Open Access
2020, 17(2):583-590

Baghdad Science Journal

P-ISSN: 2078-8665
E-ISSN: 2411-7986

DOI: http://dx.doi.org/10.21123/bsj.2020.17.2.0583

Towards Accurate Pupil Detection Based on Morphology and Hough Transform

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Received 2/1/2019, Accepted 3/9/2019, Published 1/6/2020

Abstract:

Automatic recognition of individuals is very important in modern eras. Biometric techniques have emerged as an answer to the matter of automatic individual recognition. This paper tends to give a technique to detect pupil which is a mixture of easy morphological operations and Hough Transform (HT) is presented in this paper. The circular area of the eye and pupil is divided by the morphological filter as well as the Hough Transform (HT) where the local Iris area has been converted into a rectangular block for the purpose of calculating inconsistencies in the image. This method is implemented and tested on the Chinese Academy of Sciences (CASIA V4) iris image database 249 person and the IIT Delhi (IITD) iris database v1 using MATLAB 2017a. This method has high accuracy in the center and radius finding reaches 97% for 2268 iris on CASIA V4 image and 99.77% for 2240 iris images on IITD, the speed is acceptable compared to the real-time detection speed and stable performance.

Key words: Hough Transform (HT), Morphology operation, Pupil detection.

Introduction:

Security is one of the most important topics which aims to protect human rights from thieves. There are many biometric solutions that try to introduce security. Iris recognition is the most trustworthy biometric authentication system. The iris is a donut, including the colored tissue ring around the pupil and has a very rich pattern of grooves, hills, crows, colon, freckles, and pigment spots. The fine details of the iris tissue are determined by the development of the primary eye and vary from person to person as well as being different for two eyes for the same person, see Fig. 1 (1).

Most iris recognition system incorporates four stages: iris segmentation, iris normalization, along with feature extraction and feature matching (2, 3). However, in the iris recognition system, iris segmentation is considered as the first most significant stage due to the fact that the system performance is based on this step. This step includes separation an iris from different parts in a watch image. In most cases, the iris contains two boundaries an inner and an outer. The inner limit of the iris is defined through the pupil's boundary. The outer limit of the iris, on the other hand, can be seen as the boundary between the iris and the white sclera.

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Many applications should be operated to correct pupil options detection as gaze detection, sickness diagnosis, and iris recognition. Proenca and Alexandre determined a big degradation in respect of iris recognition measures in particular within the state of translation mistake of the separated pupil border (4).

The paper is organized as follows: within the next part, a literature review is presented. Section 3 introduces the Hough Transform (HT) whereas Section 4 describes the proposed new algorithm. Then Section 5 summarizes the findings.

Literature Review

There are a set of iris segmentation algorithms. Daugman (5) proposed an algorithm that used an integral differential operator to define the circular iris boundaries. The Dougman method is considered the most commonly used method of detecting the pupil localization. On the other hand, Wildes (6) applied a Hough Transform (HT) to determine the iris boundaries. Both algorithms are powerful in the performance but they are costly to calculate the fullest image. The methods suggested by Zhu et al. (7) were like the least sequare method, depending on the approximation of the iris boundary. K. Jaehan (8) and A. Hilal (9) proposed the method that takes one of the advantages of the circle Hough Transform (HT) to create effective contour.

Recently there are various proposals suggested by many different researchers for iris recognition outline like, S. M. Talebi et al. (10) which was exercised an effective contour balloon for the iris image segmentation in CASIA V1 database. The disadvantage of this methodology is the manually set for the initial contour.

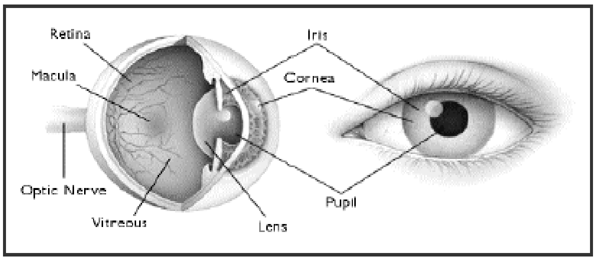


Figure 1. The structure of the eye (1).

Hough Transform (HT)

In recent years, many methods have used Hough Transform (HT) for circle detection to determine the circle (9, 11). The primary advantage of the HT helps to speed up time and reduces search time for finding lines and an identical set of point. Thus, there is also an advantage regarding some general techniques for the fast implementation of the Hough Transform (HT) (12, 13). It can be described as converting the point from the X coordinate and the Y coordinate ((X, Y) plane) to the parameter space (14, 15). According to the structure of the region of interest, the parameter space is designed. The straight line passing via the points (x_1, y_1) and (x_2, y_2) can be described in the (X, Y) plan by (14):

$$y = ax + b \qquad (1)$$

Where (a and b) represent the line parameters within the coordination system. However, Hough transformation for lines does not apply the above illustration for lines, as the lines perpendicular to the coordinate axis will have an infinity a-value.

This can force the infinite size of the parameter space a, b. Instead, a line is drawn by its traditional one, which can be drawn by an angel ‘θ’ as well as a longitudinal one ‘ρ’ as follows (15):

$$\rho = x.cos(\theta) + y.sin(\theta) \qquad (2)$$

Currently, the parameter space will be crossed by the parameter ‘θ’ and ‘ρ’ wherever ‘θ’ may have a finite size based on the resolution used for ‘θ’. The line ρ can be double the diagonal length of the image. The circle is much easier to be defined in parameter space contrasted with the line because the circle parameters can be immediately transformed into the space parameter. A circle's equation is (16):

$$r^2 = (x - a)^2 + (y - b)^2 \qquad (3)$$

As illustrated, (r, a and b) are the circle’s parameters.
Where:
r: is the radius.
a and b: are the center of the circle within the x and y-direction, severally, and
The circle's constant representation is:

$$x = a + r.cos(\theta),$$
$$y = b + r.sin(\theta) \qquad (4)$$

Proposed Methodologies

This section explains the method for circular pupil detection which is a very important stage in the iris recognition system and the pupil significantly affected by segmentation accuracy (3). The pupil is the dark eye or what is known as the glare, which is a hole located in the center of the eye, and its function allows light to pass through to reach the retina, which in turn transforms light rays to nerve signals so that the brain analyzed. The secret of the appearance of the pupil in black is that the light rays that enter the eye are absorbed either by the tissue inside the eye or after it is reflected and spread inside the eye, they out of the eye due to the narrowness of the pupil (4). The size of the pupil varies according to the intensity of the light, by the sphincter and extended muscles located in the iris. The sphincter reduces the pupil to a diameter of 3-5 mm in the case of extreme light, to prevent the large amount of light entering the eye, while the muscle extended to expand the pupil in case of total darkness to introduce the largest amount of light into the eye, and a diameter of up to 9 millimeters (4).

The two-dimensional eye can be located from the centers of the pupils by using Hough Transform (HT) and operations of the morphology. In this work, some concepts have been used as follows: (i) the original image must enhance the contrast using gamma correction then the image is binarized by choosing an appropriate threshold value, (ii) a set of morphology operators are then applied to the binarized image to detect the pupillary and limbic boundaries, then (iii) applying Hough Transform (HT) to detect the pupil. Figure 2, shows the diagram of the suggested method.

In this method, a new idea is for pupil detection. This idea depends on the differences between the intensity level in the pupil regions. A typical feature of the pupil is the darkness. In the gray image, the result will be a low grayscale. Figure 3 shows the corresponding gray histogram of the grayscale eye image. It is clear that most of the pupil region is gray or has a tendency to gray color.

Baghdad Science Journal

P-ISSN: 2078-8665
E-ISSN: 2411-7986

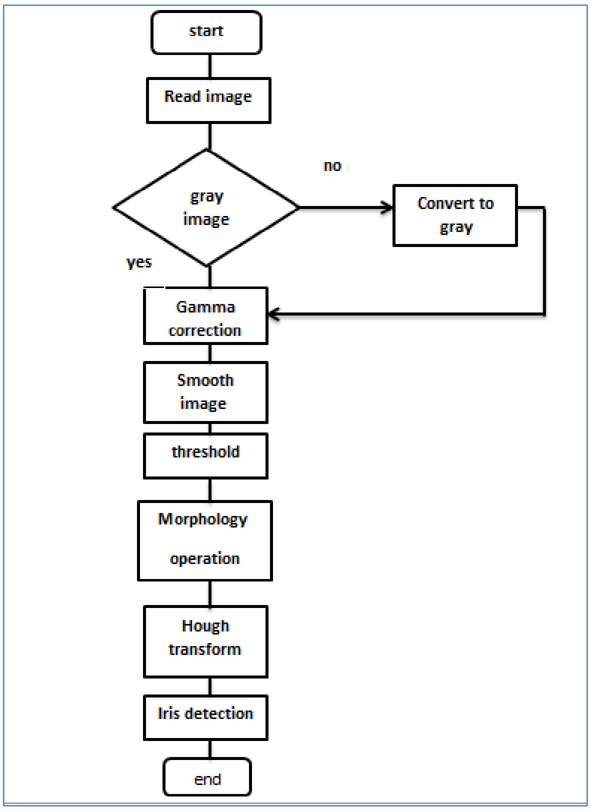


Figure 2. Flowchart of the proposed method for pupil detection

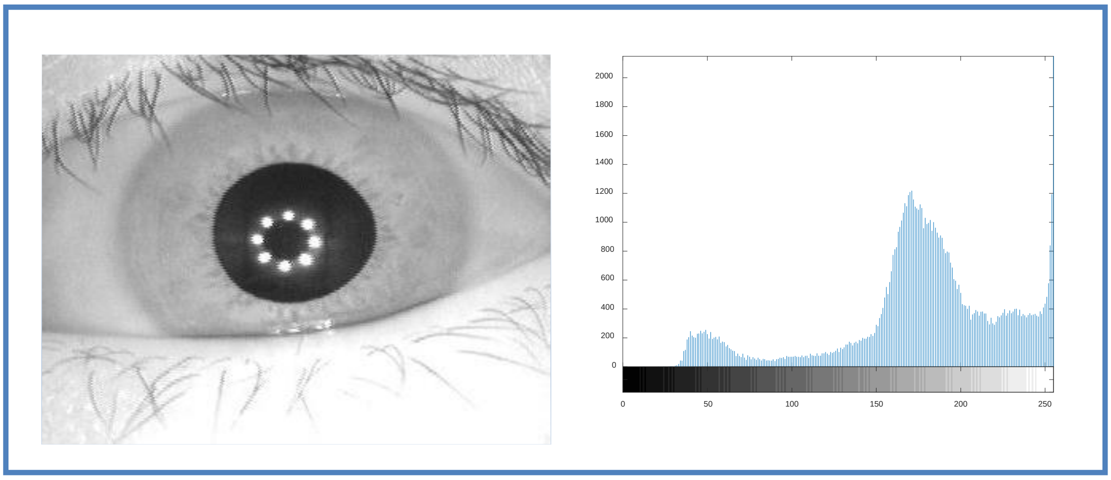
Gamma Correction

The non-linear process which is used to encode and decode luminance values in a fixed image or video systems called Gamma correction. It is an algorithm of non-linear effect compensation for signal transfer between optical and electrical devices. The simplest definition of Gamma correction can be expressed by the power-law expression (17):

$$V_{out} = A\, V_{in}\, \gamma \qquad (5)$$

Where:
A: is constant.
V_{out} and V_{in}: non-negative real values of input and output.
γ : Gamma value or encoding gamma

The mapping between the input and output value might be nonlinear, this is based on the value of gamma. The gamma value is between zero and infinity. When the value of the gamma is one (default), the mapping is linear, if the gamma value is less than one the mapping toward higher (brighter), if the gamma value is more than one, the mapping towards decreases (darker) (17). In this work, gamma is used to be less than one. Figure 4 shows this relationship and how the values are set when gamma is less, equal, and more than one, respectively. In each graph, the x-axis functions the density values in the input image, and the y-axis represents the density values in the output image. Figure 5 shows the effect of gamma correction.



A B

Figure 3. Feature of the pupil: A) Original gray image, B) Histogram of image.

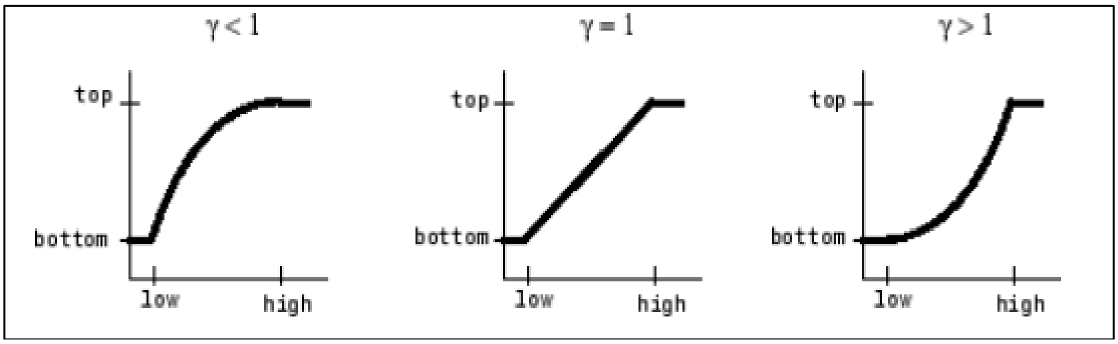


Figure 4. Different Gamma correction (17).

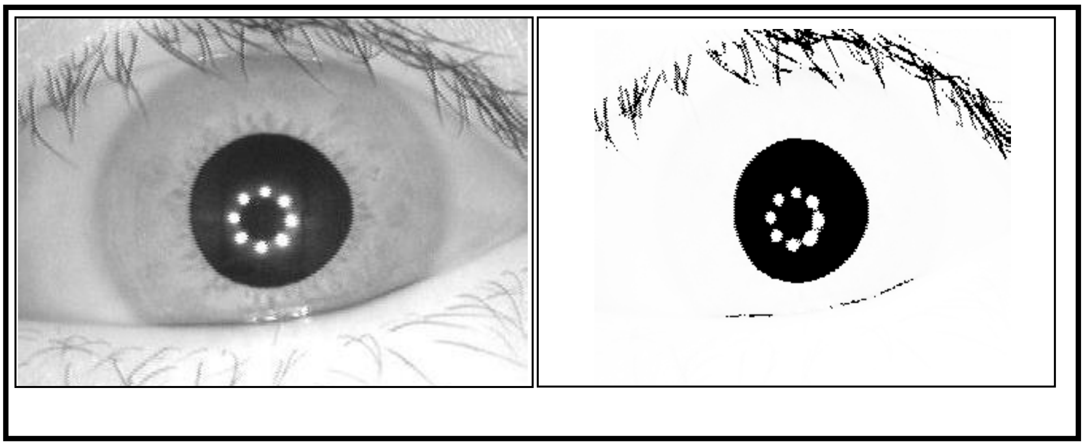


Figure 5. Gamma correction. A) Original gray image, B) Gamma correction ($\gamma = 0.01$).

Morphology

The morphological operation removes the undesirable features by accounting for the form and structure of the image. This is finished through distinctive levels such as smoothing out object outlines, filling small holes, casting off small projection, and using comparable techniques. A set of operation is used such as erosion, dilation, open, and close. Gamma correction and disk filter (circular disk averaging filter) are the first steps for preprocessing that are used to enhance and to smoothen the image. Then applying morphological operation (erosion and close) to remove the reflection and extract the pupil. The erosion process is done by putting down the structuring part on the image and moves it across the image like convolution and applying these steps:

1. If the structure component beginning the match with a '1' in the image, there is no change. Then, goes to the next pixel.

2. If the structure component begins the match with '0' in the image, then the OR system of logic operation will perform on all the pixels inside the structuring component. The dilation process is like the erosion, but the pixels change to '1', not to '0'. Closing operation of dilation will be followed by erosion with the same structuring element and can be used to filling holes and small gaps. The closing of A by structuring element B can be denoted as follows (16):

$$A \bullet B = (A \oplus B) \ominus B \qquad (6)$$

$\oplus$ Dilation and $\ominus$ Erosion

Pupil Detection Algorithm

There are different approaches to detect the pupil of an eye. The most important step in the segmentation is the detection of the circles, the centers, and the radii of these circles must be found. This is done by using circle detection algorithms. A combination of circle detection algorithms, based on morphology operators and HT have been used in this work. Morphology operators is a very time efficient detection method while HT algorithm is robust and good for detecting and fixing the circles. This section explains the steps of the proposed pupil detection algorithm.

Algorithm of Iris Localization
Input:
Image // an eye Image
Output:
$Iris_{radius}$ // radius of the detected iris boundary.
(x_{iris}, y_{iris}) // center coordinates of the detected iris boundary.
(x_{pupil},y_{pupi}l) // center coordinates of the detected pupil boundary.
$pupil_{radius}$ // radius of the detected pupil boundary.

Begin Algorithm

Step 1: "Image Enhancement – return Image Inhac"
Step 2: Convert the RGB image into a gray image.
Step 3: Apply gamma correction on the image, where $\gamma < 1$.
Step 4: Disk filter generation with size 15x15, and find the convolution between image and filter as an equation: $H(x,y) = \sum_x^n \sum_y^m h(x,y) * f(x,y)$
Step 5: Convert image $H(x,y)$ into a binary image "Image Inhac".
Step 6: "Find a circle of the pupil - returns the circle coordinates of the pupil in the image using the Morphology and Hough Transform".
Step 7: Generate a structure element with size 4x4.
Step 8: Apply morphology operation erosion and close between Image Inhac and the structure element.
Step 9: Find the complement of the Image Imagecomplement.
Step 10: Apply HT to the Imagecomlement to extraction center (x_{pupil}, y_{pupil}) and radius of pupil $pupil_{radius}$.
Step 11: Find the circle of iris - returns iris circle coordinates of the image using the following step:
Step 12: Find the minimum value of the Image.
Step 13: DO the following condition:

-If the minimum value is equal to zero apply this equation:

$$iris_{radius} = \text{pupil radius} + (11 * 5) \quad (1)$$

-If the minimum value between 30 and 40 apply this equation:

$$iris_{radius} = pupil\ radius + (minimum\ value * 2) \quad (2)$$

-If the minimum value is between 50 and 60 apply this equation:

$$iris_{radius} = (\text{pupil radius} * 2) + 20 \quad (3)$$

-If the minimum value is greater than 20 only, apply this equation:

$$iris_{radius} = (\text{pupil radius} * 2) + 5 \quad (4)$$

If the minimum value is equal to 11 only, apply this equation:

$$iris_{radius} = (\text{pupil radius}) + \text{minimum} * 5 \quad (5)$$

If the minimum value is greater than 10 only, apply this equation:

$$iris_{radius} = pupil\ radius + (minimm * 4) - 3 \quad (6)$$

If the minimum value is less than 5 only ,apply this equation:

$$iris_{radius} = pupil\ radius + (11 * 4) - 3 \quad (7)$$

If the minimum value is greater than 5 and less than 10 only, apply this equation:

$$iris_{radius} = pupil\ radius * 2 \quad (8)$$

Step 14: Show the results

End Algorithm

Experimental Results

In this section, the implementation of the proposed method is analyzed on CASIA V4-database consisting of 384 different subjects and IITD iris image database. The acquired images were saved in bitmap format. The database is consisting of 2240 images acquired from 224 different users and made available freely to the researchers. All the subjects in the database are in the age group of 14-55 years comprising of 176 males and 48 females. The resolution of these images is 320 x 240 pixels and all these images were acquired in the indoor condition. To analyze the proposed iris segmentation algorithm, two types of databases are used. The first database is the CASIA v4 interval, which consists of 2639 images for 249 people. The second database is IITD v1 which is composed of 2463 images for 240 people. The results show the detection accuracy is 97% in the first database and 99.77% in the second database. The errors are critically analyzed and corrected by adjusting a few parameters. This adjustment helps to achieve the accuracy of 97% and 99.77 on the CASIA and IITD database, respectively. The detection errors are due to the occlusion by the eyelids and eyelashes. In the CASIA Interval database, the proposed algorithm fails to detect 97 pupil, 66 pupils of them cannot be detected due to the noise on the pupil boundary, while the remaining errors are due to the specular reflection and illumination which plays a crucial role in getting properly segmented iris. The results show 70 detection errors on IITD database. These errors have been critically analyzed and corrected by adjusting a few parameters using gamma correction. The accuracy of the proposed algorithm was 97.34 at 0.001 gamma value. The adjustment of the gamma value and the conditions of the radius helps to reduce the error and improve the accuracy to reach 99.77. Table 1 shows the accuracy of the proposed algorithm and other pupil detection algorithms. Figure 6 and 7, shows the results of the pupil detection based on Morphology and Hough Transform (HT) using CASIA V4 and IITD V1 Iris Database, respectively. To evaluate the performance of the proposed algorithm, the accuracy of the pupil detection can be measured as follow (3):

$$Accuracy = \frac{\text{Number of correctly segmented pupils}}{\text{Total number of input pupils}} \quad (7)$$

All the pupil areas of the tested images are extracted correctly and the accuracy rate of the initial tests was 97% and 99.34% for CASIA and IITD iris database, respectively. This technique offers the following advantages:

1) Using morphology reduces computational time.
2) Improves overall efficiency.
3) High accuracy in detecting the center and radius of the pupil.

Many stimulations based on the experiment are promoted using MATLAB codes. The database used in this paper is obtained from The Chinese Academy of Sciences-Institute of Automation-CASIA-IrisV4 and from the Biometrics Research Laboratory at IIT Delhi- IITD Iris Database V1.

Table 1. Accuracy of different pupil detection algorithms.

The Algorithm	Accuracy%
Integro-differential Operator (5)	90.3%
Active contour with Hough transform (9)	99.3%
Hough transform with edge detection (18)	95.7%
Proposed Morphology and Hough Transform using CASIA and IITD iris database	97% and 98% respectively
Morphology and Active Contour (3)	99.5%

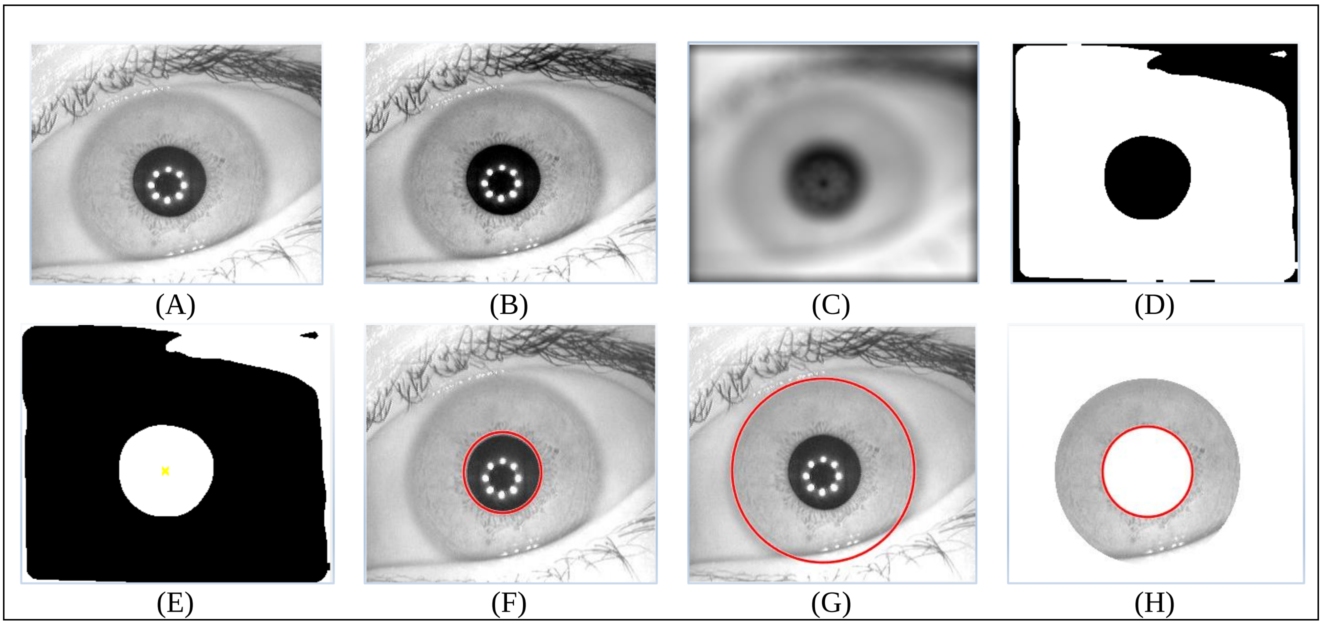


Figure 6. Running steps of the proposed algorithm on the input image for CASIA database, where A) Original image, B) Gamma correction ($\gamma = 0.01$), C) Smooth filter (disk filter of size 15*15), D) Morphology (erosion and close operation), E) Complement and HT to detect the pupil center, F) pupil detection, G) iris detection and H) circler iris detection.

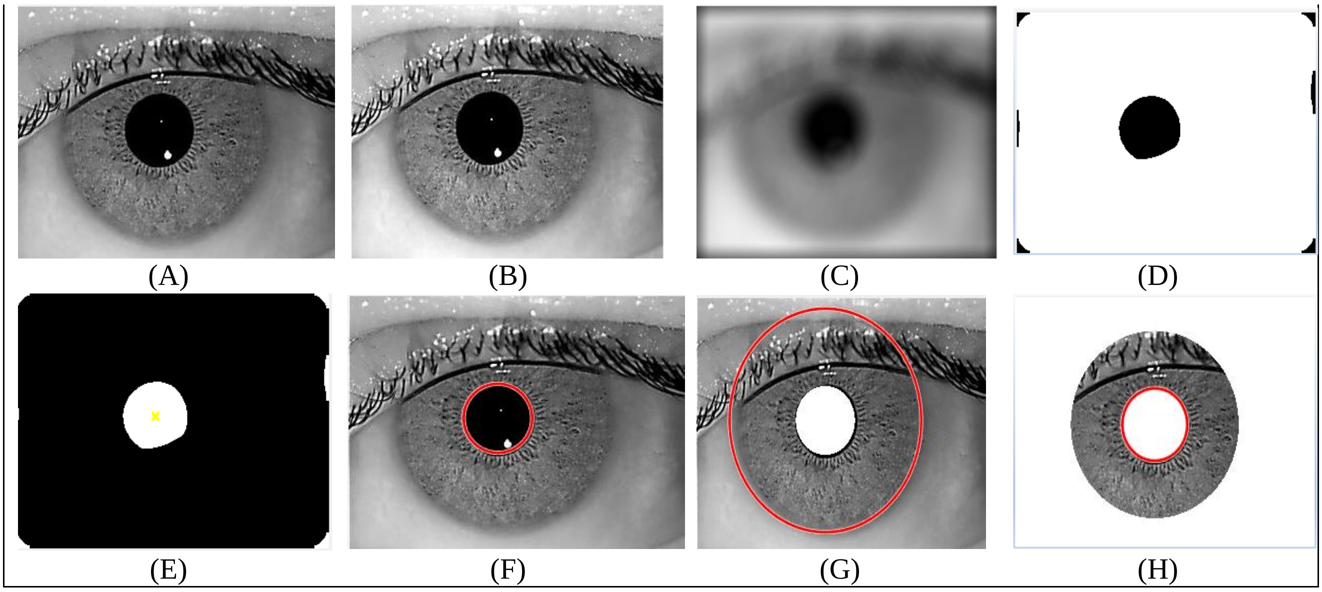


Figure 7. Running steps of the proposed algorithm on the input image for CASIA database, where A) Original image, B) Gamma correction ($\gamma = 0.01$), C) Smooth filter (disk filter of size 15*15), D) Morphology (erosion and close operation), E) Complement and HT to detect the pupil center, F) pupil detection, G) iris detection and H) circler iris detection.

Conclusion:

The use of the iris as a recognition system is one of the most stable methods of biometric technique. The overall structure of each iris recognition system is the same. Iris system must detect iris in the input image, which is the main step in this system. The introduced method relies on morphology operation and HT to select the center of pupil and radius, and then calculate the radius of the iris. The morphology reduces the complexity of the pupil detection which can improve the overall performance and reduce the speed calculation. However, eyelashes will be removed in the process of morphology, and HT generation for the more accurate contour of the pupil boundary. In addition, the proposed algorithm is good and effective with the pupil isolation from the iris and correctly iris radius and center finding. However, by some adjustment of the parameters, the segmentation accuracy has been increased from 96% to 97% for CASIA and from 96.34% to 99.77% for IITD. The proposed algorithm shows accurate results to be considered for iris segmentation.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Kufa.

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نحو كشفٍ دقيق للبؤبؤ بناءً على التشكل مورفولوجي وتحويل هوف

مريم عمران **ابتسام نجم الشمري**

قسم علوم الحاسوب، كلية علوم الحاسوب والرياضيات، جامعة الكوفة، النجف، العراق.

الخلاصة:

التعرف التلقائي على الأفراد مهم للغاية في العصور الحديثة. ظهرت تقنيات القياس الحيوي كإجابة على مسألة التعرف الفردي التلقائي. تميل هذه الورقة إلى إعطاء تقنية لاكتشاف البؤبؤ وهي مزيج من العمليات المورفولوجية السهلة ، و تحويل Hough (HT) . يتم تقسيم المنطقة الدائرية للعين والبؤبؤ بواسطة المرشح المورفولوجي وكذلك تحويل Hough حيث تم تحويل منطقة Iris القزحية المحلية إلى كتلة مستطيلة لغرض حساب التناقضات في الصورة. يتم تنفيذ هذه الطريقة واختبارها على قاعدة بيانات صور قزحية الأكاديمية الصينية للعلوم (CASIA V4) لـ 249 شخص وقاعدة بيانات IIT Delhi (IITD) iris v1 باستخدام ماتلاب MATLAB 2017a . تتميز هذه الطريقة بدقة عالية في ايجاد المركز وتبلغ نسبة الوصول إلى دائرة نصف قطرها 97٪ لـ 2268 قزحية على صور CASIA V4 و 99.77٪ لصور قزحية 2240 علىIITD ، والسرعة مقبولة مقارنة بسرعة الكشف في الوقت الحقيقي والأداء المستقر.

الكلمات المفتاحية: تحويل هوف Hough Transform (HT) ، عملية مورفولوجيا ، كشف البؤبؤ.