Ocular Biometric System Focused on Iris Localization and Embedded Matching Algorithm

Eri Prasetyo Wibowo, Karmila Sari, Wisnu Sukma Maulana and Sarifudin Madenda

Abstract—**This research aims to develop previous researches which published in the ICSPS 2009 , that were successful to perform iris localization. The indicator values perform well for doing iris localization in comparison with two previous works of Daugman's and Wildes' work. Even succeeded in iris localization, previous researches still has some weaknesses. The worst weakness about to the matching between two iris, even when applied with Hamming and Euclidean distance to perform the code matching of iris.the average similarity for matching two iris image taken from same iris is just 30 to 45 percents. Hereby, research to propose a research in ocular biometric system to identify someone by using iris part. This research is still focused on how to perform iris recognition by doing the normalization and feature extraction to get better iris localization. After iris localization step is performed, then it is continued by extracting the iris feature to get the iris code. The last step is to perform iris code matching embedded with shift bit algorithm in hamming distance to get the better result.**

Index Terms—**Algorithm, bit shift, code, iris, matching.**

I. INTRODUCTION

Human is different each other. Even they are twins, they are stillnot identical in deep. In general way, we differ ourself with a name. Each time human was born into the world, we give a name to recognize him or her among others. Therefore, we called "a name" as an human identity. Besides that, we could identify someone from his or her characteristic. Normally, we identify by looking his or her skin color, face shape, height, body, etc. Those characteristic are included to be as visible characteristic. More on, visible characteristic means that the identification is simple to do it. Invisible characteristic is harder to do the identification. Even hard to do, invisible characteristic is more accurate and unique. In invisible characteristic, using DNA, finger, face, and any of human part that could be used as an identity. So, every human has their own information that differs to others. In study research, this knowledge called by Biometric System.

Biometric system provides automatic identification of an individual based on an unique feature or characteristic possessed by the individual[13]. One of the biometric system identification is by using the human eye[1]. Ocular biometric system process the characteristic of eye. In our eye, the main unique feature is iris part[2]. In iris, it consists of distinct characteristics such as freckles, coronas, stripes, furrows, crypts, and so on. From outside visualized iris template, there is collarette and vessel that creates unique pattern. This unique pattern is used to identify person. Knowing that, the main idea of eye biometric system is by getting the iris pattern. This iris pattern is extracted to be a iris code as an identity. In real research, we have to recognize the iris with automatic way. To recognize the iris, we localize the iris from other part of eye.

In 1993, Daugman had presented a method for eye biometric system[6]. He proposed an integral differential operator to localize the iris and extract into 256 byte length of iris code with using 2D Gabor Wavelet filter to find Hamming distance in iris similarity matching. But, it has some weaknesses. The main of the weakness in the method is in the calculation of blurring factor that is too sensitive toward the light reflection and contrast. And, the calculation of the circle equation to get the iris area is dependent to the radius and middle point parameter.

Continued in 2007, Daugman had made new method with active contour approach in segmenting the area of iris, and fourier method to process the image with any direction of eyes to the camera[10]. Differ than Daugman, Wildes presented a Hough transform method[19]. This Hough transform converts the eye image into a binary edge-map via gradient-based edge detection, then voted to get the parameters of iris boundaries. Wildes' method is very computationally demanding because it introduces lots of edge points of other objects, such as eyelashes and eyelids, in Hough transform.

Another focus of ocular biometric system is iris code matching. Extracting the iris into code is influenced by the condition of original image as an input in biometric system. Different image input that is taken with different angle, position, or session from the same iris might result different iris code. It has been proven in my previous research. So that, the similarity result is still low in matching the iris code taken from same iris. One of the solution is by doing iris normalization. Masek, in his thesis, proposed a shift bit algorithm in Hamming distance algorithm to normalize the iris code[13]. The result showed well in increasing the iris similarity matching.

II. RELATED WORK

The main idea in ocular biometric system for recognizing is how to get the part of iris separated from others like pupil, sclera, and etc. This idea has been interesting many researchers to solve it. Since the input is two dimensional image, researchers tried and proposed their work in getting just the iris area. When, there are two work that has been performed to do that. First of all, it is an Integro-differential

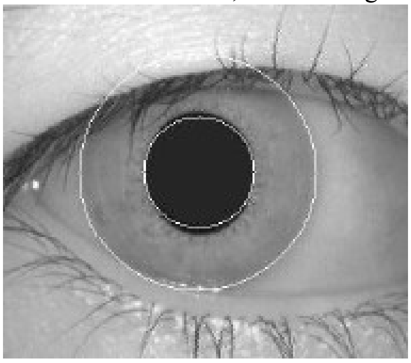


Fig 1. : Daughman's Iris Localization

method by Daugman presented in 1993[6] and continued in 2007[10]. The second is Hough transform by Wildes et al[19].

Considering the input is taken by a camera, it indirectly will affect the quality of that input-self. Beside of the camera, the environment condition gives the influence to the quality. For example, if the condition is to shiny, the input image will have high intensity of its pixel that original supposed to be. Because of that reason, many researches of eye biometric system suggest to normalize the input image before matching template code of iris-eye. The aim of normalization process is to reduce the noise on input image. One of the normalization method is by embedding the normalization algorithm in matching step. This idea has been proposed by Masek in his submitted thesis\cite{9}. Masek's idea is by shifting the iris code bits in several looping until get the closer hamming distance.

A. Integro-differential Daugman's

Daugman's method is based on applying an integro-differential operator to find the iris and pupil contour. The method actually uses 2D Gabor Wavelet to the iris localization. Daugman makes the use of an integro-differential operator for locating the circular iris and pupil regions, and also the arcs of the upper and lower eyelids[6]. The integro-differential operator is defined as:

$$max(r,x_o,y_o \quad \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x_o,y_o} \frac{I(x,y)}{2\pi r} ds \right|$$

where $I(x,y)$ is the eye image, r is the radius to search for,

$G_\sigma(r)$ is a Gaussian smoothing function, and s is the contour of the circle given by r , x_0 , y_0 . The operator searches for the circular path where there is maximum change in pixel values, by varying the radius and center x and y position of the circular contour. The operator is applied iteratively with the amount of smoothing progressively reduced in order to attain precise localization. Eyelids are localized in a similar manner , with the path of contour integration changed from circular to an arc. The iris localization result by Integro-differential Daugman's work is shown in figure 1.

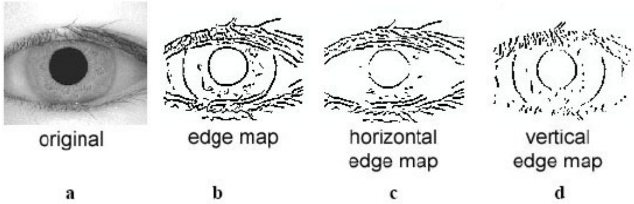


Fig. 2 : Wildes' Iris Localization

The method had been tested with many samples of eye images. And,this method had been patented in US for iris recognition algorithm. Surely, it seems a perfect method.However, the algorithm can fail where there is noise in the eye image, such as from reflections, since it works only on a local scale. Since, the blur factor measurement was sensitive to the reflection and contrast light from environment. The circle equation calculation in the method was suspended to the middle point parameter of iris and pupil radius.

B. Hough Transform-Wildes'

Wildes used Hough transform in iris recognition [19]. The Hough Transform (TH) is a standard method for detection of "shapes" such as circles in scanned images, which are easily parameterized from known formula. First step in his algorithm, Wildes does the edge detection. This edge detection is to initialize the boundary and edge of the part on the eye image as an input.

In performing the preceding edge detection step, Wildes et al. bias the derivatives in the horizontal direction for detecting the eyelids, and in the vertical direction for detecting the outer circular boundary of the iris, this is illustrated in figure 2. The motivation for this is that the eyelids are usually horizontally aligned, and also the eyelid edge map will corrupt the circular iris boundary edge map if using all gradient data. Taking only the vertical gradients for locating the iris boundary will reduce influence of the eyelids when performing circular Hough transform, and not all of the edge pixels defining the circle are required for successful localization. Not only does this make circle localization more accurate, it also makes it more efficient, since there are less edge points to cast votes in the Hough space.

From the edge map, votes are cast in Hough space for the parameters of circles passing through each edge point. The Hough transform consists of defining a mapping among the image space (x,y) and the space of parameters (c,d,r).

$$(x-c)^2 + (y-d)^2 = r^2$$

where c and d is the center of the circle and r is the radius which are able to define any circle according to the equation

To achieve this, the space parameter is discrete and acts in the form of a matrix of integers or cells, where each position of the matrix corresponds to an interval in the real space of the parameters. All circles are sought (c,d,r) which go by thefixed point (x,y). In that equation, we can see a cone in the space (c,d,r) which is fastened by the parameters (x,y).The result is shown in figure 3.

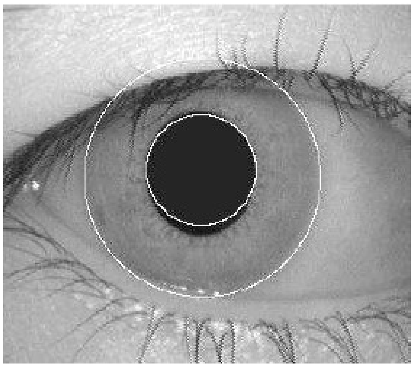


Fig.3 : Wildes' Iris Localization

Wildes' method seems better accurate. But, some researchers showed that the method should be improved. Because, the determination of threshold value differently could get the different result in final decision of iris recognition. This threshold influenced the edge detection in the iris and pupil circle localization.

C. *BitShift-Masek's*

In Masek's thesis13, the Hamming distance algorithm employed also incorporates noise masking, so that only significant bits are used in calculating the Hamming distance between two iris templates. When taking the Hamming distance, only those bits in the iris pattern that correspond to '0' bits in noise masks of both iris patterns will be used in the calculation. The Hamming distance will be calculated using only the bits generated from the true iris region, and this modified Hamming distance formula is given as:

$$HD = \frac{1}{N - \sum_{k=1}^{N} Xn_k (OR) Yn_k} \sum_{j=1}^{N} X_j (XOR) Y_j (AND)$$

$$Xn' j(AND)Ynj$$

Where Xj and Yj are the two bit-wise templates to compare,

Xn_j and Yn_j are the corresponding noise masks for Xj and

Yj, and N is the number of bits represented by each template.

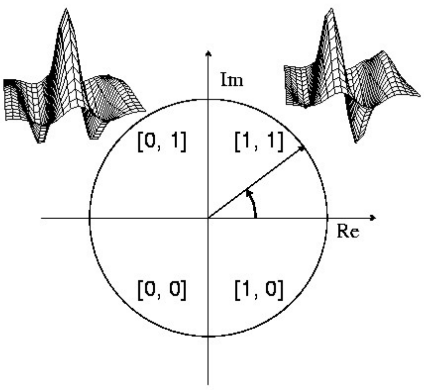


Fig. 4 : Phase Quadrant Iris Template

Fig. 5 : Phase Quadrant Iris Template

In order to account for rotational inconsistencies, when the Hamming distance of two templates is calculated, one template is shifted left and right bit-wise and a number of Hamming distance values are calculated from successive shifts. This bit-wise shifting in the horizontal direction corresponds to rotation of the original iris region by an angle given by the angular resolution used. If an angular resolution of 180 is used, each shift will correspond to a rotation of 2 degrees in the iris region. This method is suggested by Daugman[16], and corrects for misalignments in the normalized iris pattern caused by rotational differences during imaging. The calculated Hamming distance values, only the lowest is taken, since this corresponds to the best match between two templates. It was illustrated in figure 5.

III. Design Analysis

The system proposed was ocular biometric system as identifying someone with iris part. The design was explained with correlated algorithm or some mathematical function that represents on how to develop The proposed system divided into three main parts. Though, the major focus was iris localization and iris matching as seen in figure 6.

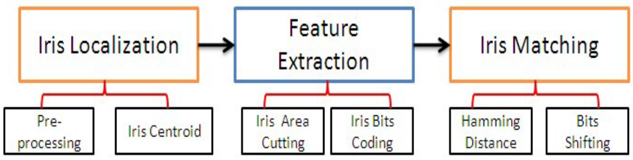


Fig. 6 : Ocular Recognition System Flow

Considering to the theory framework, ocular biometric system involves a 2-Dimensional image as an input into the system. The paper didn't concern deeply to the input process. Here, the input was already available to be proceed.

A. *Image Acquisition*

Image acquisition is considered the most critical step in the research, since all subsequent stages depend highly on the image quality. To get the good quality, it depends on some parameter such as:

- Lighting includes both artificial light sources such as lamps and natural illumination of interiors from daylight.
- Focal Length is a measure of how strongly it converges (focuses) or diverges (diffuses) light.
- Aperture is the opening that determines the cone angle of a bundle of rays that come to a focus in the image plane.

- Depth of Field is the portion of a scene that appears sharp in the image
- Pixel of Resolution

After that, the captured image is better to be converted into gray scale image. Images of this sort are composed exclusively of shades of neutral gray, varying from black at the weakest intensity to white at the strongest.

B. Iris Localization

Iris Localization is divided by two main steps. First of all, it is a "Pre-processing" . Pre-processing is to recognize the pupil boundary from others. The result will generate some white points that represents for the edges of any part. The second step is "Iris Centroid" . This second step is aimed to find the real iris centroid point on the image. The real centroid point of iris is functioned to initiate the distance for a height and width of iris area cutting.

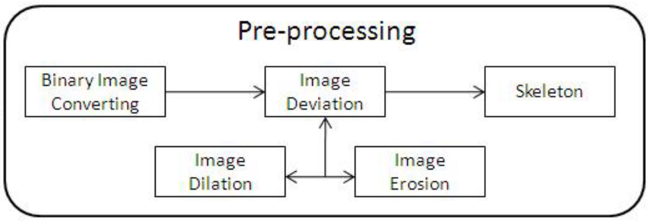


Fig. 7: Eye Recognition System Flow

1) *Pre-processing :* As seen in figure 7, Pre-processing step consists of some steps. First, it is a step to convert the original image input to be a binary image. Second, it is a deviation step processed by two extended steps which are the dilation and erosion step. The last step is a skeleton step. The detail of those steps will be explained more in each section part as following below.

- Binary process is the first step in separating the iris and pupil. The idea is to take the pupil as the main point. Since pupil area is dark dot in eye, it is simple to get this area as parameter. So, we assume that pupil area is dark and the others are bright with **thresholding**. Thresholding changes pixel value to 1 if it's greater than threshold value and 0 in opposite condition. The equation of thresholding is as following:

$$f(i,j)=\begin{cases}0 & if\ I(i,j)>T\\ 1 & if\ I(i,j)\le T\end{cases}$$

$f(i,j)$ is the threshold result from condition wether is greater than or less equal then of the threshold value which is *T*.

- Dilation After The binary result was obtained ,next step to reduce the bad effect from threshold value that sometimes narrow the pupil boundary area with **dilation** [7]. Dilation is one of the basic operations in mathematical morphology. Originally developed for binary images, it has been expanded first to grayscale image, and then to complete lattices. The dilation of A by the structuring element **B** is defined by:

$$A\oplus B=\bigcup_{b\in B}A_b.$$

The dilation is commutative, also given by:

$$A\oplus B=B\oplus A=\bigcup_{a\in A}B_a.$$

If B has a center on the origin, then the dilation of A by B can be understood as the locus of the points covered by B when the center of B moves inside A. The dilation of a square of side 10, centered at the origin, by a disk of radius 2, also centered at the origin, is a square of side 12, with rounded corners, centered at the origin. The radius of the rounded corners is 2. The dilation can also be obtained by:

$$A\oplus B=\{z\in E\,|\,(B^s)_z\cap A\neq\varnothing\},$$

where B^s denotes the symmetric of B, and z is the enlargement.

- Erosion

The dilation result is not enough. so need to concern another condition that the threshold value doesn't narrow the area, but widen it. So, The pixel should be widen by **erosion technic**. Erosion is one of two fundamental operations (the other being dilation) in morphological image processing from which all other morphological operations are based [7]. The erosion of the binary image **A** by the structuring element **B** is defined by:

$$A\,!\;\;B=\{z\in E\,|\,B_z\subseteq A\},$$

where B_z is the translation of B by the vector z, i.e.,

$$B_z=\{b+z\,|\,b\in B\},\forall z\in E.$$

When the structuring element B has a center (e.g., B is a disk or a square), and this center is located on the origin of E, then the erosion of A by B can be understood as the locus of points reached by the center of B when B moves inside A. For example, the erosion of a square of side 10, centered at the origin, by a disc of radius 2, also centered at the origin, is a square of side 6 centered at the origin.

The erosion of A by B is also given by the expression:

$$A\,!\;\;B=\bigcap_{b\in B}A_{-b}.$$

- Deviation

The value between dilation and erosion was calculated to get the deviation of them. It is important to do, since we want to reduce error of pupil boundary area localization. The basic idea in binary morphology is to probe an image with a simple, pre-defined shape, drawing conclusions on how this shape fits or misses the shapes in the image. This simple "probe" is called structuring element, and is itself a binary image (i.e., a subset of the space or grid) [7]. The equation is defined by:

$$C=\{A\oplus B\}-\{A\,!\;\;B\},$$

where $A\oplus B=\{z\in E\,|\,(B^s)_z\cap A\neq\varnothing\}$ is dilation result, and $A\,!\;\;B=\{z\in E\,|\,B_z\subseteq A\}$, is erosion result.

- Skeleton

  The next step is to perform **the skeleton algorithm**. The skeleton algorithm is used to rarefy the edge boundary result from the deviation step. Because, the deviation results a edge boundary that has thickness greater than one pixel. So, It must be made become fit[7]. The advantage of doing this is that it don't get data redundancy since each pixel has data information. The equation is represented by:

  $$ \$\, S(A) = \bigcup_{i=0}^{i} S_i(A) \,\$ $$

  where $S_i(A) = (A\,!\;\;iB) - (A\,!\;\;iB)^{\circ} B$ is elemen structure of its.
- Iris Centroid

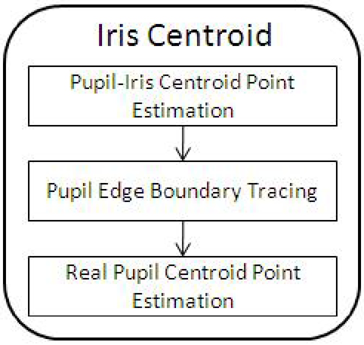


Fig. 8 : Iris Centroid Flow Step

As seen in figure 8, Iris Centroid consists of three steps. First step is "Pupil-Iris Centroid Point Estimation". Second step is "Pupil Edge Boundary Tracing". The last is "Real Pupil Centroid Point Estimation". Those three steps will be explained more in each section as following below.

- Pupil-Iris Centroid Point Estimation

  This step is to estimate the initial centroid point of the pupil-iris. Related to the theory, pupil part is inside of the iris part. And, both of the part has a same centroid point. To estimate the point, i'm using simple idea to do it.

  First of all, Two lines set up into the image. To set up first line vertically, the length of original image width is divided by two. So, Two parts separated by a resulted point in the middle between them. Performing the same way for the both of width sides. Then, A line was made vertically from two middle points of the both width sides. As same logic way, the second line horizontally was made. The result is easier to understand by looking in figure 9.

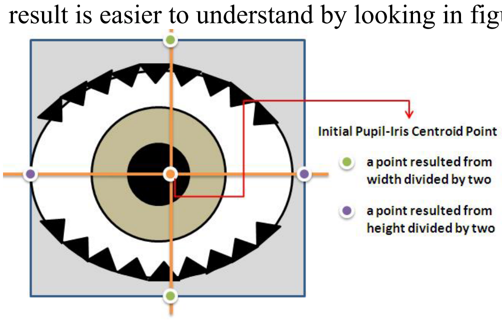


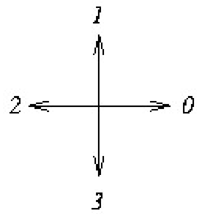
Fig. 9. Initial Pupil-Iris Centroid Point

- Pupil Edge Boundary Tracing

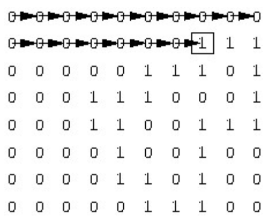
This step is to trace the pupil edge boundary. The tracing itself is to separate the pupil edge boundary from other things that sometimes has same pixel like pupil area. In the beginning, we have assume that pupil is a dark area meaning that every dark area on image can be pupil area. What if the condition like eyelashes
or other things can be said that it is also a dark area. So, to trace the edge we use **Freeman Chain Code** [7]. The Freeman chain code is a sequence of directions of the steps taken when following the boundary of a region. Let us define the anti-clockwise Freeman code as in figure 10.

The inner boundary tracing algorithm can be used to follow the boundary in the image. The algorithm is defined as:

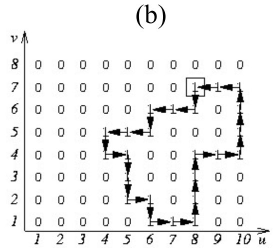
1) Search the image from top left until a pixel P_0 belonging to the region is found. For 4-connectivity assign $d = 3$, which stores the the direction of the previous move.
2) Search the neighborhood of the current pixel for another pixel P_i of the boundary in an anti-clockwise direction beginning from $(d+3) mod 4$. Update the value of d
3) If the current boundary element is equal to P_1 and the previous P_0, then stop. Otherwise, goto step 2.
4) The detected inner border is represented by pixels $P_0 \ldots P_{n-2}$.



(a)



(b)



(c)

Fig. 10 : Freeman Algorithm. (a) step1 (b) step 2 (c) step 3-4

The result is easier to understand by looking in figure 11 that describing about pupil edge tracing.

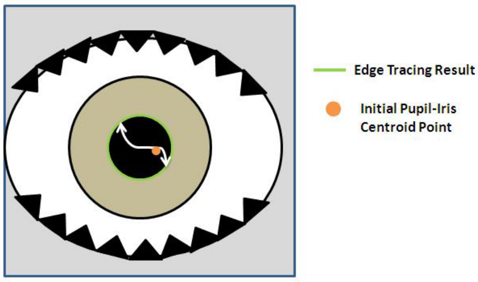


Fig. 11 : Pupil Edge Boundary Tracing

- Real Pupil Centroid Point Estimation
  This step is trying to find the pupil middle point. The reason is to determine the pupil area, so we can get the pupil circle area correctly. Then, it can be used in processing the iris feature extraction and encoding. To do that, we assume that the pupil area is a geometry plane. Since it's an image, the geometry plane is defined into 2D coordinates. One way to do is with **Centroid** method. Calculating the centroid involves only the geometrical shape of the area. Integration formulas for calculating the Centroid are:

$$C_x = \frac{\int xdA}{A} \qquad C_y = \frac{\int ydA}{A} \qquad A = f(x)dx$$

  where the distance from the $y-axis$ to the centroid is C_x , the distance from the $x-axis$ to the centroid is C_y, and the coordinates of the centroid are (C_x, C_y).The result is easier to understand by looking in figure 12 that describing about real centroid point.

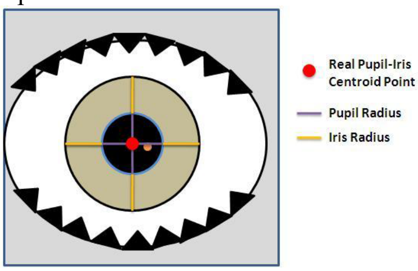


Fig. 12 : Real Centroid Point

C. Feature Extraction

This part will explain about to extract the feature image and encode it. As assumed before, extracting feature from the image is not simple one. Differ with Daugman's and Wildes' feature extraction, the area extracted with two step. First, performing the pupil and iris area cutting. Next step is to encode it with Canny Operator Detection.

1. Iris Area Cutting :The aim of this step is to pick some area of iris and pupil that really represent their feature. So, all area of iris and pupil were not need when iris area image may be closed by eyelashes or eyelids in real. Depends on the condition, the iris area was picked by cutting it. The cutting area can be defined by mathematics equation as following:

$$A = H \times W$$

where $H = \{2 \times H_m\}$ is the height of cutting area, and $W = \{2 \times W_m\}$ is the width of cutting area. H_m is the pupil radius minimum area. $W_m is the iris radius minimum area. Both of H_m and W_m must be multiplied by 2 since they are radius. Those are pixel value. The result is easier to understand by looking in figure 13 that describing about iris area cutting. In that figure, H is denoted by N. And, W is denoted by M.

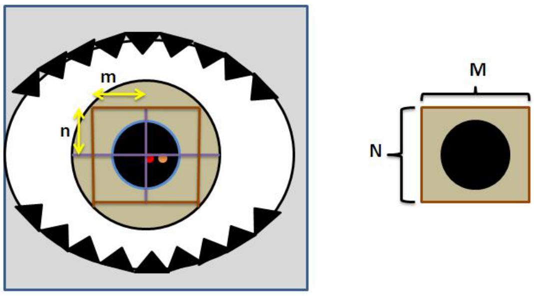


Fig. 13 : Iris Area Ccutting

2. Iris Bits Coding : In encoding, the first is edge detection. Edge detection can make the iris circle parameter calculation easier. One of the edge detection algorithm is **Canny edge detector**. The approach was based strongly on convolution of the image function with Gaussian operators and their derivatives, so we shall consider these initially. Considering the Gaussian function in one dimension, this may be expressed

$$G(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-x^2}{2\sigma^2}}$$

and the first derivative is

$$G'(x) = \frac{-x}{\sqrt{2\pi\sigma^3}} e^{\frac{-x^2}{2\sigma^2}}$$

and the second derivative is

$$G''(x) = \frac{-1}{\sqrt{2\pi\sigma^3}} e^{\frac{-x^2}{2\sigma^2}} \left[1 - \frac{x^2}{\sigma^2}\right]$$

In fact, the first derivative of the image function convolved with a Gaussian,

$$g(x,y) = D\left[Gauss(x,y) * f(x,y)\right]$$

is equivalent to the image function convolved with the first derivative of a Gaussian,

$$g(x,y) = D\left[Gauss(x,y)\right] * f(x,y)$$

Thefore, it is possible to combine the smoothing and detecting stages into a single convolution in one dimension, either convolving with the first derivative of the Gaussian and looking for peaks, or with the second derivative and looking for zero crossings.

To encode the iris pattern, i'm using two codes generated from same iris area cut. The reason to use two codes for representing an iris pattern is to give a closer code representing to the iris pattern. The two codes are initiated by "a template code" and "a mask code".

a Template Code

A template code is generated by reading the value of the imagepixel per pixel related to the N x M matrix of the iris area cut size. For example, first value of template code is read from value that represents the intensity of iris area cut image at position pixel number 1 considering to N x M matrix. After the system got the pixel value, then it will be classified whether it is "0" bit or "1" bit. The classifying condition is given from a threshold value of "T" that is "0.5" in this case. The equation of thresholding is as following:

$$f(i,j)=\begin{cases}0 & \text{if } I(i,j) \text{ divided by } 255 \le \text{T}\\ 1 & \text{if } I(i,j) \text{ divided by } 255 > \text{T}\end{cases}$$

where $I(i,i)$ is pixel value at position of i and j of the N x M matrix-iris area cut image. The result is easier to understand by looking in figure 14.

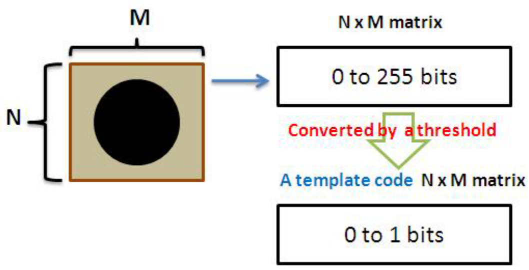


Fig. 14 : Template Code Image

a Mask Code

A mask code is simply generated by reading the value of the image pixel per pixel same as like a template code. The different code here, a mask code is generated directly to "0" or "1" bit value from N x M matrix-iris area cut image. It because that the iris area cut image is binary image. The result is easier to understand by looking in figure 15.

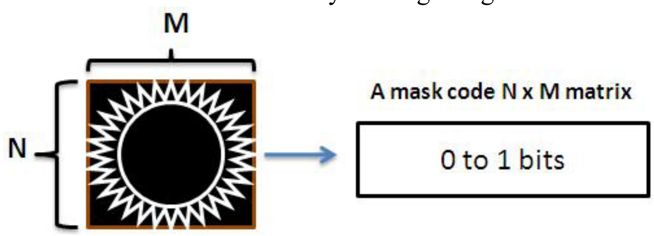


Fig. 15 : Mask Code Image

D. Matching

This part is the last step of the improved method. The aim is to match iris meaning the code. The matching process is to get the similarity value. Unlike my previous work, i'm using the Hamming Distance as the matching algorithm embedded with Bit-Shift algorithm to increase the similarity value.

1) *Hamming Distance* : For binary strings a and b the Hamming distance is equal to the number of ones in a XOR b[8]. The equation of Hamming Distance is defined by:

$$HD=\frac{1}{2{,}408}\sum_{j=1}^{2{,}408}A_j(XOR)B_j$$

Where A is the first image matrices and B is the second image matrices.

As explained before, the iris code is generated by two code whichare "a template code" and "a mask code". Knowing that, the algorithm of the Standard Hamming Distance is extended as following:

$$HD=\frac{1}{N-\sum_{k=1}^{N}Xn_k(OR)Yn_k}\sum_{j=1}^{N}X_j(XOR)Y_j(AND)$$
$$Xn'j(AND)Ynj$$

where X_j and Y_j are the two bit-wise templates to compare, Xn_j and Yn_j are the corresponding noise masks for X_j and Y_j, and N is the number of bits represented by each templates.

2) *Bits Shifting* : As explained in the theory, bit shifting is to increase the similarity of the iris codes. Before calculating the hamming distance, each codes between two iris pattern will be proceed and normalized onto the bit shifting algorithm. Both of the iris template and mask is included onto it. So, each iris template and mask from two iris pattern that is being to be calculated the Hamming distance value is shifted. The shifting process for one shift is illustrated in figure 16.

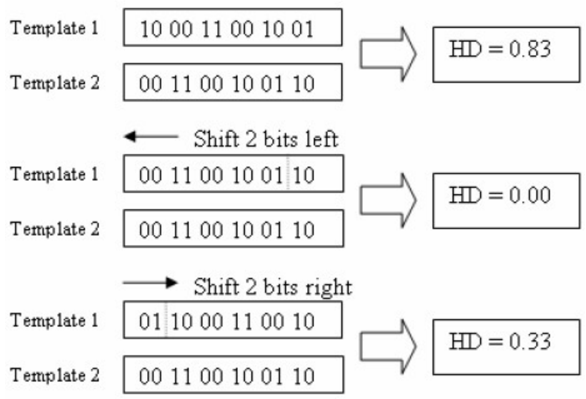


Fig. 16. Two templates bit shifting and matching

It illustrates the bit shifting from two template iris codes. One shift is defined as one shift left, and one shift right of a reference template. In this example one filter is used to encode the templates, so only two bits are moved during a shift. The lowest Hamming distance, in this case zero, is then used since this corresponds to the best match between the two templates.

IV. System Analysis and Testing

A. Data Testing

Data testing is downloaded from Image Iris Database website (http://www.cbsr.ac.cn/irisdatabase.htm) which has given permission to be used for research and education sample. There are three data set taken from three different image acquisition devices. For this research thesis, it is using the data set from CASIA-IrisV1 and CASIA-IrisV3-Interval that have some characteristic as listed in table I.

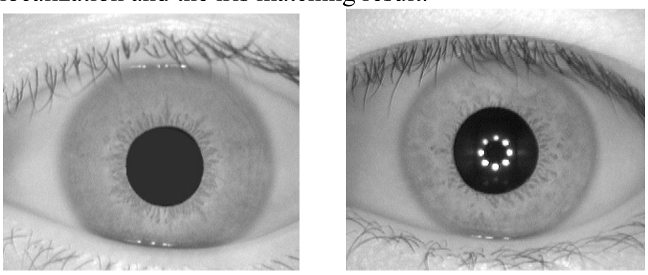
TABLE I : TABLE STATISTIC OF CASIA-IRIS-DATASET

The Characteristic Comparation		
	CASIA-IrisV1	CASIA-IrisV3-Interval
Sensor	Self-developed	Self-developed with LED
Environment	Indoor	Indoor
Session	Two sessions no interval	Two sessions with a time interval
No. of subjects	216	249
No. of classes	320	396
No. of images	2510	2655
Resolution	320*280	320*280
Features	Clear iris texture details	Deeper and with shiny LED reflection

For this research, used 30 different subject data for each CASIA Iris version. The different image of CASIA-IrisV1 and CASIA-IrisV3-Interval can be seen in figure 17 clearly as an example.

B. *Running Test*

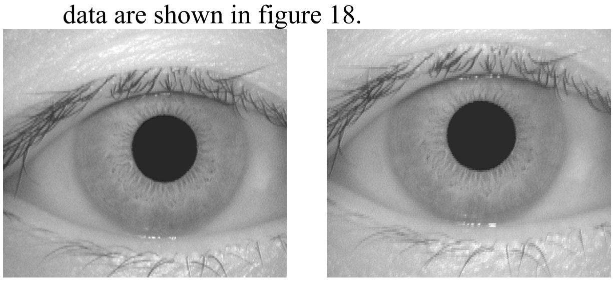
A test done to see the result while the system is running on. The running test involves CASIA-IrisV1 Image and CASIA-IrisV3-interval image. Each CASIA-Iris will use two input image from the same eye when are going to see the iris localization and the iris matching result.



(a) (b)
Fig. 17: (a)CASIA-IrisV1 Image and (b)CASIA-IrisV3-Interval Image

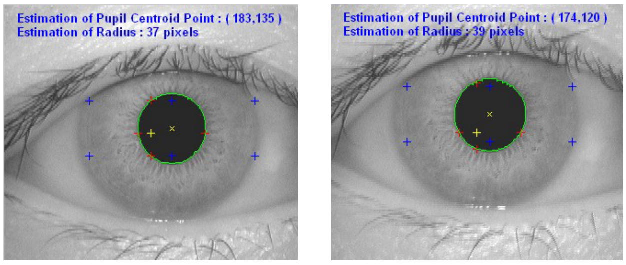
1) Case of CASIA-IrisV1 Image

It will be tested two eye image taken from same eye of person. The first data is 00111 having bitmap file type. The second data is 00113 having bitmap file type same as the first data. According to data, since both of data are from the same eye of person, then the result should be closer to the match or having the maximum percent of the match probability. Those data are shown in figure 18.



(a) (b)
Fig. 18 :Original image input of (a)00111 and (b)00113

The result of iris localization is seen in figure 19. The iris localization did well for both data. It can be seen from the green line circling the pupil outtery edge boundary fit well. The pupol outtery edge boundary indicates the iris inner boundary.



(a) (b)
Fig. 19 : Iris Localization result image of (a)00111 and (b)00113

The result of iris template image is seen in figure 20..
The result of iris mask image is seen in figure 21.
Both of the iris template and mask result 61 x 181 logical of bit matrix code.
The result of iris bit matrix seen in figure 22. The red points represent each bit matrix value from the 00111 image. And, The blue points represent each bit matrix value from the 00113 image.

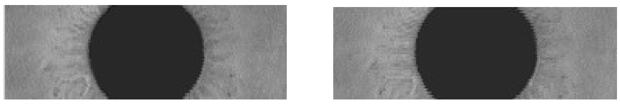


Fig. 20 : Iris Template result image of (a)00111 and (b)00113

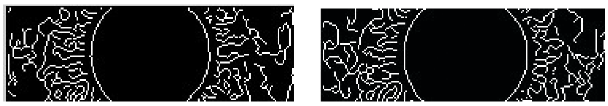


Fig. 21 : Iris Mask result image of (a)00111 and (b)00113

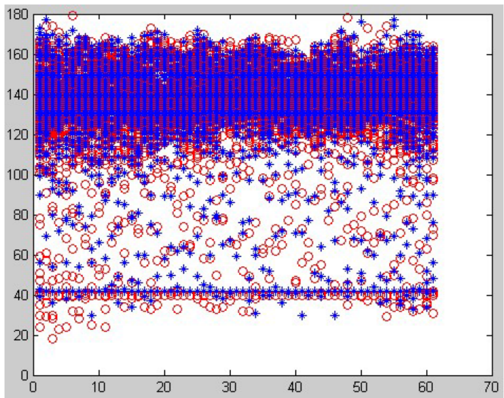
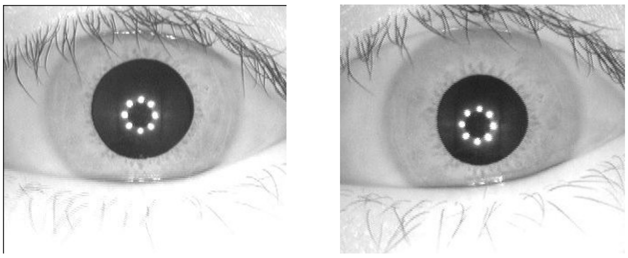


Fig. 22 : Iris Bit Matrix Plot of 00111 and 00113

Finally, it results that matchrasio = 0.0789 and matchprob = 92.1102 percents for matching between 00111 and 00113.

2) Case of CASIA-IrisV3-Interval Image

It will be tested two eye image taken from same eye of person. The first data is S1001L01 having bitmap file type. The second data is S1001L02 having bitmap file type same as the first data. According to data, since both of data are from the same eye of person, then the result should be closer to the match or having the maximum percent of the match probability. Those data are shown in figure 23.

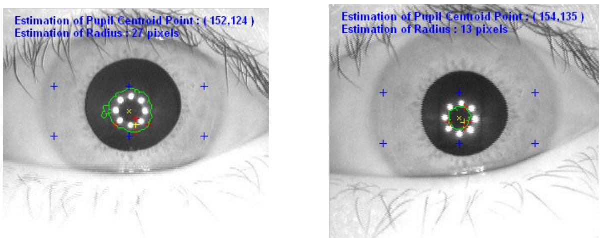


(a) (b)

Fig. 23: Original image input of (a)S1001L01 and (b)S1001L02

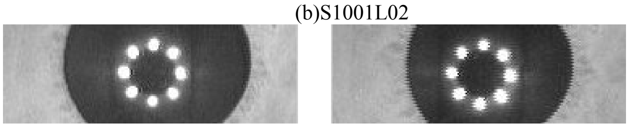
The result of iris localization is seen in figure 24. The iris localization didn't well for both data. It can be seen from the green line circling the pupil outtery edge boundary unfit worst. The green line is inside than suppose to be. The pupol outtery edge boundary indicates the iris inner boundary.

The result of iris template image is seen in figure 25.



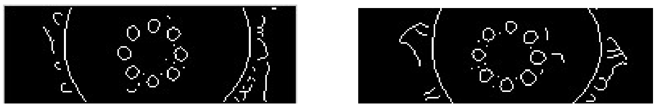
(a) (b)

Fig. 24 : Iris Localization result image of (a)S1001L01 and (b)S1001L02



(a) (b)

Fig. 25 : Iris Template result image of (a)S1001L01 and (b)S1001L02



(a) (b)

Fig. 26 : Iris Mask result image of (a)S1001L01 and (b)S1001L02

The result of iris bit matrix seen in figure 27. The red points represent each bit matrix value from the S1001L01 image. And, The blue points represent each bit matrix value from the S1001L02 image.

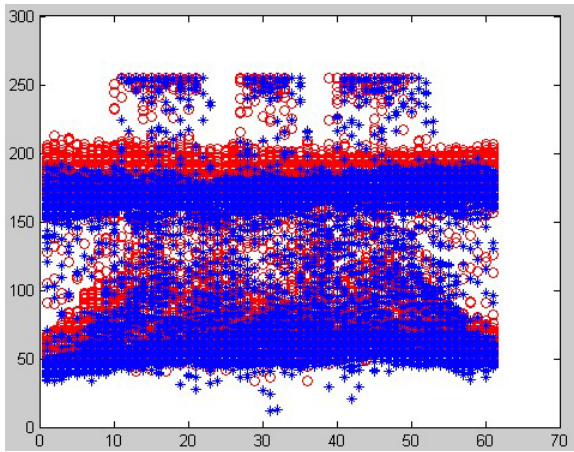


Fig. 27 : Iris Bit Matrix Plot of 00111 and 00113

Finally, it results that matchrasio = 0.0801 and matchprob = 91.9859 percents for matching between S1001L01 and S1001L02.

C. Matching Test

Matching test is aimed to know the similarity value of the iris codes. The similarity is generated from the Hamming distance whether it is closer to 0 or 1 value. If the value is closer to 0, it means dissimilar or the ratio of the match is worst. Despite to closer to 0, value closer to 1 is going to similar or the ratio of the match is good. Hence, there are two attribute values to declare the analysis as following:

1) **match ratio** means the ratio value of the match between two iris code. If the value of the match ratio is small that means the matching between two iris code is going to match well or closer. The limitation match ratio is from 0 to 1. The value match ratio is closer to 1, so the matching between two iris code is going to unmatch.
2) **match probability** means the probability of the match between two iris code. The match probability is resulted from 1 minus match ratio then multiplied by 100 percents. The limitation match probability is from 0 until 100 percents. For example, if the match prob. value is 90, it means ninety percents match well. So, the match prob. more on to maximum is closer match well.

As explained before, the matching test only use 30 data. The 30 data come from five subject of eye tested with six other data that still in same eye of person.

CASIA IRIS V1

The data testing were taken from CASIA IRIS V1. Notification is as following:

- all data are bitmap file.
- the three first digit of 00114 that is 001, means subject number 1.
- the fourth digit of 00114 that is 1, means that it was taken from first session of eye image acquisition.
- the last digit of 00114 that is 4, means the number of the eye image taken.

TABLE II : TABLE MATCHING TESAT OF CASIA IRIS VI

Tested with 00114 (bmp file)							
Test 1	00111	00112	00113	00121	00122	00123	Average
Match Ratio	0.0948	0.1012	0.0851	0.1816	0.0772	0.0858	0.1042
Match Prob.	90.5154	89.8774	91.4932	81.8351	92.2783	91.4212	89.5701
Tested with 00224 (bmp file)							
Test 2	00211	00212	00213	00221	00222	00223	Average
Match Ratio	0.0199	0.0351	0.0638	0.0238	0.0178	0.0148	0.0292
Match Prob.	98.0135	96.4923	93.6222	97.6228	98.2242	98.5208	97.0826
Tested with 00324 (bmp file)							
Test 3	00311	00312	00313	00321	00322	00323	Average
Match Ratio	0.0985	0.0726	0.1113	0.0695	0.0405	0.0234	0.0693
Match Prob.	90.1473	92.7409	88.8729	93.0531	95.9467	97.664	93.0708
Tested with 00424 (bmp file)							
Test 4	00411	00412	00413	00421	00422	00423	Average
Match Ratio	0.1221	0.09	0.0927	0.0879	0.0822	0.087	0.09365
Match Prob.	87.7911	91.0041	90.7293	91.2108	91.781	91.2992	90.6359
Tested with 00524 (bmp file)							
Test 5	00511	00512	00513	00521	00522	00523	Average
Match Ratio	0.1934	0.1174	0.1191	0.145	0.1427	0.1264	0.1406
Match Prob.	80.6566	88.262	88.0905	85.5004	85.7315	87.3623	85.9338

As seen in table II, The system did well in iris matching. From the first test until the last that is the fifth test, the average hamming distance of the match probability is 91.258 percents match well.

CASIA IRIS V3 Interval

The data testing were taken from CASIA IRIS V3 Interval. Notification is as following:

- all data are jpeg file
- the four first digit of S1001L04 that is S100, means subject number 1.
- the fifth digit of S1001L04 that is 1, means that it was taken from first session of eye image acquisition.
- the sixth digit of S1001L04 that is "L", means it was captured from the Left eye. If it is "R", it means Right eye.
- the last two digit of S1001L04 that 04, means the number of the eye image taken.

TABLE III : TABLE MATCHING TEST OF CASIA IRIS V3 INTERVAL

Tested with S1001L04 (jpg file)							
Test 1	S1001L01	S1001L02	S1001L03	S1001R01	S1001R02	S1001R03	Avg
M Rt.	0.066	0.0546	0.0476	0.0846	0.1269	0.0859	0.0776
M Pb.	93.403	94.536	95.240	91.542	87.314	91.409	92.241
Tested with S1002L04 (jpg file)							
Test 2	S1002L01	S1002L02	S1002L03	S1002R01	S1002R06	S1002R03	Avg
M Rt.	0.05	0.0653	0.0696	0.0993	0.0885	0.1114	0.08
M Pb.	95.004	93.47	93.035	90.066	91.147	88.858	91.93
Tested with S1004L04 (jpg file)							
Test 3	S1004R01	S1004R02	S1004R03	S1004R05	S1004R06	S1004R07	Avg
M Rt.	0.059	0.116	0.051	0.062	0.071	0.062	0.07
M Pb.	94.043	88.375	94.892	93.722	92.812	93.772	92.936
Tested with S1006R04 (jpg file)							
Test 4	S1006R01	S1006R02	S1006R03	S1006R05	S1006R06	S1006R07	Avg
M Rt.	0.122	0.09	0.092	0.087	0.082	0.087	0.093
M Pb.	87.791	91.004	90.729	91.210	91.781	91.299	90.635
Tested with S1007L04 (jpg file)							
Test 5	S1007L01	S1007L02	S1007L03	S1007R01	S1007R02	S1007R03	Avg
M Rt.	0.055	0.054	0.044	0.090	0.089	0.092	0.0711
M Pb.	94.427	94.568	95.550	90.975	91.062	90.71	92.882

As seen in table III, The system did well in iris matching. From the first test until the last that is the fifth test, the average hamming distance of the match probability is 92.987 percents match well.

V. CONCLUSIONS

There are some points that could underlined as following:

- the resolution of camera can influenced the depth of field in image captured. The resolution in here depends on focal length of camera and its aperture.
- the shiny lighting can influenced the image pixel. Because, the shiny image changes the pixel from the low intensity to high intensity. As higher the intensity, the pixel becomes higher too.
- Iris Localization in CASIA IRIS V1 did well. But, in case of CASIA IRIS V3 didn't well since it's been affected by noise of shiny points of LED reflected from the Camera.
- Both of the case for CASIA IRIS V1 and CASIA IRIS V3, the iris matching is done successfully with match probability in 90 percents.
- The Bit Shifting algorithm has increased the hamming distance between two iris codes as seen in Bit Matrix Plot.

In general, when the input is good image like from CASIA, the algorithm is powerful to get the iris localization. The boundary edge is fit well. And, the bit shifting has succeed to reduce the noise of the iris image. The result of it is that the hamming distance similarity is closer to similar.

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Eri Prasetyo Wibowo was born in Kendal, Indonesia, in 1966. He received the B.S degree in Electronics and Instrumentation from Gadjah Mada University, Indonesia, in 1992, the M.S. degree in Information System from Gunadarma University, Indonesia, in 1994 and the Ph.D. degree in Electronics Informatics from the Burgundy University, France, in 2005. He was as Secretary of Doctoral Program in Information Technology at Gunadarma University. He was member of EACOVIORE Project to promoted Master VIBOT which founded by Erasmus Mundus. His current interests are in Real time Image processing applications and System On CHIPs Design.

Karmila Sari was born in Bogor, Indonesia, in 1970. She received the B.S, M.S in Information System degree at 1994, 1998 and Ph.D degrees in Information Technology at 2008 from Gunadarma University, Indonesia. In 2007, she got scholarship from ministry of education of Republic Indonesia for doing research in LE2I Laboratory site Dijon with supervised by Prof. Michel Paindavoine. Her current interests are in Image processing applications.

Wisnu Sukma Maulana was born in Jakarta, Indonesia in 1986. He received M.S degree from Gunadarma University, indonesia, in 2010. In 2009, he did researches in LE2I Laboratory site in Le Creusot, Burgundy University, France, during 6 months. his speciality are in security system and Image processing. Now he works in ministry of Sports of Republic Indonesia.

Sarifudin Madenda was Prof. at Gunadarma University Indonesia, he was born in Indonesia in 1963. He received B.S degree in electronics and instrumentation from University of Indonesia,Indonesia in 1989, the M.S degree in Electronics from Lyon University, France, in 1992 and the Ph.D degree in Electronics and Image processing from Burgundy University Framce in 1995. He touch also in UQO, Quebec, Canada since 2002. His current interests are in real time image processing and Multimedia System.