Thin Iris Region Recognition Using the RED Algorithm

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ABSTRACT

Iris recognition system provides automatic identification of an individual based on a unique feature that located inside the iris. To detect these features Ridge Energy Detection (RED) algorithm, which is one of the most accurate and fast identification method to detect iris, features today. RED algorithm is applied to rectangle iris that generated from the normalization process. RED algorithm constructed a template contains the features of the iris by using two types of filter (horizontal and vertical). In this paper, two different rectangle iris templates were generated, the first rectangle iris template is generated as common way in this filed by taking rectangle iris template that contains full iris region, while the other is a novel rectangle iris template which contains a ring from the iris that near to the pupil. Both rectangle iris templates were applied to the RED algorithm in order to compare the accuracy and time between them. The novel rectangle iris template has 0% fault in recognition and faster in extraction process by six times than the common rectangle iris template in extracting the features of iris when using RED algorithm and also three times faster in matching process when comparing with novel rectangle iris template than rectangle iris template that contains full iris region.

Keywords: Iris recognition, ring iris region recognition, Ridge Energy Direction, Hamming Distance.

INTRODUCTION

TheIris recognition is one of the most accurate identification methods that verify user and secure the information. Iris identification is accepted in our world since the feature inside the iris is unchanged over the years and almost impossible to be imitated by others. This approach has been developed in past years to give more reliable security for saving information and identification. The first iris recognition algorithm was introduced by Dr. John Daugman [1]. Iris recognition requires four main steps; the first step is capture image of eye. While the second steps is preprocessing processes, which includes segmentation, which is a process of isolating the iris from the captured image, and normalization process which is a process of converting the iris from the polar form to rectangle form [2]. The third step is feature extraction, which extract the iris features from the eye and finally the last step is the comparison of iris templates and recognition (matching) decision.

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Theory of iris recognition system

The first step in iris recognition is to capture the image. Once the image captured various preprocessing steps are carried out on it. It includes segmentation, normalization (polar to rectangular conversion) and then template and mask generation by applying the RED algorithm to the rectangular template. This template is matched with the database using Hamming distance (which the most foremost method that used for matching between irises) and the match identification is displayed [3].

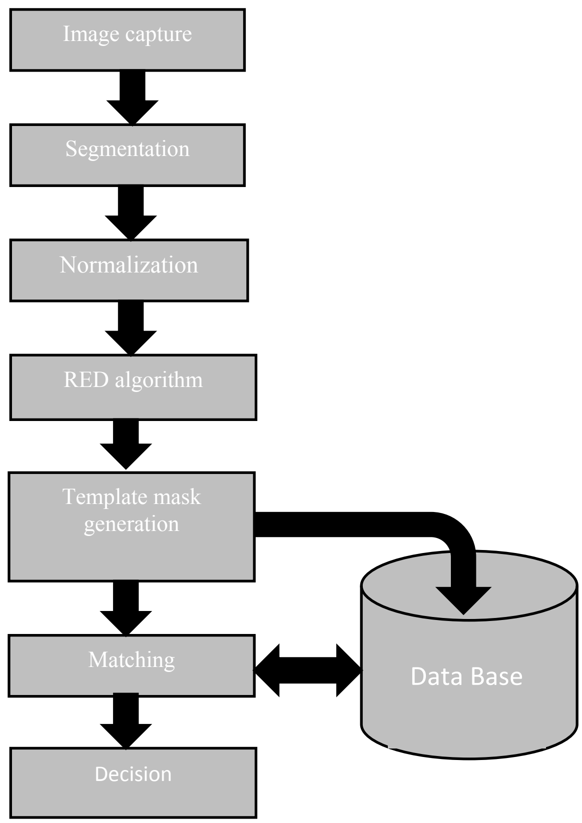
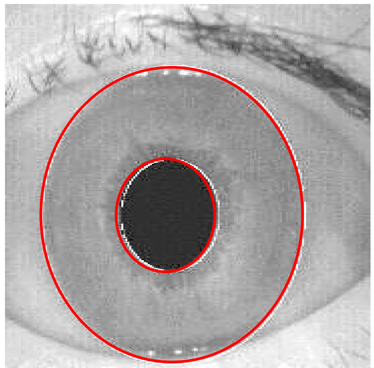


Figure (1). Iris recognition system

Segmentation

Segmentation process is used to isolate the iris region from the captured image. Segmentation is the most crucial factor in the iris recognition since it is the core of all other process. The more the segmentation process is accurate, the more the identification will be accurate. The accuracy of the segmentation depends on quality of the captured image, where it has the specular reflection or not. Segmentation is used to isolate the iris region, which is circular colored part in the eye and located between the sclera and pupil. Usually, the iris region can estimate by two circles, one circle constructed in the edges between iris and sclera, where other circle constructed in the edges between iris and pupil as shown in figure 2. The segmentation process is located the iris region by estimated the parameters of these two circles. There are various algorithms have been proposed to segment the iris region from the captured image. Some of these algorithms depend on the pupil reflection in detecting the iris region and some of algorithms used the integro-differential operator in detecting the iris region while other algorithm used Circle Hough Transform (CHT).



Figure(2). The two constructed circles of iris and pupil

The CHT is used in this paper as a way to detect the circle parameter of both iris and pupil. The CHT is a process of locating uncompleted circles. The CHT is required to apply edge detector on the captured image to enable the CHT to locate the edges of both iris and pupil circles. The first process in the segmentation is canny edge detector. The canny edge detector is used as an edge detector to detect the edges of pupil and iris circles. While the second process in segmentation is applying the CHT to detect the parameters (radius and center point of both pupil and iris circles). An automatic segmentation algorithm based on the circular hough transform is employed by Wildes et al. [4], Kong and Zhang [5], Tisse et al. [6], and Ma et al [7]. To detect the iris, Hough space will detect the outer boundary of the iris by locating larger circle that constructed from edge detector. Equation (1) is used to define any circle by its parameters. These parameters are the center coordinates x and y, and the radius r, and x_0, y_0 is a shift in the x-axis and in the y-axis respectively. A maximum point in the Hough space will correspond to the radius and center coordinates of the circle that has defined by the canny edge points.

$$(y - y_0)^2 - (x - x_0)^2 = r^2 \quad \ldots(1)$$

Normalization

Normalization is the process of converting the iris from the polar coordinate to the rectangular coordinate. After completing the segmentation process and locating the boundary of the pupil and iris. The next step is polar to rectangular conversion. Rectangular conversion is applied to the region locating between the radius of the pupil and the radius of the iris. This process will generate the rectangular template as shown in Figure (3).

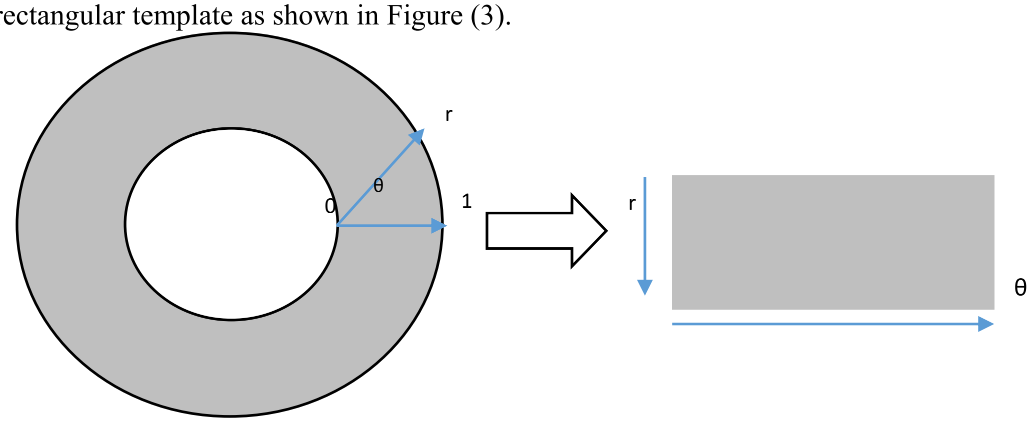


Figure (3). Polar to rectangular templates conversion.

Conversion process for iris image to rectangular template is performed using the common polar to rectangular coordinate transformation. This process is called as normalization, Re-maps each pixel within iris reign to pair polar co-ordinates (r, θ), where “r“ lies in the unit interval [0, 1] and “θ“ is the usual angular quantity that is cyclic over [0,2π]. This called homogenous rubber sheet model which used by Daugman [8]. The remapping of the iris image I(x, y) from raw Cartesian coordinates (x, y) to the dimensionless non-concentric polar coordinate system (r, θ) can be represented as:

$$\boldsymbol{I}(x(r,\theta), y(r,\theta)) \rightarrow I(r,\theta) \quad \ldots(2)$$

$$x(r,\theta) = (1-r)\, x_p\,(\theta) + r\, x_l(\theta) \quad \ldots(3)$$

$$y(r,\theta) = (1-r)\, y_p\,(\theta) + r\, y_l(\theta) \quad \ldots(4)$$

Where $I(x, y)$ is the iris region image, (x, y) is the original Cartesian coordinates, (r, θ) is the corresponding normalized polar coordinate, and x_p y_p and x_l $y_l$are the coordinates of the pupil and iris boundaries along the θ direction. Since the radial coordinate ranges from the iris inner boundary to its outer boundary as a unit interval, it is inherently correct for the elastic pattern deformation in the iris when the pupil changes in size.

$$\boldsymbol{r} = \sqrt{x^2 + y^2} \quad \ldots(5)$$

Where $x = r\cos\theta$ and $y = r\sin\theta$ …(6)

Rectangle iris template is generated based on these equations. The rectangle iris template that created contains iris region that contains the sufficient features to distinguish between users. The rubber sheet model takes into account pupil dilation and size inconsistencies in order to produce a normalized representation with constant dimension. In this way, the iris region is modelled as a flexible rubber sheet anchored at the iris boundary with the pupil center as the reference point. The dilation and constriction of the elastic meshwork are on iris when the pupil changes size [1].

Feature Extraction

The feature extraction is a process of extracting the iris features from the rectangle iris template. There are various algorithms have been proposed to extract the features from the rectangle iris template. The Ridge Energy Direction (RED) algorithm is one of algorithm that used for extracting the features from the rectangle iris template. The RED algorithm is extracting iris features based on the direction of the ridges that appear on the image [9]. The energy of each pixel is simply the square of the value of the infrared intensity within the pixel. The RED algorithm states on filtering the rectangle iris templates by two directional filters to determine the existence of ridges and their orientation. More specifically, the result is computed by first multiplying each filter value by the corresponding input data value. Then a summation is performed, and the result is stored in a memory location that corresponds to the centroid of the filter. This process repeated for each pixel in the rectangle iris, stepping right, column-by-column, and down, row-by-row, until the filter is applied to all the pixels in the rectangle Iris. The filter processing is repeated two times on the rectangle iris one with vertical filter and the other with horizontal filter, as shown in figure 4. In this paper 9*9 RED filter have been chosen to apply to both rectangle template since this filter have balance between the accuracy and speed [10] [11].

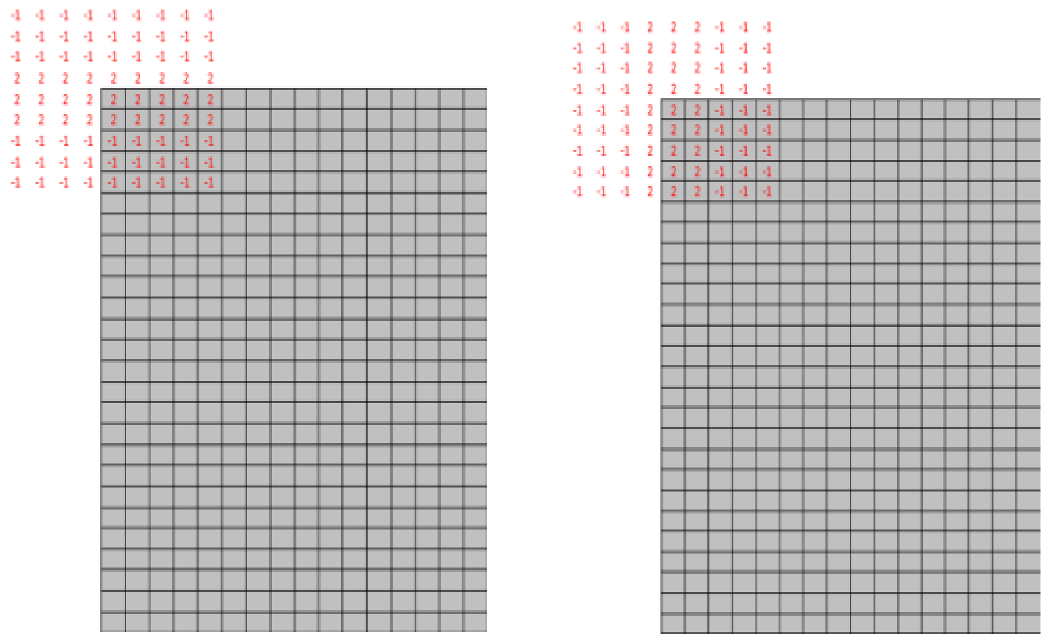


Figure (4.) a) RED vertical filter size 9*9. b) RED horizontal filter size 9*9.

Template matching

The template can now be compared with the stored template using Hamming distance (HD) as the measure of closeness. The more the HD closes to zero the more the accurate the identification. Highest closeness between matched eyes is 0.32 as indicated by Daugman [1].

$$HD = \frac{\|(Template\ A \otimes \ Template\ B) \cap MaskA \ \cap Mask\ B\|}{\|Mask\ A\ \cap Mask\ B\|} \qquad \ldots(7)$$

Where templates A is the Iris template captured image and Template B is the iris template form the database and ⊗ symbol indicates the binary exclusive-or operator to detect disagreement between the bits that represent the directions in the two templates, ∩ is the binary AND function, ‖●‖ is a summation, and mask A is associated binary mask for captured image template and also mask B is associated binary mask for database. The denominator ensures that only required valid bits are included in a calculation.

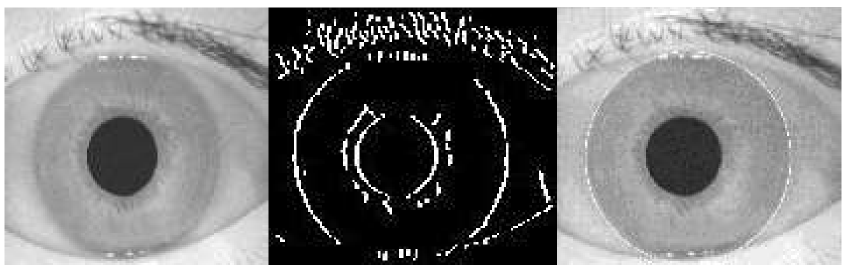
Methodology

image captured

Chinese Academy of Sciences, Institute of Automation (CASIA) Version 1 (V1) used as image captured and database in this paper, due to this database has been captured specially for testing iris recognition and iris recognition researches purpose.

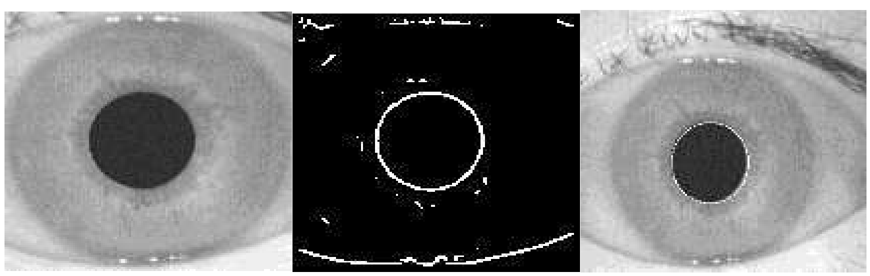
Segmentation

Segmentation is a process of extracting the iris from the captured image as previously mention. The algorithm that used in this paper for calculate the iris and pupil parameters is CHT, which is most common method for detecting circle parameters. The segmentation process consist from two parts, the first part is edge detector for detecting the edges of both iris and pupil. While the second part is CHT, which is used for calculating circles parameters of both iris and pupil. Canny edge detector is used in this paper as way of detecting the edges due to it is greater ability to locate edges of iris and pupil over others edges algorithm. The canny edge detector is converted the captured image to binary image as shown in figure 5 (b). After converting the captured image into binary image, the CHT will try to locate the edges of iris. The result of locating the iris circle parameters by using CHT is shown in figure 5(c). After finding the iris from the captured image, it is the time to locate the pupil using CHT. First stage to detect the pupil is to make a mask to the captured image and extract only the iris image as shown in figure 5a, since the pupil is always inside the iris. This way is used in order to decrease processing time of the circle Hough transform space, since CHT is "brute-force" and try many pixels to locate the pupil in it. The mask will decrease number of pixels that CHT search in it for the pupil parameters. The same process of finding the center and radius for iris is applied for finding the center and radius of the pupil. The results of detecting the pupil circles is shown in figure 6 while the result of the segmentation process is shown in figure 7**.**



(a) (b) (c)

Figure (5.) a) RED vertical filter size 9*9. b) RED horizontal filter size 9*9.



(a) (b) (C)

Figure (6). a) Adjustment image extracted from original image based on the center point of the Iris b) the canny edge detector of the pupil c) Pupil detection from the Hough transformer.

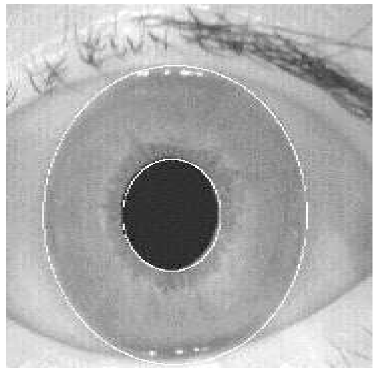
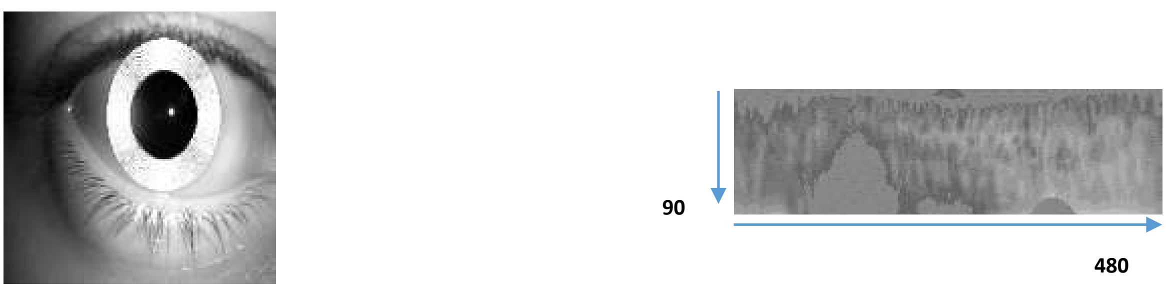


Figure (7). Result after Segmentation process.

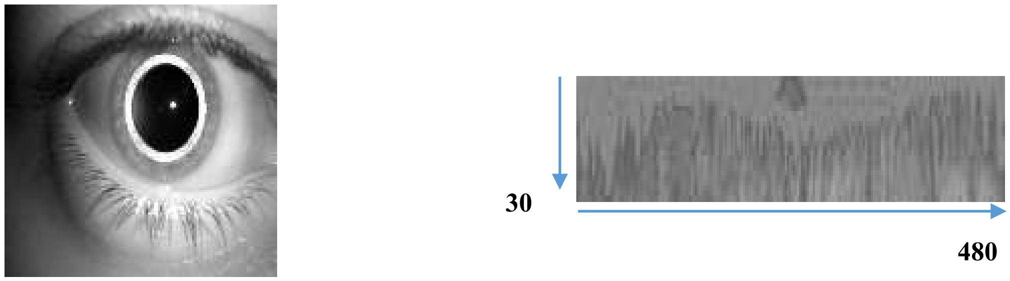
Normalization

The normalization process is a way for converting segment iris from its polar coordinate form to rectangle coordinate form. This section will focus on describing choosing iris region that contains most iris features. The rectangle iris template is generated according to equations (2-6). Most researchers of this field are generated rectangle iris template contains full iris region to ensures that the generated rectangle iris template contains all iris features inside of it. However, this rectangle iris template contains noise that may effect on recognition accuracy. So some enhancement has been made in this paper about the rectangle iris template by taking the iris region that near to the pupil over taking the full iris region. The iris region contains sufficient iris features that can distinguished between people without any false in recognition and contains low amount of noise compare to full iris region. In this paper two-rectangle iris template are generated. The first rectangle iris template with size 90x480 is generated as most of researchers in this field generate contains full iris region as shown in figure 8**.** While the second rectangle iris template with size 30x480 is generate as novel rectangle iris template contains only the iris region that near to the pupil as shown in figure 9. The same processes applied on the two rectangle iris template to obtain the accuracy and the speed among them



(a) **(b)**

Figure (8). a) Taking full iris from the eye. b) Rectangular Iris with height 90 pixel and width 480 pixel of the Full iris.



Figure(9). a) Taking a ring from iris that near to the pupil. b) Rectangular Iris with height 30 pixel and width 480 pixel of ring form iris that near to the pupil

Feature extraction

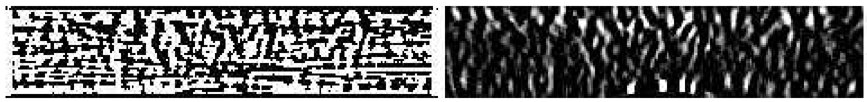
The RED is algorithm for extracting the features from the rectangle iris template. The RED algorithm used in this paper as way for extracting the features from the rectangle iris template. The RED algorithm is consisting from two digital filters, which are vertical and horizontal filters. The RED algorithm will applied these two filters on the two rectangle iris templates that generated by normalization process. However, the time needed for applying the RED algorithm on both rectangle iris templates are different, since the first rectangle iris template contains more pixels than the other rectangle iris template as shown in table 1. The multiplication required to applied one of RED filters on the rectangle iris template is found by multiply the size of the RED filter by the height and width of the rectangle iris template (size of filter * height * width).

Table (1). Size of rectangle iris templates.

No.	Rectangle iris template	Number of pixel in the template	Number of multiplication needed by filter size 9*9	Time (sec)
1	Full iris region	90*480 = 43200	9*9*43200 = 3499200	0.366052
2	Ring from iris that near to the pupil	30*480 = 14400	9*9*14400 = 1166400	0.166766

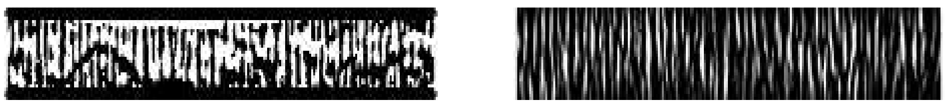
Table 1 indicates that as the size of the rectangle iris template increases the processing time for complete only one of RED filter will increase, from table 1 the first rectangle iris template with size of 90 pixels height and 480 pixels width. This rectangle iris template is contain the full iris region. This rectangle iris template needs 3499200 multiplications to end only one filter RED of size 9*9. While the rectangle iris template with size of 30*480 that contains a ring region of the iris, which is iris region that near to the pupil, it needs 1166400 multiplications to complete the same RED filter of size 9*9. The results of the multiplication show that the second rectangle iris template is three times faster ($3499200/1166400 = 3$) than the first rectangle iris template when applying only one of the RED filters. Since, there are two RED filters (horizontal and vertical) the multiplication process will be doubled to complete RED process, so second rectangle iris will be six times faster than the first rectangle iris template when applying the two RED filters on the rectangle iris templates.

After the rectangle iris template is pass through two filters the horizontal and the vertical dimension will generate two images one of them the result is the multiplication of the vertical filter with rectangle iris template, and the other results is created by multiplication the horizontal filter with the rectangle iris template. The vertical and horizontal templates that generated by RED algorithm for first iris template that contains the full iris region are as shown in figure 10. While vertical and horizontal templates of second iris template that contains a ring region of the iris near to the pupil is shown in figure 11.



(a) **(b)**

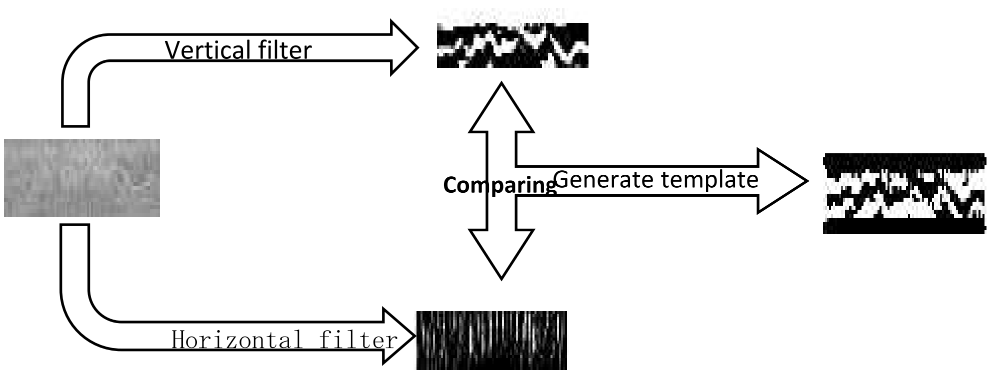
Figure (10). a) Vertical template result from vertical filter with first iris template. b) Horizontal template result from horizontal filter with first iris template.



(a) **(b)**

Figure (11). a) Vertical template result from vertical filter with second iris template. b) Horizontal template result from horizontal filter with second iris template.

Finally, the template is generated by comparing the results of the two different directional filters (horizontal and vertical) and writing a single bit that represents the filter with the highest output at the equivalent location. The output of each filter is compared and for each pixel, a ‘1’ is assigned to strong vertical content or a ‘0’ for strong horizontal content. These bits are concatenated to form a bit vector unique to the “iris signal” that conveys the identifiable information. The mask also will generate at this process if any value of the resulting of the two different directional filters (horizontal and vertical) is above the threshold, this location will mark as not valid by putting 1 to it as shown in figure 12.



Figure(12). Ridge Energy Direction process for generating template

This characterization of the RED algorithm filters is applied to iris into first template 90x480 = 43,200 bits template and the other 30*480 = 14,400 bits. Therefore, the algorithm requires 43,200 iterations of this process to encode a full iris template for the first iris template, and the second iris template requires 14,400 iterations for RED process to encode a thin ring iris template.

Matching

The matching is process of comparing two template mask with each other and see the closeness between each other's as described previously. The hamming distance is used in this paper as way of comparing between iris templates. Two test is done using the hamming distance, since two type of iris templates are generated by the RED algorithm. The first iris template that tested is the iris template that contains the full iris region inside of it. The test shows that there is some issue with some of picture that contains larger amount of noise and this led to failed recognition in some cases. While for the second test of iris template that contains the iris features that near to the pupil the test shows great performance and accuracy, zero fault recognition. The time required to complete comparing two iris templates is different due to the size of iris template that compared. For example, the time required for testing iris template of size 90x480 is 3 (90x480/30x480=3) times higher than the time required for testing iris template with size of 30x480. Therefore, the iris template that contains iris region that near to pupil is three times faster than the iris template that contains full iris region.

Results

The proposed method is tested on a widely used free iris database (CASIA V1). The method is applied to all images in the selected databases. Proposed method is programmed using MATLAB-2013a on a computer of 2.6 GHz Core i5 processor and 8GB RAM. from table 2 it's clear that selected iris template which generated by taking iris features that near to the pupil is more reliable than the iris template that is generated by taking features of full iris. Hence, we can conclude that selected iris template have two advantages over taking of full iris template. The first advantage is the speed, since the selected iris template have less pixels than the full iris template so processing time to complete the RED algorithm on the iris template is small comparing to first iris template as shown in table 1, it's clear from table 1 that the time to complete the process of applying RED algorithm on rectangle iris for selected iris template is 0.166766 sec while the time to complete the same process on full iris template is 0.366052 sec. The second advantage is that selected ring iris template is more accurate than the first iris template, since the area of selected iris template that near to the pupil is most of the time didn't contains any eyelid and eyelash which considers as noise, while the full part of the eye may contain some of eyelid and eyelash which result from error and effect on accuracy. From table 2 it is clear shown that HD of matched picture between thin ring iris of eye 1,2 and 3 is much closer to zeros than the HD of matched picture between irises that near to pupil. This is because those eyes (1, 2 and 3) have some eyelid and eyelash (noise) that close to the upper boundary of the pupil as shown in figure 11, so this cause the HD to increase.

It's clear that the HD of the full iris templates is greater than the HD of thin ring iris this because noise in the upper boundary has major effect on the full iris compared to thin ring iris, since it remove more features in full iris than in thin iris templates. So this causes full iris template less accurate than thin iris templates.

Table (2). Result of Matched iris

Iris template	Size of iris template	Correct matching
Iris template contains feature from the full iris	90*240 pixel	98.14%
Iris template contains feature from iris that near to the pupil	30*480 pixel	100%

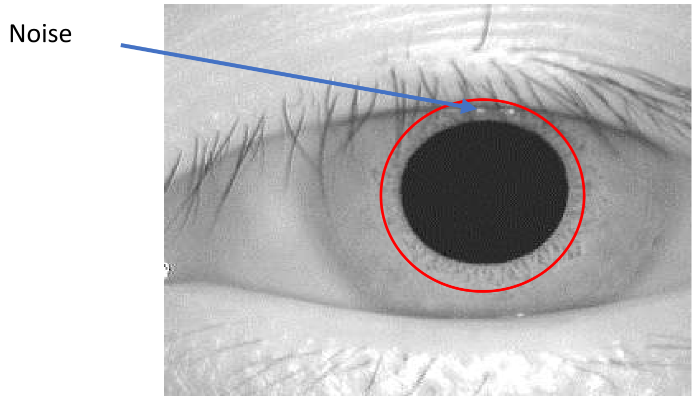
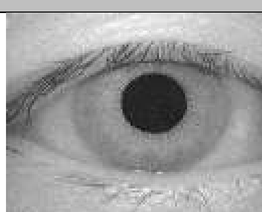
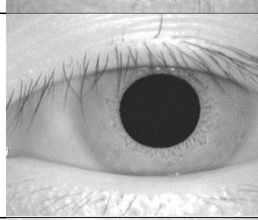
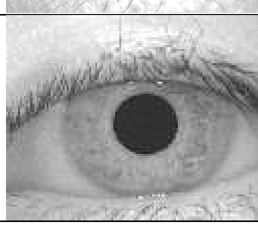


Figure (13). Noise in iris that upper side boundary of pupil

Table (3). Matching percentage between two iris templates of chosen eye from CASIA V1

No.	Eye chosen form CASIA-V1	HD of Matched picture between full irises	HD of Matched picture between irises that near to pupil
1		0.297749	0.208889
2		0.305965	0.288958
3		0.28406	0.273264

CONCLUSION

A new developed RED algorithm method is applied for iris recognition by generating two iris templates one taking the full iris and the other takes the iris that near to the pupil. This technique enhanced the RED algorithm since this part of an area contains a small amount of eyelid and eyelash that considered as noise. Both, the first iris template, and the second iris template are generated and tested by RED algorithm and tested on different database and no image have rejected. Table 1 shows that the first iris template needs much more time to complete the RED process than the second iris template due to the large size of the first iris template than the second template. The iris template that was taken from the boundary near the pupil has higher accuracy than the iris template that was taken full iris region, since it has lower noise as shown in table 2. Table 3 shows that the thin ring iris template has much lower HD than the second iris template due to major effect of noise on full iris template.

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