Detecting Pupil and Iris under Uncontrolled Illumination using Fixed-Hough Circle Transform

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Abstract

The use of characteristics of iris and pupil are very useful in wide range of applications. There have been many studies about detecting pupil and iris, however most of these studies focused on images which are taken under controlled illumination conditions. In this paper, we focus on images in which are taken under uncontrolled illumination using compact digital cameras. We propose an efficient method for detecting pupil and iris accurately. Our method is based on Hough Circle Transform by fixed radius. This algorithm combines face recognition, edge detection and characteristics of LAB images. We implement our method into 125 face images which are taken by compact digital camera under uncontrolled illumination, varying pose and expression conditions of human face. The result shows that our algorithm has performance about 82%.

Keywords: *iris detection, pupil detection, uncontrolled illumination, fixed-hough circle transform, Lab images, face recognition, edge detection*

1. Introduction

Iris is a circular and colored curtain of the eye. The opening of the iris forms the pupil. The iris helps regulate the amount of light that enters the eye [1]. Iris has many varieties of properties to be used as an individual identification. The characteristics of iris which can be used as a supporting of individual identification are: stable, unique, universal, random, permanent, complexity of texture and structure.

The pupil of eye is simply a hole in the iris through which one can peer into the eye. It appears black because of the darkness inside [2]. Referring to this definition, we conclude that the color of pupil is universal; it does not depend on ethnicity although the color of the iris is different for different ethnicity as shown in Figure 1.

The pupil gets wider in the dark but narrower in light. When narrow, the diameter is 3 to 4 millimeters. In the dark it will be the same at first but will approach the maximum distance for a wide pupil of 5 to 8 mm depending on a person age. In a real condition, we can measure size of pupil and iris, it is expressing by unit mm, while in a digital image the size of pupil and iris are expressing by pixel.

Currently, there are a lot of related researches about iris and pupil detection. Each research has different methods for extracting features and template matching processing of iris and pupil. Researchers have a different algorithm for solving problems to find object of pupil and iris.

Figure 1. Color of Pupil (source: www.google.com)

Daugman proposed an infero differential operator to find pupil, iris and eyelid [3]. Wildes proposed a parabolic Hough transform to detect eyelid, upper and lower threshold. This method requires an appropriate threshold value [4]. Ebisawa proposed an algorithm for windowing around the pupil image on the basis of difference pupil detection method which is work on a relatively cheap contstruction [5]. Xhifei proposed a method for estimating the center and radius of the pupil [6]. Funahashi proposed a system for extracting eye gaze information and introduced a system for supporting na video conference system [7].Wan proposed a novel iris quality assessment based on Laplacian of Gaussian operators [8]. Jomier developed a new tool for automatic quantification of the pupil dilation to test the hypothesis that dark adaptation is slowed proportional to the amount of stress that an individual has experienced [9]. Bhuiyan proposed a robust and precise scheme for detecting faces and locating the facial features in image with complex background. Facial features, such as eyes, nose, mouth, eyebrow, etc. are localized from face skeleton with the knowledge of the face geometry [10]. Gupta proposed an iris recognition algorithm with the help of corner detection [11]. Cho proposed a method for pupil and iris segmentation in the mobile environment [12]. Yuan proposed a method for localizing pupil in non-ideal eye images [13]. Park proposed a new iris recognition method for mobile phones based on corneal specular reflection [14]. Masek developed an 'open source' iris recognition system in order to verify both the uniqueness of the human iris and also its performance as a biometric [15]. Almost all data acquisition in the existing works using different equipment and conditions with our system. Sometime they use a web camera [7], special cameras [9], or if they use a regular camera but the condition while data acquisition process arranged to be the same illumination condition [5, 8, 12]. However, the input images in our system cannot be classified based on the above information because data acquisition process using a variety of types and brands of digital cameras. Also, our data was taken from different places and different illumination conditions as well.

In this paper, we propose a method for detecting pupil and iris using fixed-radius Hough circle. This transformation is derived from algorithm of Hough-Circle transform. We prefer to this algorithm according to the compatibility of our data in this research. In addition, Hough-Circle Transform has many advantages especially in speed detecting eye compared with other algorithms [16].

2. Methods

Basically, our algorithm for identifying pupil and iris is divided into four steps. Before performing this stage, in order to simplify image processing operations therefore the size of original image is changed to 50 %.

Four steps of our algorithm are:

a. Masking step

Masking step is a separation process of facial image based on skin color. We utilized the luminance component Cb and Cr and performed a facial box based on skin color.

b. Region of eye step

After getting a facial image in the box then we got an eye area automatically. We assume that for normal facial image, eye area is located in 1/3 of the whole of facial image in the box.

c. Pupil step

In this step we explored characteristics of LAB color to determine image of pupil. Then we implemented fixed-radius hough transform to determine 'center point 'of circle as a candidate of pupil center.

d. Iris step

In this step we assume that center of pupil already determined in Pupil step. Then we determine location of iris by widening radius of pupil refers to normal size.

2.1. YCbCr Image

The YCbCr color space is widely used in digital video, image processing, etc. In this format luminance information is represented by a single component Y, and color information is stored as two color-difference components, Cb and Cr [17].

Component Cb is the difference between the blue component and a reference value, while component Cr is the difference between the red component and a reference value. The YCbCr color model was developed as a part of ITU-R BT.601 during the development of a worldwide digital component video standard. *YCbCr* is a scaled and offset version of the *YUV* colour model. *Y* is the luma component defined to have a nominal 8-bit range of 16-235; *Cb* and *Cr* are the blue-difference and red-difference chroma components respectively, which are defined to have a nominal range of 16-240. The transformation used to convert from *RGB* to *YCbCr* color space is shown in the Equation 1.

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 65.481 & 128.553 & 24.966 \\ -37.797 & -74.203 & 112 \\ 112 & -93.786 & -18.234 \end{bmatrix} + \begin{bmatrix} R \\ G \\ B \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

In contrast to RGB the YCbCr color space is lumain dependent, resulting in a better performance. The corresponding skin cluster is given as [18]:

$Y > 80$
$85 < Cb < 135$
$135 < Cr < 180$,

Where $Y, Cb, Cr = [0, 255]$.

Chai and Ngan [19] have developed an algorithm that exploits the spatial characteristics of human skin colour. A skin colour map is derived and used on the chrominance components of the input image to detect pixels that appear to be skin. Working in this colour space Chai and

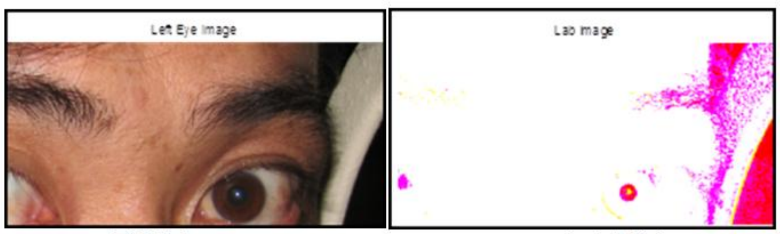
Ngan have found that the range of *Cb* and *Cr* most representatives for the skin–colour reference map are:

$$77 \leq Cb \ \leq 127 \ and \ 133 \leq Cr \leq 173$$

Due to our propose research, we utilize YCbCr model for detecting face colour only. It is based on the fact that YCbCr model has a good performance for presenting luminance in digital monitor. Characteristic of component Cb and Cr have a clear appearance for presenting face skin [16].

2.2. LAB Image

LAB image is produced by Comission Internatinale d'Eclairage (CIE). This colour model is made according to human perception on colour. LAB model extract colour referring the relationship between luminance or lightness components (L) and two chromatic components. Two chromatic components in LAB model are red-green components yellow-blue components]. The characteristics of LAB model is described in Figure 2.



a. RGB image b. LAB image

Figure 2. RGB image and LAB Image

LAB model is representation of light response that could be caught by eye; therefore we can identify many objects with different level of brightness. Black colour will have different colour effect compared with other colours. If the colour is approaching to black colour, it will be easy to detect this colour using LAB colour model. According to the performance of LAB colour model we could detect the colour of pupil that almost had a black colour.

2.3. Edge Detection

One of image segmentation method is edge detection. Edge detection is used for getting edge of an object [20]. The main function of edge detection is for identifying a boundary of an object contained in an image. An edge could be regarded as a pixel location when there is an extreme difference intensity value. An edge detector works by identifying and highlight the locations of pixels that have these characteristics. Edge detector has various types of operators such as Prewitt, Sobel, Robert and Canny. Input from the edge detector requires a single layer color models, ie gray scale. In this research, we prefer to use Canny edge detector because this edge detector has more detail information about edges in an object of image.

2.4. Hough Circle

Circle Hough transforms could be used to determine a circle when the same number of points located on the unknown parameters [21]. A circle with radius R and Center (a,b) can be described by Equation 2 and Equation 3.

$$x = a + R\cos(\emptyset) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (Eq\ 2)$$

$$y = b + R\sin(\emptyset) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (Eq\ 3)$$

From the equation, when the angle θ rotated to 360 ° then it will form a circle. If an image contains a lot of points, and some of them can form a circle, then the circle can be found by finding the first value of R, a and b.

According to above equation, R is the radius of the circle to be searched, a and b are the center point of the circle. Figure 3 below is an illustration of how the Hough transform circle.

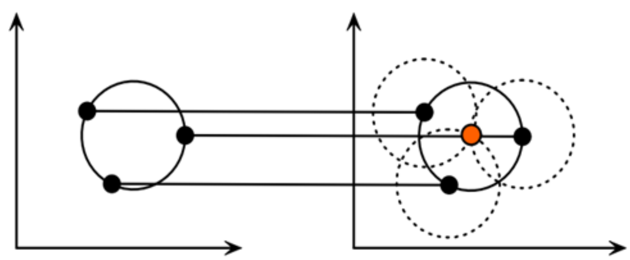


Figure 3. Illustration of Circle Hough Transform

By doing do some image processing operations, the algorithm is able to detect pupil Hough circle with an error rate of 10% [16].

In this research we focused for using Circle Hough Transform. According to the ability of Circle Hough transform for detecting a circle, it is useful to detect a pupil and iris that are generally circular or spherical.

3. Experiments

3.1. Masking Steps

One method to recognize human face is color segmentation. The main idea of this method is to utilize human face area that mainly consists from human skin. In this method, RGB color converts to YcbCr as described in Figure 4. As shown in Figure 4, components Cb and Cr have special characteristics. Then each component Cb and Cr is conducted to be face area segmentation by converting into 1 layer model (Black and white color model).

The segmentation process is carried out by taking the desired face image information based on threshold value. Threshold value is determined by looking at the characteristics of histogram components Cb and Cr as described in Figure 5.

After getting area components of Cb and Cr, then we combined both of components. It is intended to strengthen the effect of luminance produced. After getting sum area of components Cb and Cr, then we restore the image information into the original image as described in Figure 7.

Figure 4. Original Image and YcbCr Components

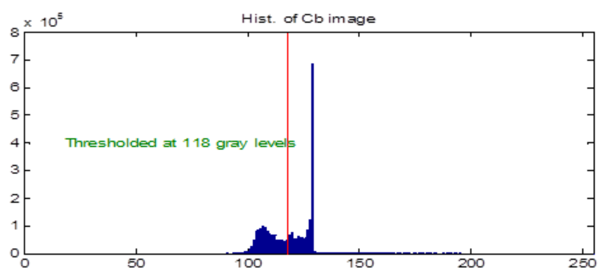


Figure 5. Histogram of Cr component

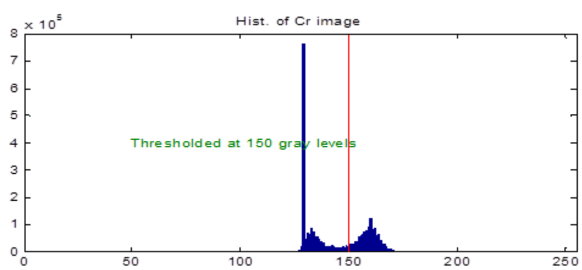


Figure 6. Histogram of Cb components

3.1 Region of Eye Step

In order to detect the eyes, first we have to determine face area of an image as described in Figure 7. After getting face image as shown in Figure 7, then we make a box simulation as described in Figure 8.

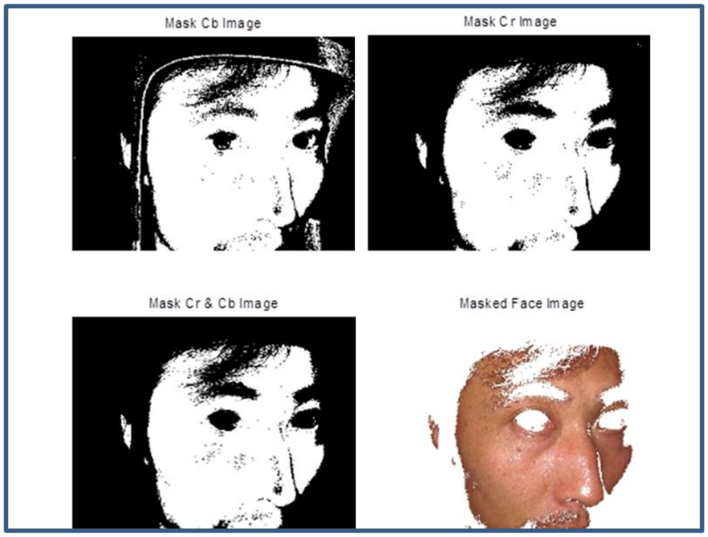


Figure 7. Process of Face Masked

This box will be used to store entire image pixel information inside it. Box borders are determined by finding the minimum and maximum values of axis coordinate and box ordinate [16]. On the horizontal coordinate, each row of pixel will be traced to find minimum and maximum pixels of face masked image that produced by previous step. This case will produce value of Y_{min} and Y_{max}. This also happen in vertical coordinate, each column will be traced to find X_{min} and X_{max} as described in Figure 8.

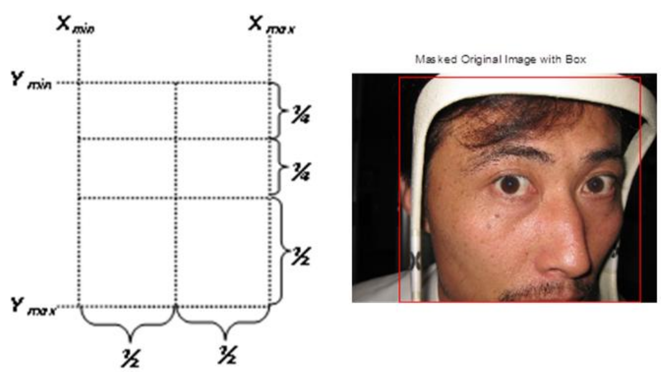


Figure 8. Box simulation

According to Figure 8, after getting a box then we cut an eye area appropriate with normal proportion of human face. As described in Figure 9, left eye area is shown by the shaded box between $X_{mid} – X_{max}$ and $Y_{mid1} – Y_{mid2}$. Then we apply a boundary box to the face masked image.

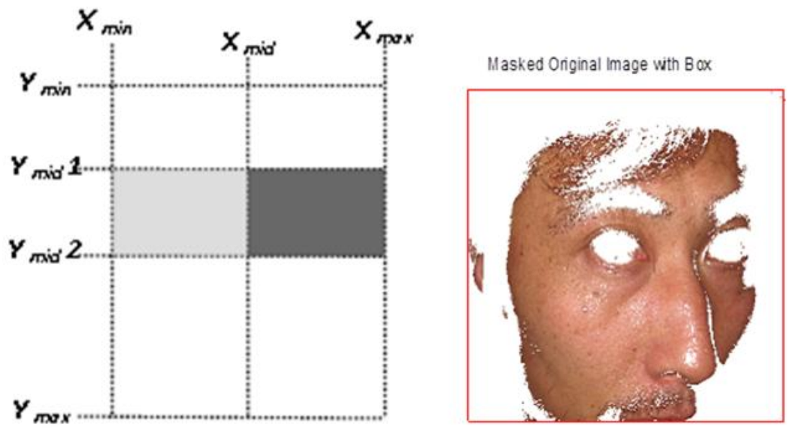


Figure 9. Estimation of Eye Area

Cutting pixel information appropriate to the eye area is did on 1 layer image model. After cutting, then we restore the image information to the original image. The result is described in Figure 10.

Figure 10. Image of Left Eye Area

3.3. Pupil Step

This stage is the core of the whole process of this research. Illustration of the pupil step is described in Figure 11. After getting an image of eye area, then we convert RGB image to LAB image. The advantages of LAB image is capability for displaying brightness image color based on human visual perception. This is give us a benefit to highlight the black color compared to other colors as described in Figure 1.

In order to make an easy process for using Circle Hough Transform , first we have to reduce noise in LAB image by applying segmentation process using Canny edge detection, because Canny detector has a lot of character output to display detailed of image compared to other edge detector.

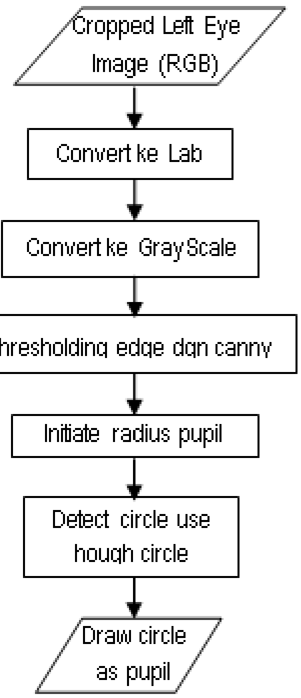


Figure 11. Flowchart of Pupil Step

As described in Figure 12, Robert edge detector shows apart that has wide connectivity elements only. Sobel edge detector is almost same as the Prewitt edge detector.

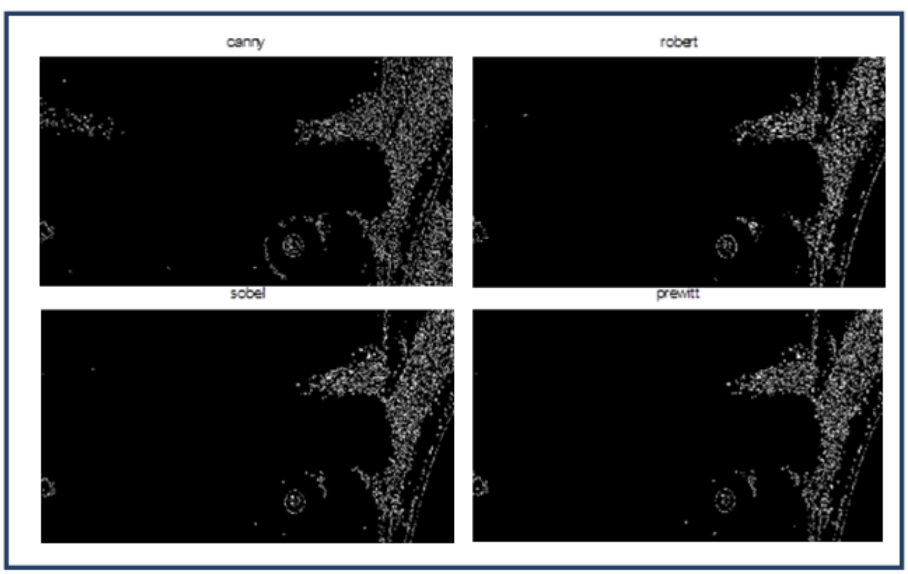


Figure 12. Results of Variety Edge Detectors

The result of edge detection operation is 1 layer image. Then this image is traced using Circle Hough transform. Circle Hough tracing method will do the looping-making circles at each point in the image and find the end point. The end point is determined by finding the point of tangency some circles points. This point will be used to be a center of new circle. Formed new circle is the candidate of pupil image as described in Figure 13.

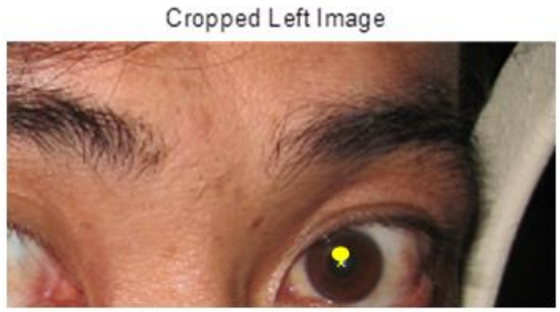


Figure 13. Candidate of Pupil Center

After finding a new circle which is the candidate's pupil, then we create a line based on the center of circle that has been found. By drawing a straight line from the center of pupil to pupil radius, then this line is rotated 360 ° and we will get a circle as described in Figure 14. Following the experimental data of Carlos [22] that pupil diameter is varies between 2.9 to 4.3 mm and the image size 300dpi then we obtained a value 11.8 dots per mm [8]. Thus the distances obtained ranged from 32 to 50 pixel pupil radius. After finding radius then converted into pixel. Every human has different pupil size depends on sex and age. Usually a men has smaller pupil size than women in the same age condition [23]. Because we have a random variant data and does not have the same pattern, then pupil radius is determined by the fix value of different data, varying from 10 to 17 pixels. This variation is caused by several factors such as, lighting, age, eye focusing position and gender.

Figure 14. Pupil Circle

3.4. Iris Step

After getting the center of desired pupil radius, then our algorithm iris circle area. Using pupil radius ranged from 16 – 25 pixels, the best value is 20 pixels. Comparison of iris value is derived from a general size of iris that usually is ranged from 80-130 pixels [3]. Therefore in this research we used ratio of pupil radius and iris radius 1:4 as shown in Figure 15.

Figure 15. Iris Circle

4. Results

After detecting pupil by many variation of radius value, then our algorithm plots iris image appropriate to the center of the same circle. As discussed in previous sub section, we used a distance method by implementing size ratio between pupil and iris is 1:4.

In this research, we implement our algorithm to 125 face images and about 82% images detected successfully. There are 3 kinds of success detection of pupil and iris:

a. Iris boundary detected perfectly (Type1)

b. Iris boundary detected in sclera(Type 2)

c. Iris boundary cut off a part of image (Type 3)

Figure 16 to 18 describes example of iris detection, while Figure 19 describes performance of our algorithm.

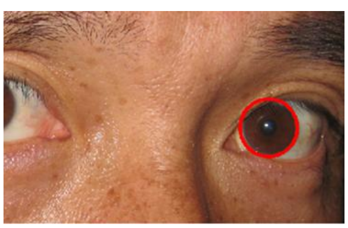


Figure 16. Iris Type 1

Figure 17. Iris Type 2

Figure 18. Iris Type 3

Refer to Figure 16, Iris boundary detected right at the actual location of iris on an object. It is showed by the edge of iris which is described by the red line. There is no error and all edges are detected perfectly. Figure 17, iris boundary is too wide to detect actual edges of iris, resulting a bit of sclera is carried out in the red circle. Figure 18, Iris boundary present a part of actual iris only. It is caused by some objects have a part of visible iris only. Also, sometimes it is caused by step of cropping image is not perfect therefore some part of iris is lost.

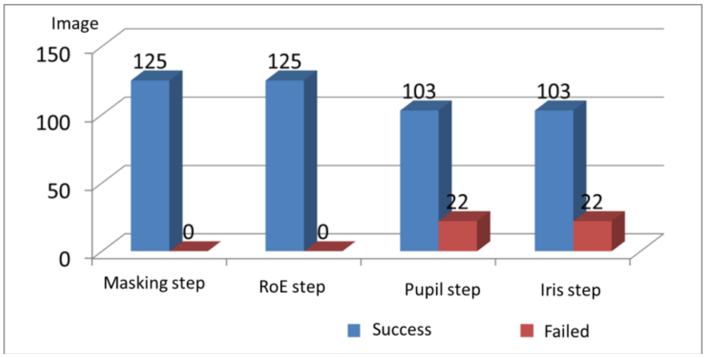


Figure 19. Graph of Performance

In order to summary the steps of our algorithm,. Figure 18 describes steps of our method for detecting pupil and iris

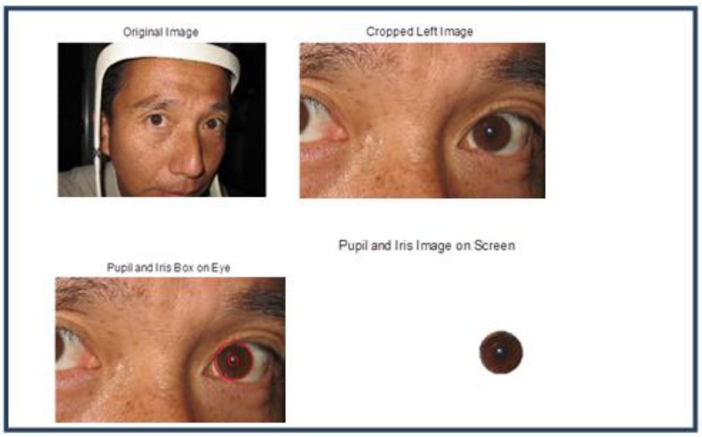


Figure 18. Example of Success Result

5. Conclusions

According to the experiment results, we conclude that Circle Hough Transform could be used to detect pupil and iris by using 4 stages; Masking stage, Region of Eye stage, Pupil stage and Iris stage. This method is promising for detecting pupil and iris under uncontrolled illumination. However, in order to get a good result for further research we have to consider about the procedure for getting an appropriate image acquisition.

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