. At F2 layer, the well known winner node and the node will update the weights.

In this research, the fixed parameter is set as follows: a=b=10, c=0.1, d=0.9, e=0.00001 while rho, alpha and number of iteration was kept as variables. Rho value ranges from 0 to 10. Rho parameter affects the successfulness of identification because it will influence the number of output nodes. Alpha parameter determined of learning speed. Alpha value ranges from 0 to 1. The number of iteration changes the weight of the winner when it reaches stability.

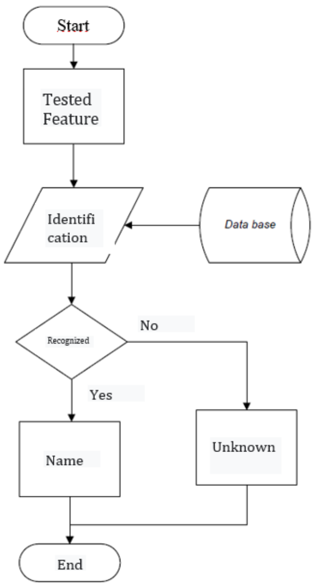

Fig 8. Identification flowchart

3.4 Test Scenario

There are several scenarios which are implemented in 128x128 pixel with 4th order of DOST. The scenarios are as follows.

1. The Rho effect test is applied on slow learning (Alpha=0.1) and fast learning (Alpha=0.9).
2. The Alpha effect test is applied with 0.997, 0.998, or 0.999 of rho value.
3. The iteration effect test is applied with 0.997 of rho value and 0.1 of alpha value.
4. The combining parameter test is a test to know the combination effect to the system performance. The number of iteration is 10.

4. RESULTS AND DISCUSSION

4.1. Rho Analysis

Table 2 showed the test of rho variable. The result showed that the higher the rho value, the more clusters are formed. The network is more sensitive to recognize patterns. High rho value actívates the new cluster even if there is a very small difference of input vector because the network recognizes it as a new pattern. Conversely, small rho value limit the cluster number although the difference of input vector is very large because the pattern is classified in the same cluster.

Table 2. The test results of rho parameter against the accuracy

Rho	Right Retina							
	256 * 256 Pixels				128*128 Pixels			
	Slow Learning		Fast Learning		Slow Learning		Fast Learning	
	AC	Cl	AC	Cl	AC	Cl	AC	Cl
0.9	40	2	60	4	40	2	60	3
0.93	50	3	70	5	30	2	60	4
0.96	60	3	70	6	40	2	60	4
0.99	70	5	80	7	60	5	80	6
0.993	70	6	80	8	60	5	80	6
0.996	80	7	100	9	80	6	90	8
0.997	80	7	100	9	80	6	100	9
0.998	80	7	100	9	80	7	100	9
0.999	80	8	100	9	100	7	100	9
0.9993	80	8	100	9	90	7	100	9
0.9996	100	9	100	9	90	8	100	9
0.9999	100	9	100	9	100	9	100	9

*AC = Accuracy (%) *Cl = Number of cluster

It can be concluded that plastic condition is formed faster when the network is set at fast learning mode and rho value is high. Plastic condition occurs when too many clusters are formed. This is due to the fast learning mode makes greater weight value so that the value of u and p sublayer increases and the length of the vector r decreases. This condition speeds up the reset condition because the condition of rho / (e + ‖r ‖) > 1 are formed and the number of clusters are increased. The plastic condition reduces the ART 2 behavior to remember the previous pattern.

In this test the optimal accuracy was obtained when rho value are 0.997, 0.999, 0.9996 with the slow learning mode.

4.2. Alpha Analysis

Tabel 3 showed the test on alpha variable. Form the result, it can be concluded that alpha paramater influences network performance to classify. The larger alpha value, the more cluster are formed. The reason has been explained previously. From the table, the relation between alpha and rho parameter are obtained. The greater rho value, the lower alpha parameter to reach the plastic condition. It is due to alpha and rho has an inverse relationship according to reset equation. The cluster is formed when reset is reached. This test can be seen that rho parameter provides more dominant influence to improve the network sensitivity than alpa. From the test, it also proves that the system would be optimal when slow-learning method applied because when the alpha value is low, the accuracy obtained is increasing and plastic condition is longer. Moreover, the slow learning method can maintain the ART2 behavior which can remember the previous pattern.The optimal accuracy was obtained when alpha value is 0.05 or 0.1

Table 3. The test results of alpha parameter against the accuracy

Alpha	Right Retina											
	256*256 pixels						128*128 pixels					
	0.997		0.999		0.9996		0.997		0.999		0.9996	
	AC	Cl	AC	Cl	AC	Cl	AC	Cl	AC	Cl	AC	Cl
0.01	40	3	50	4	80	5	40	2	40	3	60	3
0.03	100	5	70	6	80	7	60	3	60	5	80	7
0.05	70	5	80	7	80	8	60	5	80	6	100	7
0.07	70	6	80	7	100	9	60	5	80	7	80	7
0.09	80	7	80	8	100	9	80	6	10 0	7	90	8

0.1	80	7	80	8	100	9	80	6	100	7	90	8
0.2	80	7	100	9	100	9	80	7	90	8	90	8
0.3	80	8	100	9	100	9	100	7	100	9	100	9
0.4	90	9	100	9	100	9	80	7	100	9	100	9
0.5	100	9	100	9	100	9	90	7	100	9	100	9
0.6	100	9	100	9	100	9	90	7	100	9	100	9
0.7	100	9	100	9	100	9	100	9	100	9	100	9
0.8	100	9	100	9	100	9	100	9	100	9	100	9
0.9	100	9	100	9	100	9	100	9	100	9	100	9

*AC = Accuracy (%) *Cl = Number of cluster

4.3. Iteration Analysis

Table 4 showed the test on number iteration. If more iterations are done then the weight will increase and the network sensitivity will be improved. In this test, the parameter was set 0.999 for rho parameter and 0.1 for alpha parameter. The best iteration parameter is 8. In this condition, ART 2 behavior can be maintained.

Table 4. Iteration Test

Iteration	**Right Retina**	
	AC	**CI**
1	50	3
2	60	4
3	60	5
4	80	6
5	80	6
6	80	7
7	80	7
8	100	7
9	100	7
10	100	7

*AC = Accuracy (%) *Cl = Number of cluster

4.4. Combination of Parameter Analysis

Table 5 showed the combination of rho and alpha parameters.

Table 5. The test result of the combination of parameter against the system accuracy

Right Retina			
Combinasi		**256*256 pixel**	**128*128 pixel**
Rho	**Alpha**	**Accuracy**	**Accuracy**
0.997	**0.09**	50%	12.5%
0.999	**0.05**	50%	25%
0.999	**0.1**	50%	12.5%
0.9996	**0.05**	12.5%	12.5%

The successfulness of the system is affected by a combination of the right parameters because each parameter influences the network sensitivity. The best combination is obtained when rho value is 0,999 and *alpha* value is 0.05. With this combination, the network is more sensitive but still retain the ability to remember the previous pattern.

4.5. System Performance Analisis

Table 6 showed the confussion matrix of testing the system using 10 right retina images. System performance is shown in Table 7.

Table 6. Confussion Matrix

	Right Retina		
	P	**N**	**Total**
True	4	0	4
False	1	3	4
Total	5	3	8

*P = positive N = negative

Table 7. System Performance

Performance Parameter	**Right Retina**
FAR = $\frac{False\ Positive}{Whole\ testing\ image}$	**12.5%**
FRR = $\frac{False\ Negative}{Whole\ testing\ image}$	**37.5%**
AC=$\frac{True\ Positive\ +True\ Negative}{Whole\ testing\ image}$	**50%**

Based on the results of the entire test, the identity recognition system based on the retina image works optimally at order 4 DOST with 256x256 pixel of image dimensión. The best accuracy is obtained when rho parameter is 0.999, alpha parameter is 0.05 (slow learning) and iteration number is 8 times. The system accuracies are 50% for right retina with the FAR and FRR values are 12.5% and 37.5 %.

From the whole result, it can be concluded that the system security is still low. The system is said to be secure if the FAR is below 1%. Systems with 12,5% of FAR value means that the system has not been able to identify accurately. From 10 inputs, there are 2 false identification.

The system has a FRR value more than 7% means that the access control of the system is still low. If the value of FRR is high, there's a big chance that the system can not identify or reject someone's identity existing in the database of the system. In this system, the FRR value is above 37.5 %. It means there are 4 unidentified inputs from 10 inputs.

Computation time to identify one image is about 4 seconds and mainly used for preprocessing and segmentation. The details can be seen at the Table 8.

Table 8. System computation time

No	**Proccess**	**Computation Time (s)**
1	***Preprocessing & Segmentatio***	3.841240
2	***Feature Extraction***	0.396859
3	***Identification***	0.02394
	Total	**4.262039**

5. CONCLUSION

From the test analysis of identity recognition system based on retina biometric using DOST and ART 2, the conclusions of this research are:

1. Rho parameter test is done by increasing the rho parameter gradually. Rho parameter values are 0.9, 0.95, 0.99, 0.995, 0.997, 0.9998, and 0.999 with 10 images as input. From the test, it was obtained that the higher rho value, the more clusters are formed. The number of lowest cluster is two and the number of higher cluster is nine. Plastic condition is formed faster when the network is set to fast learning mode.

2. Alpha parameter test was tested by increasing the alpha parameter gradually. Alpha values are 0.01 to 0.99 with 10 images as input. The test was obtained that the larger alpha value, the more cluster are formed. The number of lowest cluster is three and the number of higher cluster is nine. Plastic condition is formed faster when the rho value is 0.9996.
3. Iteration parameter was tested by increasing the iteration number gradually from one to ten with 10 images as input. The test was obtained that the larger iteration, the more cluster are formed The number of lowest cluster is three and the number of higher cluster is seven.
4. The system accuracies are 50 % for right. Identity recognition system works optimally by using order 4 DOST with 256x2568 pixel of image dimension with 0.999 of rho value and using slow learning method with 0.05 of alpha parameter 8 times of iteration.
5. FAR values are 12.5 % and FRR values are 37.5% for right retina. From this result, it can be concluded that the system performance as access control or security system is still low.
6. Computation time to identify an image is 4.262039 second.

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