

# Iris Localization using Circle and Fuzzy Circle Detection Method

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**Abstract**—Iris localization is a very important approach in biometric identification systems. Identification process usually is implemented in three levels: iris localization, feature extraction, and pattern matching finally. Accuracy of iris localization as the first step affects all other levels and this shows the importance of iris localization in an iris based biometric system. In this paper, we consider Daugman iris localization method as a standard method, propose a new method in this field and then analyze and compare the results of them on a standard set of iris images. The proposed method is based on the detection of circular edge of iris, and improved by fuzzy circles and surface energy difference contexts. Implementation of this method is so easy and compared to the other methods, have a rather high accuracy and speed. Test results show that the accuracy of our proposed method is about Daugman method and computation speed of it is 10 times faster.

**Keywords**—Convolution, Edge detector filter, Fuzzy circle, Identification

## I. INTRODUCTION

SINCE development of automatic identification systems in recent years, using of biometric patterns as trusted features have been grown in this field. In fact, these systems, that using biometric patterns, work based on “who really you are”. The color ring around pupil known as iris is one of these patterns.

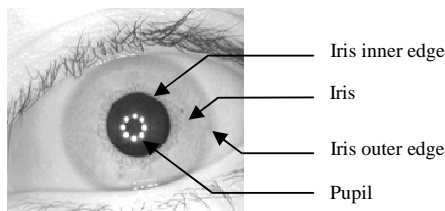


Fig. 1 Iris Image

Iris is the most unique feature of everyone; after DNA, as twins have different iris patterns, too [1]. Even right and left irises of each one are different.

In 1936, ophthalmologist Frank Burch proposed the concept of using iris patterns as a method to recognize an individual [2]. In 1985, Leonard Flom and Aran Safir, ophthalmologists, proposed the concept that no two irises are alike, and were awarded a patent for the iris identification concept in 1987. Then Flom approached John Daugman to develop an algorithm to automate identification of human iris. In 1993, the America Defense Nuclear Agency (ADNA) began work to test and deliver a prototype unit of identification based on iris, which was successfully completed by 1995 due to the combined efforts of Flom, Safir, and Daugman.

In 1994, Daugman was awarded a patent for his automated iris recognition algorithms. In 1995, the first commercial product of it became available. In 2005, the broad patent covering the basic concept of iris recognition expired, providing marketing opportunities for other companies to develop their own algorithms of iris recognition. The patent on the Iris Codes implementation of iris recognition developed by Daugman will not expire until 2011.

First step in an iris recognition system is localizing and segregating the iris from the eye image. That is rather difficult and affects the accuracy of the next steps. In this paper, we will propose a new method on iris localization based on circle detection. Our proposed method is very simple to implement and also have high accuracy and appropriate speed. This simplicity of implementation makes this algorithm to be very usable; also appropriate speed and high accuracy of that make it very applicable in many applications.

The reminder of this paper is organized as follows: Section 2 is the overview of former iris localization methods, especially Daugman's algorithm. In Section 3, we describe our suggested methods, start from simpler one. Finally, in Sections 4 and 5, we analyze and compare result of our methods and Daugman's method on some iris image databases.

## II. OVERVIEW ON IRIS LOCALIZATION METHODS

Due to, significance of iris recognition as one of the most important biometric patterns and influence of iris localization on it, plenty of works in this field has been carried out so far. Many methods and algorithms in iris localization have been provided so far with diverse range of avail. Some of these proposed algorithms are based on morphology, distance transform, Gaussian filters, Gabor filters, and neural networks and so on. Daugman method is the most important one [3]. However, since high performance of this method, it is the main reference to analyze and compare other methods in accuracy

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and runtime. Meanwhile, it has shown some disadvantages in both implementation complexity and generality. Daugman method used iris grayscale images. Each image ( $I(x, y)$ ) is assessed by integrodifferential operator, then by computing maximum of the result, center of iris ( $(x_0, y_0)$ ) and its inner radius ( $r$ ) are specified (see Equation (1)). Next we use this relation once again to compute the outer radius of this iris.

$$DM = \max_{(r, x_0, y_0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r, x_0, y_0} \frac{I(x, y)}{2\pi r} ds \right| \quad (1)$$

This equation act as a circular edge detector where  $*$  denotes the convolution and  $G_\sigma(r)$  is a smoothing function such as a Gaussian of scale  $\sigma$ . Image is a discrete signal then this operator is applied discrete space [4]. Result of this modification is Equation (2):

$$DM = \max_{(n\Delta r, x_0, y_0)} \left| \frac{1}{\Delta r} \sum_k \{ (G_\sigma((n-k)\Delta r) - G_\sigma((n-k-1)\Delta r)) \sum_m I[(k\Delta r \cos(m\Delta\theta) + x_0), (k\Delta r \sin(m\Delta\theta) + y_0)] \} \right| \quad (2)$$

Almost, pupil has a monotonous black color, then by dividing equation above to the same amount with smaller radius (that could be placed inside the pupil). Although having a smaller radius may increase the error and vice versa.

$$DM = \max_{(n\Delta r, x_0, y_0)} \left| \sum_k \{ (G_\sigma((n-k)\Delta r) - G_\sigma((n-k-1)\Delta r)) \sum_m I[(k\Delta r \cos(m\Delta\theta) + x_0), (k\Delta r \sin(m\Delta\theta) + y_0)] \} / \left( \Delta r \sum_m I[(k-2)\Delta r \cos(m\Delta\theta) + x_0), ((k-2)\Delta r \sin(m\Delta\theta) + y_0)] \} \right| \quad (3)$$

Parameters of this equation are similar parameters of (1) and (2).

### III. THE PROPOSED METHOD

Since inner and outer bounds of the iris are almost circular, we can look up for circles in a picture. In this mater we firstly extract a binary image having edges using a edge detector filter such as Canny. Then we have to perform the next operations on that binary picture.

In order to specify iris edges, we used simple circles, then by applying fuzzy circles, increase accuracy of our method and finally implement surface energy difference idea by usage of fuzzy circles difference.

#### A. Standard Circle based Method

We define the circle with the most conformity by edges as

the iris bound. Value of conformity of every circle and edges calculated by an AND operator between that circle and edges binary image, and summing up the result. Greater value locate closer circle to the iris edges. Since examining all circles in an image is time consuming and rather impossible, for each size of radiuses ( $r$ ), we convolve a circular filter ( $C_r$ ) to image ( $I(x, y)$ ):

$$E(x, y) = C_r * I(x, y) \quad (4)$$

$E(x, y)$  shows the conformity of a circle defined by the center pixel ( $x, y$ ) and radius  $r$  with image, so (5) is a suitable way to finding the best candidate for the iris bound.

$$M_1 = \max_{(r, x, y)} (C_r * I(x, y)) \quad (5)$$

#### B. Fuzzy Circles Method

Our proposed method in Section A is a very simple algorithm that it is easy to implement, and has high computation speed. However, in most cases, bounds of an iris do not have an exact circular form. Also, sometimes because of unsharped edges in the input pictures, we do not have complete circle in binary images. These two reasons motivated us to overcome these disadvantages using a fuzzy circle instead of a simple crisp one. So we define a fuzzy circle by using several concentric circles with continuous radius. The definition of this fuzzy circle changes by variation of circles number and their coefficients; these variations have a different sensation on localization accuracy.

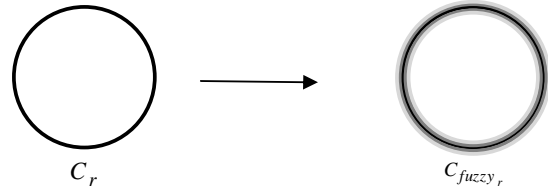


Fig. 2 Fuzzy circle vs. simple circle

We used two different groups of weighted coefficients to analyze affects of different fuzzy circles. The first group includes three circles with  $\{\frac{1}{2}, 1, \frac{1}{2}\}$  coefficients and the second one has five circles with  $\{\frac{1}{4}, \frac{1}{2}, 1, \frac{1}{2}, \frac{1}{4}\}$  coefficients. Suitable circles for iris bounds obtained by (6), where  $C_{fuzzy_r}$  is a fuzzy circle with radius  $r$ .

$$M_2 = \max_{(r, x, y)} (C_{fuzzy_r} * I(x, y)) \quad (6)$$

#### C. Fuzzy Circles Difference Method

Meanwhile, there is massive difference between inner and outer bounds of an iris, so using this advantage, we can looking for two circle with two adjacent radiuses ( $r$  and  $r-1$ ) having most difference in conformity with the image instead of looking for a fuzzy circle with the most conformity. Therefore, radiuses and center of the target circle compute as (7). This

method is implemented easily and has an appropriate accuracy and speed.

$$M_3 = \max_{(r,x,y)} \left( (C_{fuzzy_r} - C_{fuzzy_{r-1}}) * I(x,y) \right) \quad (7)$$

#### IV. TEST RESULTS

We implemented our proposed methods on an Intel Core2Duo / 2.40 GHz computer with 2.00 GB RAM and Windows Vista operating system using Matlab R2007a environment. Furthermore, we applied some standard iris databases such as CASIA V3 [5]. CASIA V3 database includes 2655 iris images from 249 different persons and 396 different classes (right iris and left iris of a person are different). These images are grayscale in JPEG format with 320×280 pixels. Result of localization on this dataset is shown and compared in Table I.

We used the same environment for Daugman algorithm implementation. But this method needs nested loops and is unacceptable due to its run time. Therefore, we try to implement this algorithm using matrices and matrix operators. To materialize that, we use 2 and 3 dimensional convolutions and matrices for summation in Equation (3) and computing maximum of them. However, Daugman method is a time consuming algorithm any way. Result of this implementation is illustrated Table I too.

TABLE I  
ACCURACY AND SPEED OF IRIS LOCALIZATION METHODS

Localization methods	Accuracy (%)	Run time (sec, per iris)
Daugman	97.12	386
Circle based	64.82	27.39
Fuzzy circle based	57.30	27.24
Circle difference based	57.39	27.42
Fuzzy circle difference	92.34	27.62

Table I suggests that accuracy of the fuzzy circle difference method is more than other proposed methods, but is lower (about 5%) than of the Daugman method, yet. Between other methods, the simple circle method is the most accurate one. Perhaps because there is a huge difference between iris and pupil surface, and this makes iris inner edge (pupil edge) very sharp and thin. Therefore, using AND operator and fuzzy circle context, in contrary of other points with a band of edges (around eyelashes, reflex points in pupil, and color rings in iris and etc.), may give a greater value. So this can decrease the accuracy of localization.

In aspect of speed, proposed methods are approximately equivalent, and in comparison with Daugman method is more than 10 times faster. It must remind that these results may be change on difference in implementation environments, operating systems and computers.

We claim that the fuzzy circle difference method is quicker than Daugman method in any case; Firstly since computations of this method perform on binary image whereas Daugman method use grayscale image. Second reason is that our method is implemented using one convolution but Daugman method

needs more than one convolution. These reasons cause a serious decrease in running time of fuzzy circle difference method compared to Daugman method. In general, time complexity of our proposed method is much less.

Regarding the obtained results, severe decrease of time cost of fuzzy circle difference based method in compare with Daugman method (lower than 0.1), to waive 5% more accuracy of Daugman method in some applications is justifiable.

#### V.CONCLUSION

In this paper, our proposed method and Daugman method are compared and analyzed in aspect of accuracy and speed. Based on the obtained results, Daugman method is more accurate than all our proposed methods. But in aspect of iris localization speed, our methods are much faster. In other case, fuzzy circle difference method, accuracy (92.34%) is near to accuracy of Daugman method (97.12%) and computing time per iris of this method is 0.1 times of Daugman. Therefore, we propose this method as a more suitable method for real time and online applications.

Finally, we remind that change in shape of edges, like as using four arcs instead of one complete circle, may improve the accuracy.

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