A New Circle Detection Algorithm for Pupil and Iris Segmentation from the Occluded RGB images

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ABSTRACT

In this paper we introducė a new circle detection algorithm for occluded on/off pupil and iris boundary extraction. The proposed algorithm employs 7-step processing to detect a center and radius of occluded on/off eye images using the property of the chords. The algorithm deals with two types of occluded pupil and iris boundary information; one is composed of circle-shaped, incomplete objects, which is called occluded on iris images and the other type consists of arc objects in which circular information has partially disappeared, called occluded off iris images. This method shows that the center and radius of iris boundary can be detected from as little as one-third of the occluded on/off iris information image. It is also shown that the proposed algorithm computed the center and radius of the incomplete iris boundary information which has partially occluded and disappeared. Experimental results on RGB images and IR images show that the proposed method has encouraging performance of boundary detection for pupil and iris segmentation. The experimental results show satisfactorily the detection of circle from incomplete circle shape information which is occluded as well as the detection of pupil/iris boundary circle of the occluded on/off image.

***Keywords**: Circle Detection, Pupil segmentation, Iris Segmentation, RGB Image.*

1. INTRODUCTION

Detecting geometrical shape in an image is a fundamental issue in image processing applications. Extracting circles from digital images has received more attention for several decades because an extracted circle can be used to yield the location of a circular object in many industrial applications. So far, many circle-extraction methods have been developed. The Circle Hough Transform (CHT) [1] is one of the best known algorithms and aims to find circular shapes with a given radius r within an image. Usually an edge map of the image is calculated then each edge point contributes a circle of radius r to an output accumulator space. For an unknown circle radius, the algorithm should be run for all possible radii to form a 3-dimensional parameter space, where two dimensions represent the position of the center, and the third one represents the radius. The output accumulator space has a peak where these contributed circles overlap at the center of the original circle.

In spite of its popularity owing to its simple theory of operation, the CHT has some disadvantages when it works on a discrete image. The large amount of storage and computing power required by the CHT are the major disadvantages of using it in real time applications. Many modifications have been reported to increase the CHT performance so far. Tsuji and Matsumoto decomposed the parameter space and used the parallel property of circles [2]. Several methods utilize randomized selection of edge points and geometrical properties of circle instead of using the information of edge pixels and evidence histograms in the parameter space. Xu et al. [3] presented an approach that randomly selects three pixels. The method selects three non-collinear edge pixels and votes for the circle parameters which are found by using the circle equation. Chen and Chung [4] improved Xu et al.'s method by using the randomized selection of four pixels. However, the randomized selection method has its own problems such as probability stimulation, accuracy and speed that are dependent on the number of edge pixels. Yip et al. [5] proposed a method which has reduced the parameter dimension, but estimated the parameters of the circles based on local geometrical properties which often have suffered from poor consistency and location accuracy due to quantization error. To overcome these disadvantages, Ho and Chen [6] used the global geometrical symmetry of circles to reduce the dimension of the parameter space. There are several approaches without using the gradient information [6][11-13]. Ioannou et al. [11] adopted the property that the line perpendicularly bisecting a chord of the circle passes through its center. The UpWrite method used the spot algorithm to produce the local models of the chosen edge pixels [7]. The chosen edge pixels are those in a circular neighborhood of the parameter radius r centered on the chosen edge pixels. Also there has been many works to make the CHT size-invariant [8]. Though these approaches reduced heavy computational burden, other problems have still remained.

With some prior knowledge about an image, we can simplify

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the CHT and reduce the algorithm's difficulties according to especial features of the problem. Use of edge orientation information was first suggested by Kimme et al. [9], who noted that the edge direction on the boundary of a circle points towards or away from the circle's center. This modification reduced computational requirements as an arc only needed to be plotted perpendicular to the edge orientation at a distance r from the edge point. In the limit, arcs may be reduced to a single point in the accumulator space. Minor and Sklansky [10] extended the use of edge orientation, by plotting a line in the edge direction to detect circles over a range of sizes simultaneously. This has the added advantage of using a two rather than a three-dimensional parameter space.

As an example of application of our algorithm we will present iris segmentation for automatic retinal vessel extraction from RGB images. On the relevant methodologies of iris segmentation, J. Daugman presented one of the most relevant methodologies, constituting the basis of many functioning systems [14]. This author introduces an integrodifferential operator to find both the iris inner and outer borders. Wildes proposed iris segmentation through a gradient based binary edge map construction followed by circular Hough transform. This methodology is the most widely used [15]. Liam et al. proposed one simple method based on thresholds and function maximization in order to obtain two ring parameters corresponding to iris inner and outer borders [16].

Authors from [17] propose one iris detection method based on priori pupil identification. The image is then transformed into polar coordinates and the iris outer border is identified as the largest horizontal edge resultant from Sobel filtering. This approach may fail in case of non-concentric iris and pupil, as well as for very dark iris textures. Morphologic operators were applied by [18] to obtain iris borders. They detect the inner border by applying threshold, opening and image closing and the outer border with threshold, closing and opening sequence.

Based on the assumption that the image captured intensity values can be well represented by a mixture of three Gaussian distribution components, authors in [19] proposed the use of Expectation Maximization algorithm to estimate the respective distributions parameters. They expect that 'Dark', 'Intermediate' and 'Bright' distributions contain the pixels corresponding to the pupil, iris and reflections areas.

In our research, we get the main idea of the property of intersecting chords, and design an algorithm to find center point and radius from circular shapes that are totally thinning representation of background image. Later, we will show that there would be some applications that satisfy such conditions using simple preprocessing.

We presented an approach that selects the candidate six pixels. The method selects six pixels as compared with the numbers of pixels and votes for the circle parameters which are found by using the circle equation. The condition of being circular boundary edge information forces all edge directions of a circle to be outward or inward, so we can use the property of intersecting chord to detect the linear equation passing the center of the circle. We can find the center of the circle using the chosen six-pixels and the linear equation. Then we compute the radius and redraw a circle from the center information. Our method is not based on CHT, but on the property of the chords to improve the circle detection's complexity.

The rest of the paper is organized as follows. Section 2 describes our algorithm in detail, and section 3 presents experimental results based upon two-type incomplete circular shape objects as well as center and radius detection results of pupil/iris part from the occluded on/off RGB images and IR(Infrared) images. Section 4 is assigned to present conclusion and future works.

2. THE PROPOSED CIRCLE DETECTION ALGORITHM

2.1 The properties of the intersecting chords

In this section, we describe the property that relates the center of a circle to its chord as illustrated in Fig. 1.

Consider a circle and its chord AB (Fig. 1). Let C(x, y) be a center point of the circle, passing its chord p1p2. Let C' be the midpoint of the perpendicular line of the chord AB and an interior point of the circle with its center at C(x, y) and its diameter p1,p2. Note that the perpendicular bisector of any chord of a circle passes through its center C(x, y). If the perpendicular line of any chord AB passes its center C(x, y) of the circle, the perpendicular line will be a diameter of the circle and the midpoint C' is the center of the circle. The points A, B are defined as the endpoints of the circle boundary edge information.

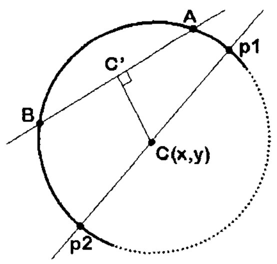


Fig. 1. A property of the chord of the circle

2.2 The proposed circle detection algorithm

In this section we present our algorithm. Suppose that we gave a circular shape object in binary thinned edge information. The following paragraphs explain the major steps of our algorithm.

2.2.1 Finding all the edge information of a circle.

The first step is to learn all the pixels information and storing two-dimensional array. This information would be used to select the candidate six pixels of circular boundary edge information.

2.2.2 Selecting the candidate six points of a circle.

The second step is to select the candidate six pixels of circular boundary edge information, as compared with the numbers of pixels.

2.2.3 Computing the center point if the distance between endpoint A and endpoint B is diameter.

The third step is for dealing with the image that includes the approximately circle shape information but incomplete. This process is computed from the center (C') between endpoint (A) and endpoint (B) and compared with the distance of the rest of the candidate four pixels. If the differences of the distances are smaller than thresholds, the center (C') between endpoint (A) and endpoint (B) is considered as the real center of the total circular shape edge information. The process deals with the case when diameter is the distance between endpoint (p1) and endpoint (p2). The endpoints A, B are automatically selected by the algorithm when they find and storing all the pixels.

2.2.4 Finding the linear equation of the candidate center point.

The fourth step is applied to find the linear equation for locating the center from incomplete circle information that is partially discarded, and/or that the center of the circle does not exist in the image. In the case that the center of the circle does not exist in image, we expand the size of image. Then we find the candidate linear equation passing the candidate center of the circle. From the linear equation we find the candidate center.

2.2.5 Finding the global minimum.

The fifth step is searching for the global minimum to find the center of the circle by avoiding local minima using the candidate six pixels. This method of choosing global minimum is performed by comparing with all the candidate results that are considered, all the possible candidate centers of the circle on the linear equation of the previous step. Then, we deduce the center information from incomplete circular object through this process.

2.2.6 Computing radius.

The sixth step is to compute radius of the circle using the candidate six pixels. The candidate six pixels might not place on the exact edge points of circle boundary. Also the experimental image does not have all the information of the circle boundary. We need to draw the exact circle shape based on the center and radius in the next step.

2.2.7 Drawing the circle.

The seventh step is for draw the estimated circle with the center and radius of the circle.

3. EXPERIMENTAL RESULTS

The proposed algorithm was implemented in Matlab v7.0.2 and executed on 2.66 GHz Pentium IV desktop PC.

Its performance was demonstrated with various synthetic thinned representations of binary images. Experimental results on RGB images and IR images are given here. We present experimental results based on two-type incomplete circular shape objects. One is the image that includes incomplete but roughly present circle object within the image. The other example deals with the images that locate the center from incomplete circle information which is partially occluded and discarded, and/or that the center of the circle does not exist in the image.

The thinned images including incomplete but roughly circle information objects are shown in Fig. 2(a), (c). The proposed algorithm was applied to it and the detection results are shown in Fig. 2(b), (d). The algorithm still worked well even if incomplete and discrete (disconnected) information of the circle was presented as the original thinned edge image.

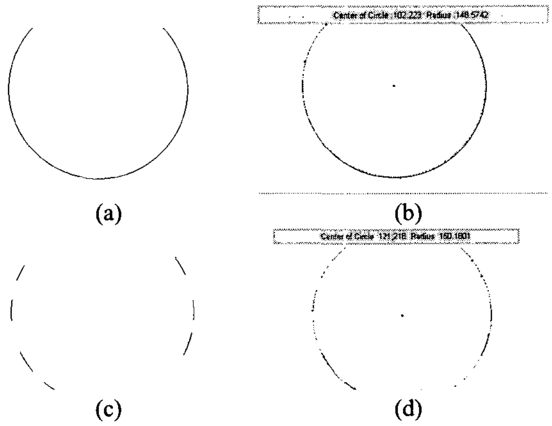


Fig. 2. Examples of center and radius detection of circle from incomplete but roughly circle shape information. (a) Image with the disappeared upper part of a circle. (b) Center and radius detection result from (a), which shows a blue circle according to the result of the center and radius. (c) Image with the disconnected and cut off upper and lower part of a circle (b) Center and radius detection result from (c).

The second type of the circular information images are shown in Fig. 3(a), (c) which contain incomplete and particularly partially disappeared circular information. Fig. 3(b), (d) shows the result of the detected circle, respectively. Even though two-thirds of a circle as well as semicircle were occluded by the image boundary, it was successfully detected. The results of these images are not depicted the center point of a circle because the center is not exist in the image.

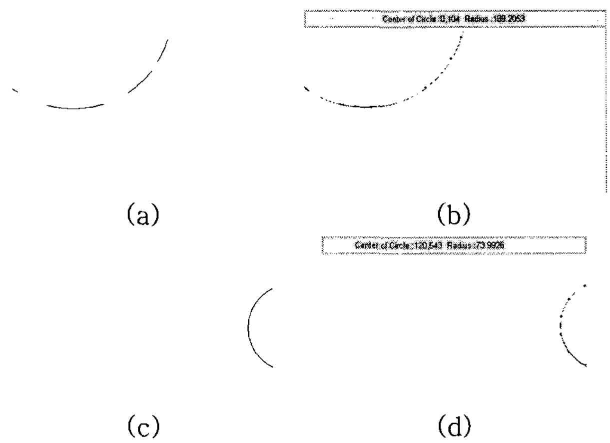


Fig. 3. Examples of center and radius detection of circle from incomplete circle shape information that has no center points within the image and/or is partially disappeared. (a) Image with the disconnected and as little as one third of the

circular information. (b) Center and radius detection results from (a) (c) Another example of image with incomplete circular information. (d) Center and radius detection results from (c)

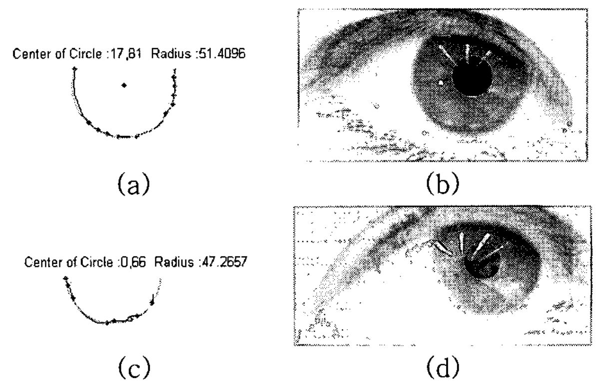
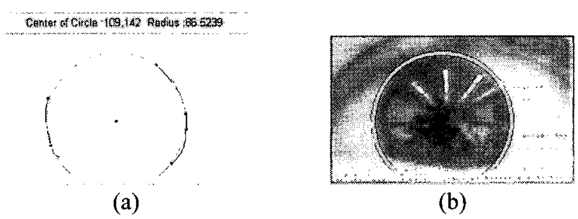


Fig. 4. The Examples of pupil circle detection of RGB images. (a) Center and radius detection result on the thinned representation of eye image. (b) The result of pupil boundary detection with the result of (a). (c) Center and radius detection result on the thinned representation of occluded off iris image. (d) The result of pupil boundary detection with the result of (c)

Experimental examples of the proposed algorithm for automatic pupil and iris segmentation from the occluded pupil and iris on RGB images and IR images are illustrated in Fig.4, Fig.5, and Fig.6. Because of the space limitation, we do not deal with the preprocessing for the thinned representation of pupil/iris boundary. The experimental examples of center and radius detection of pupil from RGB images are illustrated in Fig. 4. The experimental results of center and radius detection of iris boundary from RGB images are illustrated in Fig. 5. Circle and radius detection result from the thinned representation of occluded iris image is shown Fig. 5(a). The applied result of the original RGB image with the result of Fig. 5(a) is presented in Fig. 5(b). Circle and radius detection result on the thinned representation of iris image as the example of occluded off iris image is depicted in Fig. 5(c). The applied result of the original RGB image with the result of (c) is illustrated in Fig. 5(d). The examples of pupil and iris detection from IR images are represented in Fig. 6. Actually, the iris boundary of the occluded off eye image such as Fig. 5(d), Fig.6(b) and Fig. 6(d) is not circle shape, but we can also use the proposed algorithm to segment iris for iris recognition and retinal vessel extraction.



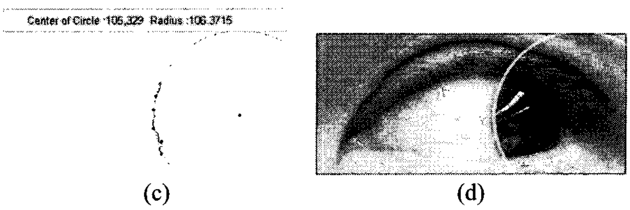


Fig. 5. The Examples of center and radius detection of occluded iris from RGB images. (a) Circle and radius detection result on the thinned representation of iris part. (b) The result of iris boundary circle detection with the result of (a). (c) Circle and radius detection result on the thinned representation of iris part as the example of occluded off iris image. (d) The applied result of the eye image with the result of (a)

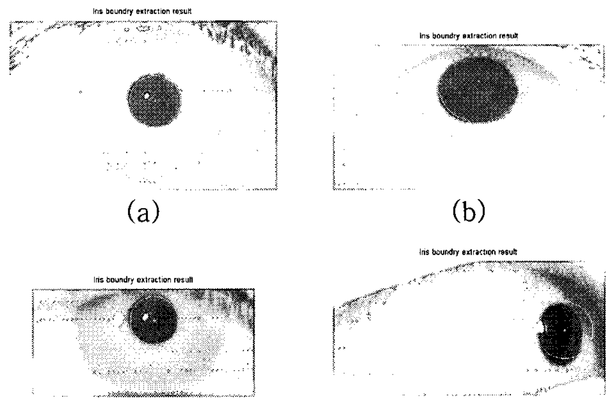


Fig. 6. The Examples of center and radius detection of pupil/iris from IR images. (a) The result of pupil/iris detection result on straight direction (b) The result of pupil/iris detection from occluded off image (c) The example of pupil/iris detection from occluded IR images on straight direction. (d) The result of pupil/iris detection from occluded off image

4. CONCLUSION AND FUTURE WORKS

We propose an new circle detection algorithm for detecting the center and radius of pupil and iris from occluded RGB image and IR images for iris recognition and retinal vessel extraction. The proposed algorithm employs 7-step processing to detect a center and radius of occluded on/off iris image. Our algorithm is not based on CHT, but on the property of the chords to improve the circle detection's complexity.

The algorithm deals with two types of occluded circle shape information on RGB images and IR images; one is composed of circle-shaped, incomplete objects, which is called occluded on iris images and the other type consists of arc objects in which circular information has partially disappeared, called occluded off iris images.

The proposed method supports an effective circle detection algorithm for pupil/iris segmentation and is very helpful in detecting circular shape information in industrial and medical fields. Especially it will be applied for eye tracking for motion detection and pupil/iris segmentation for human eye image.

The experimental results show that the proposed algorithm is robust and accurate circle detection from incomplete, occluded and disconnected information of the circular shape information. Even though two-thirds of a circle as well as semicircle were occluded by the image boundary, it was successfully detected. The Experimental results of pupil and iris segmentation from the occluded on/off RGB and IR images are presented as an example of various applications of the proposed algorithm.

In the sequence of this work this method will be expanded for a center and ellipse detection of pupil and iris on occluded off images and improved to support an automatic pupil/iris segmentation algorithm for iris recognition and retinal vessel extraction from raw color digital images.

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