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Iris localization by means of adaptive thresholding and Circular Hough Transform

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Abstract

In this paper, a new iris localization method is presented for mobile devices. The proposed system uses both the intensity and saturation thresholdings on the captured eye images to determine the iris boundary and sclera area, respectively. The estimated iris boundary pixels placed outside the sclera are removed. The remaining pixels are mainly the iris boundary inside the sclera. Then a circular Hough transform is applied to such iris boundary pixels in order to localize the iris. The experiments are carried out on 60 iris images taken by an HTC mobile device from 10 different persons with both the left and right eye images available per person. We also evaluate the proposed algorithm on the MICHE datasets for iphone5, Samsung Galaxy S4, and Samsung Galaxy Tab2. The evaluation results obtained show that the developed system can successfully localize iris on the tested images.

Keywords: *Iris Localization, Iris Segmentation, Adaptive Thresholding, Circle Hough Transform, Mobile Biometrics.*

1. Introduction

Currently, about 1.7 billion people all over the world are connected to the internet via mobile devices. This number has been projected to be close to 2.5 billion in 2016 [1]. This explosion of communication via mobile devices has oriented many image-processing techniques to be adapted with mobile devices. Iris segmentation and localization have a wide range of applications in some image-processing tasks like iris recognition and eye-gaze estimation. To be integrated in such systems, an iris segmentation algorithm must be fast (as a pre-processing step) and robust to different noise factors (specular reflections, obstructions due to eyelashes, eyelids, glasses, etc.). Furthermore, and more importantly, mobile cameras use the visible spectrum of light, unlike the normal iris cameras that use the IR spectrum of light (700–900nm). There is a huge problem in the visible band: most people in the world have dark brown eyes (in terms of the visible band), thus the lightness of iris is very low. Therefore, corneal reflections of a bright ambient environment completely dominate the iris image. This is not a problem with the IR band because iris is much lighter (the melanin pigment does not absorb the IR light), and thus optical tricks can be played to scrub away the environmental corneal reflections, allowing only a narrow waveband of light from the camera itself to return to the camera with an iris image. However, this is not possible with mobile devices whose cameras indeed sense only the visible band. This is the main problem with iris recognition on mobile devices.

Nevertheless, most of the earlier studies on iris segmentation have focused on the accurate detection with iris images, which are captured in closely-controlled conditions [2]. It is possible to use simple image-processing tools under controlled lighting conditions. However, the performance of iris segmentation decays significantly if the lighting conditions are irregular; the acquisition is accomplished on the move or with mobile devices.

Daugman has used an integro-differentio operator to localize the iris [3]. A new algorithm has been designed using genetic-based Hough transform algorithm (GACHT) to implement iris detection [4]. The Department of Computer Science in the

University of Beira Interior has organized the contest of “noisy iris challenge evaluation – part I” (NICE.I) in order to examine the performance of the existing methods until 2009 [5]. The NICE.I team has compared different iris segmentation algorithms to indicate the best solutions when the natural noise factors are present in the eye images taken under the visible light. They have pointed out which solutions perform better and which ones should be avoided in analyzing a particular type of iris images. In [6], segmentation of the noise-free regions of iris from the RGB input images has been performed. To this end, firstly, the reflections in the input image have been localized, segmented, and filled in. Then on-concentric circles have been employed to model the iris boundaries. Next, the authors have localized the lower and upper eyelid boundaries modeled as a circular arc and a line segment, respectively. In [7], the authors have proposed to represent the segmented iris region based upon a combination of the appearance-based pixel-level segmentation and eye geometry-based iris delineation.

In [2], the AdaBoost eye detection has been employed to compensate for the errors caused by the two circular edge detection operations. In [8], it has been proposed to add a new pre-processing step using the K-means algorithm to exclude the non-iris regions, which cause many errors and decrease the searching time of the circular Hough transform. In [9], the authors have proposed a model selection method (one circle model and two ellipse ones) to enhance the stability and accuracy of color iris segmentation. They have extracted the histogram of oriented gradients (HOGs) [10] from a ring-shaped region as a feature vector. Then a classifier has been trained using the HOG features, and the classification decision has been used to select the optimal segmentation in the test phase. In [11], the authors have introduced the watershed-based iris detection technique for smart mobile devices.

The advantage of a watershed transform is that the contours delimiting the regions into which an image is divided are mostly placed where human observers perceive them. In [12], the authors have employed the generalized Hough transform (GHT) for an accurate segmentation of the eye region subsequently elaborated by a modified integro-differential Daugman operator. In [5], the iris region has been obtained by setting the threshold values for the saturation and intensity layers of the processed eye image.

In this article, we propose a new scheme based on thresholding saturation and intensity layers of image and choosing a circle model for iris localization. We investigate the color iris segmentation using the images captured by a mobile device HTC desire. The proposed method is also applied on well-known MICHE datasets. The remainder of the paper is organized as follows. Section 2 introduces the proposed method involving thresholding and circle Hough transform. In section 3, the experimental evaluation of the proposed method is presented. Finally, the paper will be concluded in section 4.

2. Proposed method

The diagram of the proposed iris segmentation scheme is depicted in figure 1.

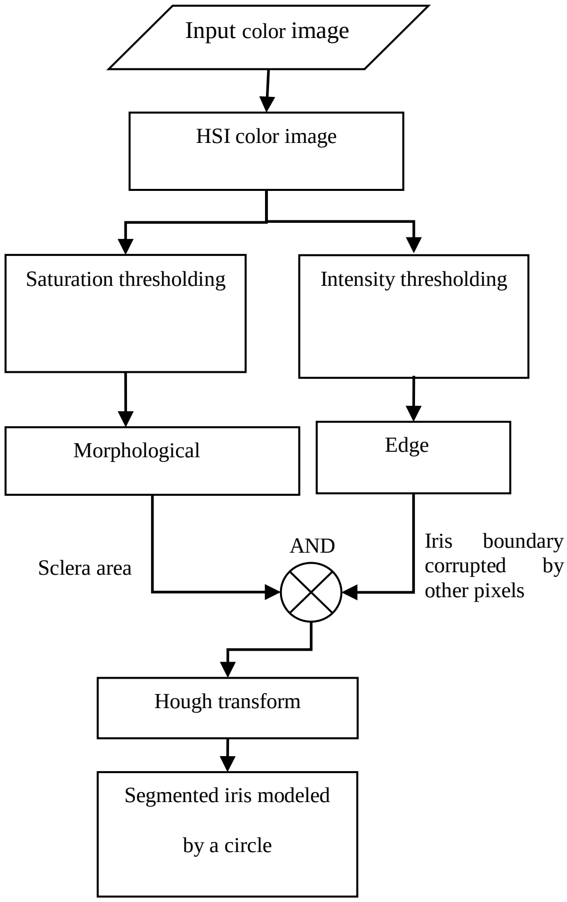

Figure 1. Flow diagram of proposed iris segmentation system.

The heart of the proposed system is the circle Hough transform (CHT). CHT is a robust algorithm used in finding circles in an image; it, however, suffers from computational complexity. In the proposed system, we employed a thresholding procedure as a pre-processing stage in order to remove the unnecessary data and to speed-up CHT.

In the thresholding stage, our aim was to detect the iris boundary. Investigation of different databases showed that the iris was usually the darkest part of the eye image. Thus by thresholding on the intensity layer of the image, we tried to segment the iris region. However, distinguishing between sclera and skin by thresholding on intensity was very difficult. Our experiments showed that the image saturation level was more suitable for segmentation of sclera. Thus by thresholding on the saturation level, the sclera region was segmented. By considering the fact that most of the iris boundary pixels were in the sclera neighborhood, we used the logical AND operator to extract the pixels, which had a more chance to be in the boundary of iris and sclera. These pixels were fed into CHT in order to model the iris by a circle. This system is detailed in the following sub-sections.

2.1. Intensity and saturation thresholdings

Intensity thresholding was employed in order to determine the iris region in the eye image. The input color image was represented in the HSI color space. The intensity layer (known as the gray level) was converted into a binary image using a thresholding method described by the process shown in figure 2 [13].

As it can be seen in figure 2, the input gray level image, f(x,y), was segmented using an initial threshold value, τ, which was determined by:

$$\tau = \frac{1}{2}[\min(f(x,y)) + \max(f(x,y))] \tag{1}$$

Then the binary image g(x,y) was computed by:

$$g(x,y) = \begin{cases} 0 & if \quad f(x,y) > \tau \\ 1 & if \quad f(x,y) < \tau \end{cases} \tag{2}$$

This will produce two groups of pixels; G1 (as the object) consisting of all pixels with gray level values lower than τ, and G2 (as the background) consisting of pixels with values greater than τ. μ_1 and $\mu_2$werecomputed as the mean value of G_1 and G_2, respectively. The threshold value τ was updated using the mean value of μ_1 and μ_2, as depicted in the flow diagram. The process was iterated until the difference in τ in successive iterations was smaller than a pre-defined value T_0.

The aforementioned threshold scheme will extract iris as well as some parts of the eyelids and eyelashes. The opening morphological operator was applied to remove small spots (e.g. salt). Then the Laplacian edge detector was applied to the image to get the contours of the cavities. However, it is okay to replace recent edge detection methods like that proposed in [14] instead of our simple edge detection algorithm. Figure 3 shows an eye image and its results after thresholding, opening, and application of the Laplacian edge detector.

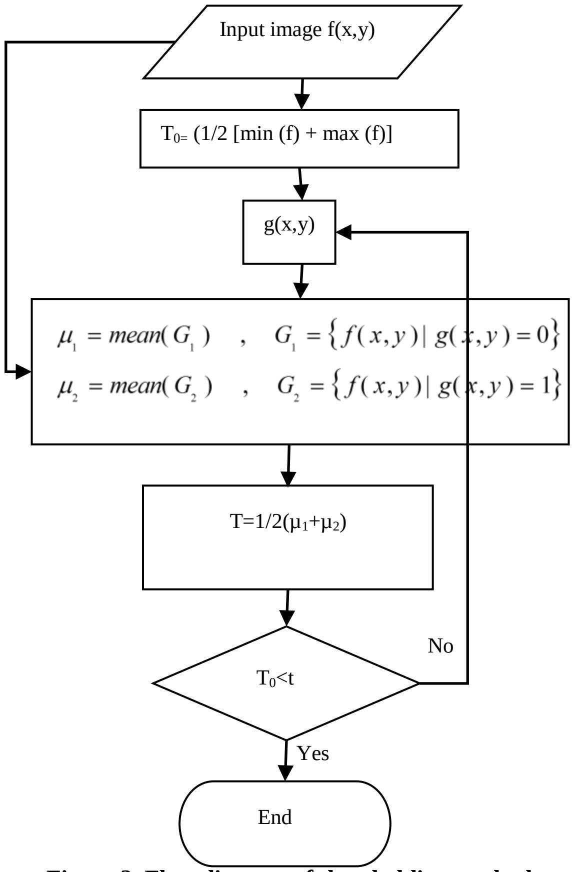

Figure 2. Flow diagram of thresholding method.

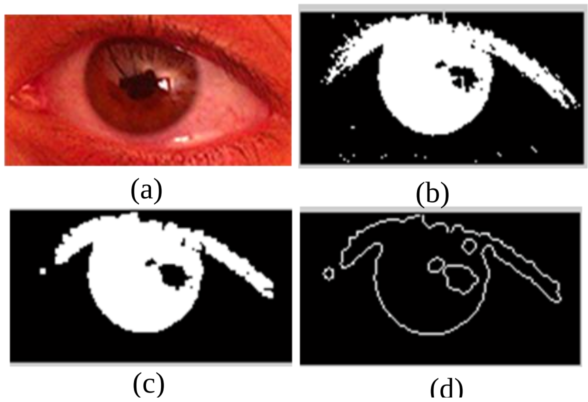

Figure 3. (a) eye image, (b) thresholding result (by process described in figure 2), (c) opening result, (d) result of Laplacian edge detector.

Figure 3(d) contains not only the iris boundary but also some other unwanted parts of the image. In the next stage, the thresholding process shown in figure 2 was applied to the saturation layer of the eye image. This could segment the sclera area of the eye image. By considering the fact that the iris was placed inside the sclera, the pixels of the iris boundary shown in figure 3(d) that were not placed inside the sclera were removed by applying the logical AND operator to the edge image (Figure 3(d)) and the sclera area (Figure 4(b)). Figures 4(a) and 4(b) show the eye image saturation shown in figure 3(a) before and after thresholding, respectively. Figure 4(c) shows the result of removing pixels outside the sclera from figure 3(d).

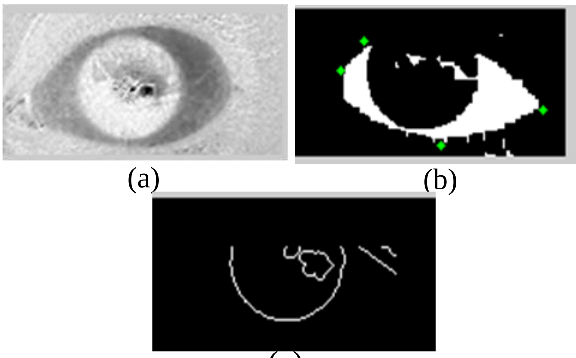

Figure 4. (a) eye image saturation, (b) thresholding result (by process described in figure 2), (c) result of applying logical AND operator applied to iris boundary image and sclera image.

As it could be seen in figure 4(c), the image still contained non-iris boundary pixels.

2.2. Circle hough transform

If we consider the image shown in figure 4(c) as a geometric space, each point in it generates a circle in the parameter space. Figure 5 shows this process for three exemplar points.

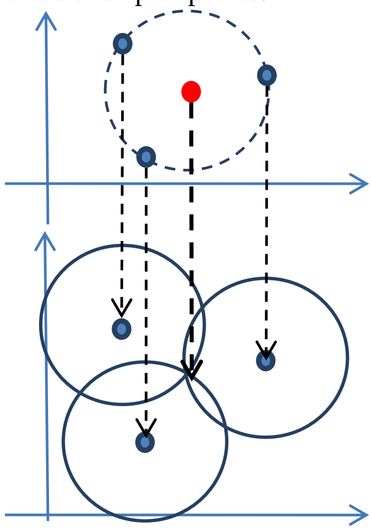

Figure 5. Each point in geometric space (up) generates a circle in parameter space (down). Circles in parameter space intersect at center in geometric space.

In a circle Hough transform (CHT), the problem is to find the center of a circle passing through three or more points. If the radius of the circle is known, it is enough to draw a circle for each point. The intersection of these circles determines the center of the circle passing through the points.
Generally, in CHT, the parameter space can be considered as a 2D array with the same size as the input image, in which the peaks show the potential centers of the circles passing through the points in the input image.
If the radius of the circles is not known, it should be estimated, and the problem should be solved for this variable as well. In our problem, the size of the iris in the image depends on factors such as the distance to camera. However, for each database, it can be easily estimated in a small interval.
It is interesting to know that, based on our experiments, we can find the iris with this method even if we remove the left side of our algorithm shown in figure 1 (saturation thresholding) because CHT is very robust to noise. However, CHT is a time-consuming algorithm, and removing the non-relevant points can effectively speed-up the algorithm.

3. Experiments and results

We implemented the iris localization algorithm in MATLAB version R2014a on windows 8.1 0s with a core i7 processor. Our database images were captured by the mobile device HTC desire. Some image details are listed in table 1. Our database consisted of 60 images collected from 10persons (3 left eyes and 3 right ones).The images were taken in unconstrained outdoor and indoor environments and daylight with the size of 150*76. The results of iris localization for seven selected images are illustrated in figure 7.

Table 1. Details of eye images.

Mobile device	HTC desire
Number of images	60
Resolution	8M(3264*1952),72 dpi
Widescreen	5:3
White balance	Daylight or cloudy
Image size	150*76

In figure 7, for each eye image, the upper one shows the eye images with the detected iris region sounded by a green circle. The lower image depicts the result of the intensity thresholding followed by CHT when the saturation thresholding has been by-passed. It is interesting to see that the results obtained are completely the same. As it can be seen in this figure, the proposed thresholding technique cannot accurately detect iris in the last two images, which is due to the non-circular shape of the iris in some cases. However, in such cases the results are acceptable.
Figures 8-10 show the results of applying the proposed method on some images randomly chosen from theiphone5, Samsung Galaxy S4, and Samsung Galaxy Tab2 datasets. As it can be seen in these figures, the proposed technique can perfectly localize iris in all images.

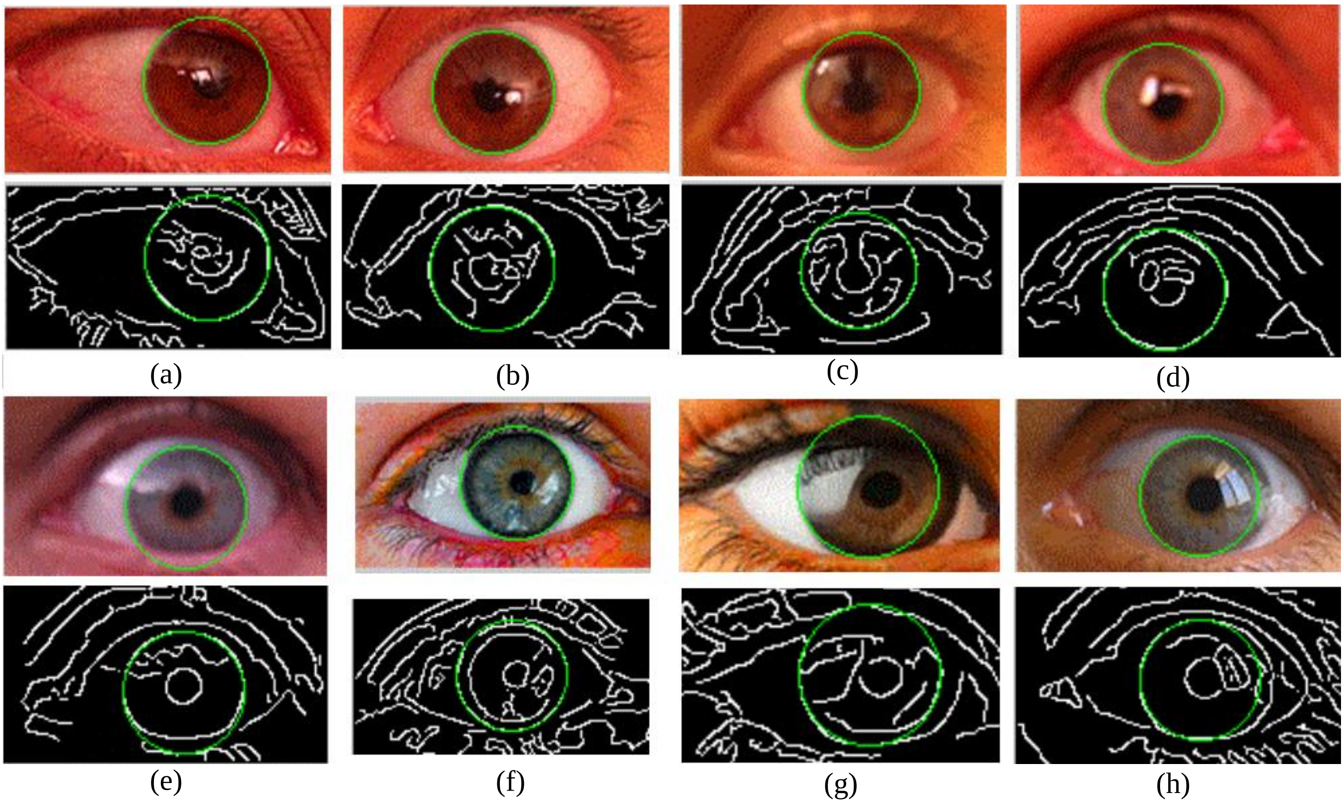

Figure 7. Process of proposed iris localization technique.

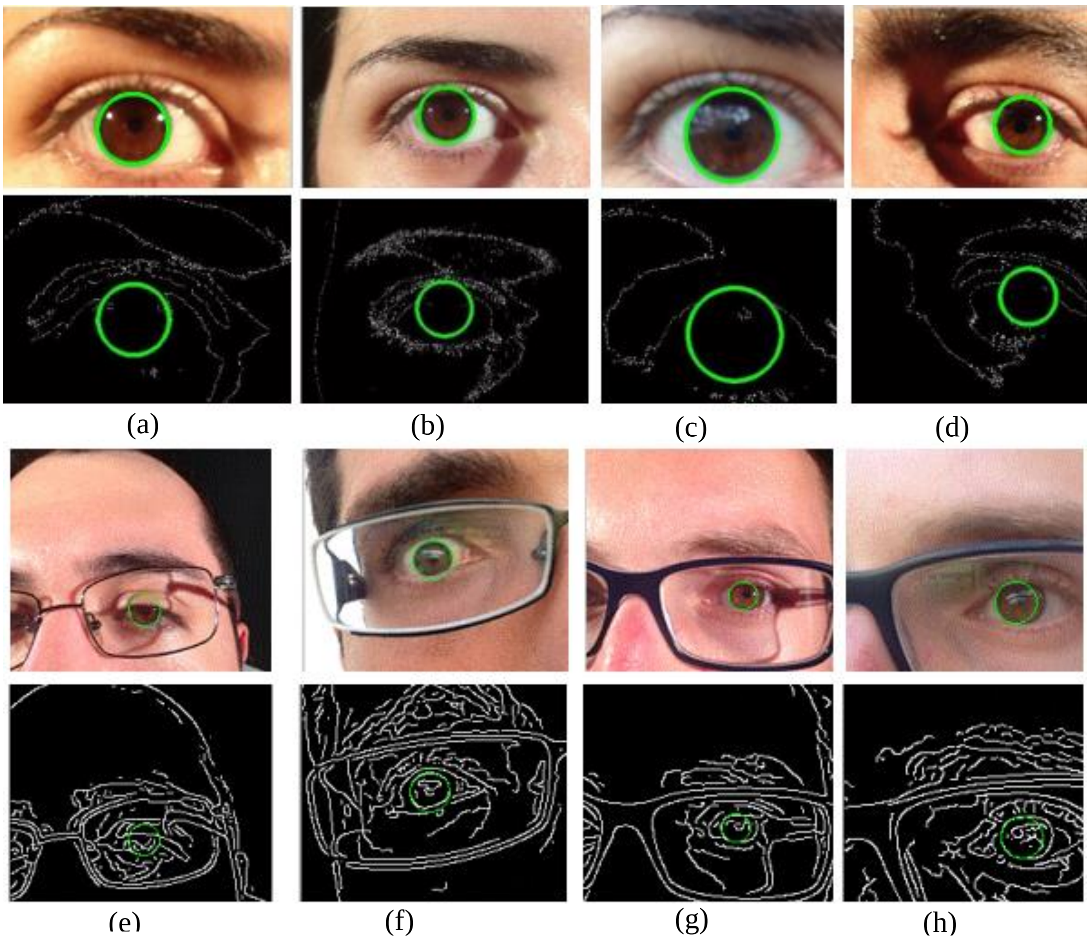

Figure 8. Results of iris detection on iphone5 dataset.

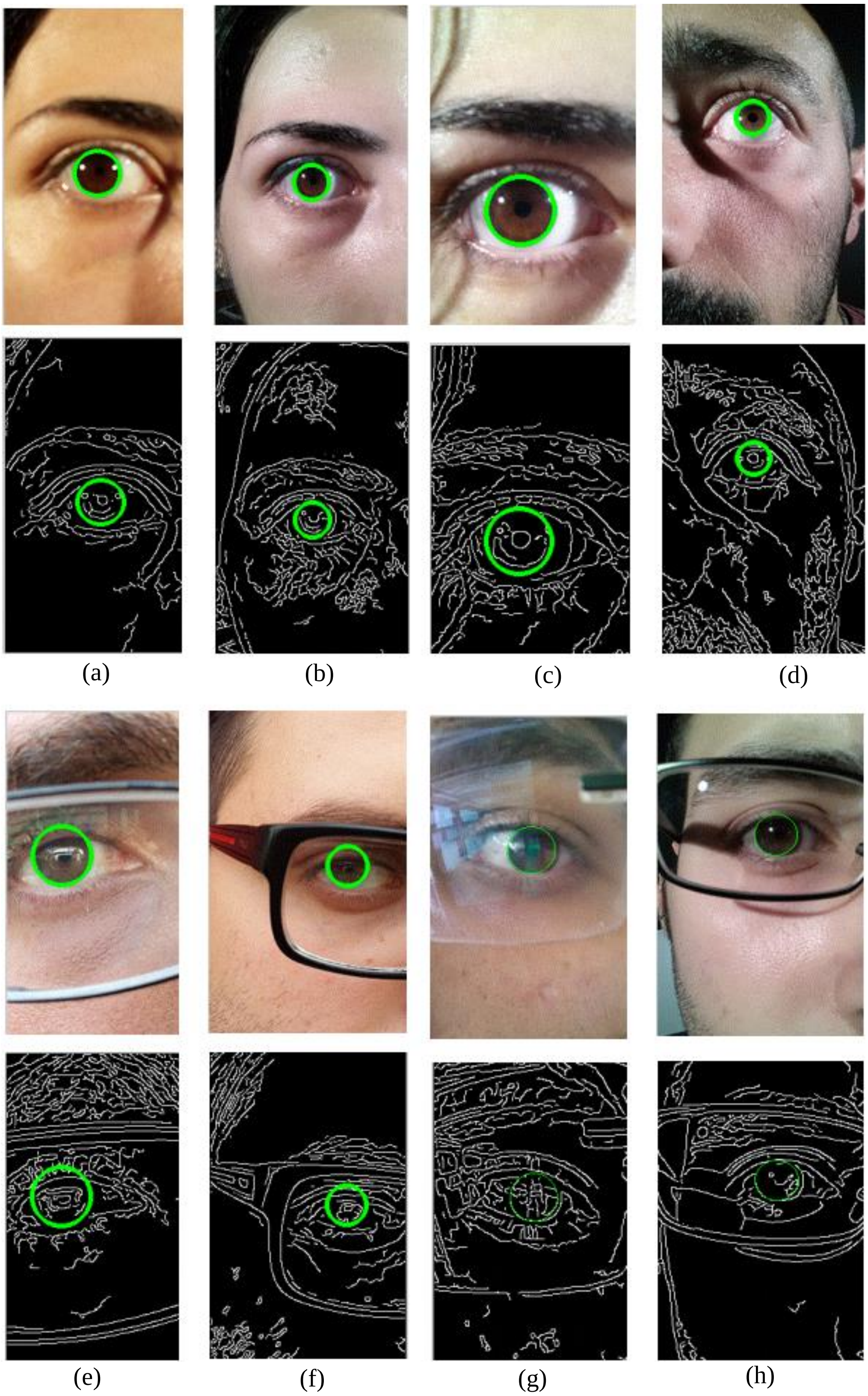

Figure 9. Results of iris detection on Galaxy Samsung S4 dataset.

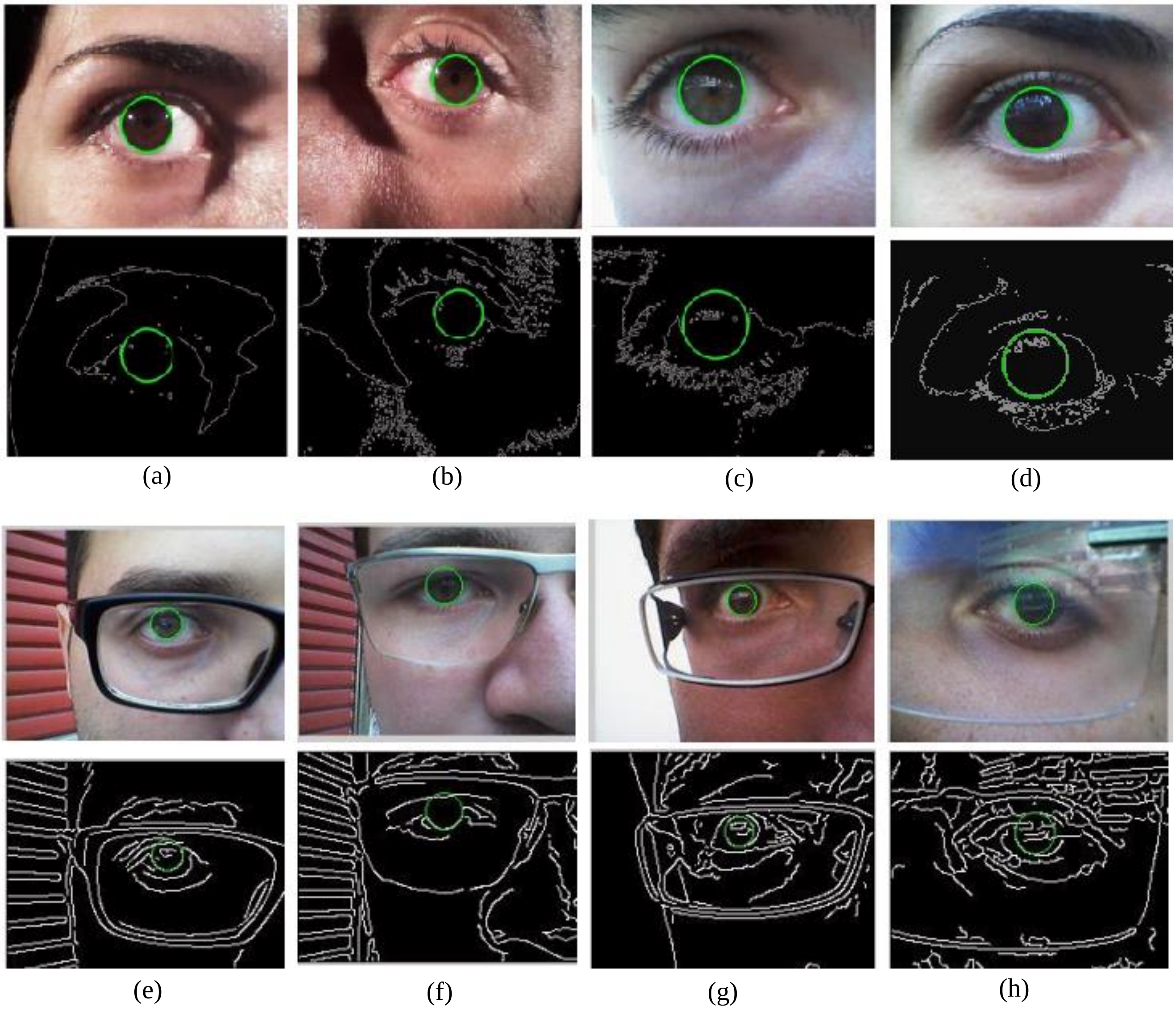

Figure 10. Results of iris detection on Galaxy Samsung Tab2 dataset.

Time complexity and the large amount of memory required are the two major leakages of most of the methods proposed by other researchers. Here, the proposed algorithm tries to solve the problem using a thresholding process as a pre-processing stage of the Hough transform.

It is also useful to review briefly the performance of the figures reported by other works. In [15], the authors have reported a 99.2% accuracy using a robust segmentation method. In [16], a 93% accuracy has been reported using the optimized Daugman algorithm on the UPOL iris image database. In [8], a98.76%accuracy has been reported for images taken in an unconstrained environment. In [11], a 94.9% accuracy has been reported for the images taken by a mobile device. In this work, the proposed algorithm could successfully localize iris on the tested images.

4. Conclusions

In this article, we proposed an automatic iris localization technique for eye images taken by a mobile device. The following conclusions can be drawn from this work.

First, thresholding on intensity is useful for segmentation of iris but, unfortunately, it takes some parts of eyelids and eyelashes. In order to solve this problem, removing the segmented area outside the sclera and small connected components could be effective. Thresholding on saturation has a good performance for segmentation of sclera and removing the irrelevant pixels.

Secondly, the proposed technique of using circular Hough transform (CHT) can precisely localize the iris region on the eye image. Our experiments showed that CHT was very robust in finding circles in an image even in noisy and difficult conditions.

Thirdly, our experiments showed that while the proposed saturation thresholding technique reduced the computational complexity of CHT, by-passing this part of the algorithm did not affect the final result.

Finally, although the circular model could precisely localize the iris region on the eye image, it could not estimate the upper and lower iris boundaries occluded by eyelids. Furthermore, in some cases, the iris was not a circle. In such cases, CHT could not successfully determine the iris boundaries.

There are several major challenges involved in the color iris segmentation. Firstly, the quality of the iris images depends upon the imaging distance. Estimation of eyelid, eyelash, and specular reflection locations is the second challenge. Finally, different colors of skins and irises can degrade the performance of the iris segmentation algorithms. These challenges restrain iris segmentation and localization as an unsolved open problem.

References

[1] Jillela, R. R. & Ross, A. (2015). Segmenting iris images in the visible spectrum with applications in mobile biometrics. Pattern Recognition Letters, vol. 57, pp. 4-16.

[2] Jeong, D. S., Hwang, J. W., Kang, B. J., Park, K. R., Won, C. S., Park, D.-K. & Kim, J. (2010). A new iris segmentation method for non-ideal iris images. Image and Vision Computing, vol. 28, pp. 254-260.

[3] Daugman, J. (2003). The importance of being random: statistical principles of iris recognition. Pattern Recognition 36, 279-291,Daugman, J. G. (1993). High Confidence Visual Recognition of Persons by a Test of Statistical Independence. IEEE Trans. Pattern Anal. Mach. Intell, vol. 15, pp.1148-1161.

[4] Farhan, R. N. (2008). Iris segmentation using GA based circular hough transform (GACHT). J. ofal-anbar university for pure science, vol. 2, no.1.

[5] Ogata, K. & Niino, S. (2015). Automatic threshold-setting method for iris detection for brown eyes in an eye–gaze interface system with a visible light camera. Optics & Laser Technology, vol. 66, pp. 112-121.

[6] Sankowski, W., Grabowski, K., Napieralska, M., Zubert, M. & Napieralski, A. (2010). Reliable algorithm for iris segmentation in eye image. Image and Vision Computing, vol. 28, pp. 231-237.

[7] Pundlik, S., Woodard, D. & Birchfield, S. (2010). Iris segmentation in non-ideal images using graph cuts. Image and Vision Computing, vol. 28, pp. 1671-1681.

[8] Sahmoud, S. A. & Abuhaiba, I. S. (2013). Efficient iris segmentation method in unconstrained environments. Pattern Recognition, vol. 46, pp. 3174-3185.

[9] Hu, Y., Sirlantzis, K. & Howells, G. (2015). Improving colour iris segmentation using a model selection technique. Pattern Recognition Letters, vol. 57, pp. 24-32.

[10] Dalal, N. & Triggs, B. (2005). Histograms of Oriented Gradients for Human Detection. International Conference on Computer Vision & Pattern Recognition (CVPR '05), San Diego, United States, pp. 886–893.

[11] Abate, A. F., Frucci, M., Galdi, C. & Riccio, D. (2015). BIRD: Watershed Based IRis Detection for mobile devices. Pattern Recognition Letters, vol. 57, pp. 43-51.

[12] Haindl, M. & Krupička, M. (2015). Unsupervised detection of non-iris occlusions. Pattern Recognition Letters, vol. 57, pp. 60-65.

[13] Gonzalez, R. C. & Woods, R. E. (2006). Digital Image Processing (3rd Edition), Prentice-Hall, Inc.

[14] Dorrani, Z. & Mahmoodi, M. S. (2016). Noisy images edge detection: Ant colony optimization algorithm. Journal of Artificial Intelligence & Data Mining (JAIDM), vol. 4, pp. 77-83.

[15] Chawla, S. & Oberoi, A. (2011). A Robust Segmentation Method for Iris Recognition. International Journal of Advanced Research in Computer Science, vol. 2, pp. 340-343.

[16] Soltany, M., Toosi Zadeh, S. & Pourreza, H.-R. (2012). Daugman's Algorithm Enhancement for Iris Localization. Advanced Materials Research, vol. 403-pp. 408, 3959-3964.

نشریه هوش مصنوعی و داده کاوی

تعیین مکان عنبیه به وسیله آستانه‌گذاری وفقی و تبدیل هاف دایره‌ای

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چکیده:

در این مقاله، یک روش جدید برای تعیین موقعیت عنبیه در تصاویر عنبیه تهیه شده از گوشی تلفن همراه ارائه شده است. در این روش آستانه‌گذاری بر روی لایه‌های روشنایی و خلوص رنگ تصویر به ترتیب مرز عنبیه و محدوده‌ی صلبیه تعیین می‌شوند. پیکسل‌های تشخیص داده شده بعنوان مرز عنبیه که خارج از محدوده‌ی صلبیه باشند از تصویر حذف می‌گردند. پیکسل‌های باقی مانده همان مرزهای عنبیه هستند که داخل ناحیه‌ی صلبیه قرار گرفته‌اند. سپس از تبدیل هاف دایره‌ای برای تعیین موقعیت عنبیه استفاده می‌شود. الگوریتم پیشنهادی بر روی ۶۰ تصویر تهیه شده بوسیله‌ی تلفن همراه مدل HTC desire که از ۱۰ شخص مختلف و برای هر دو چشم چپ و راست تهیه شده است آزمایش شده است. همچنین پایگاه داده‌ی MICHE شامل بخش‌های iphone5، Samsung galaxy s4 و Samsung galaxy Tab2 مورد ارزیابی قرار گرفته است. نتایج بدست آمده حاکی از موفقیت کامل روش پیشنهادی در تعیین موقعیت عنبیه در تصاویر مورد آزمایش می‌باشد.

کلمات کلیدی:تعیین موقعیت عنبیه، ناحیه‌بندی عنبیه، آستانه‌گذاری وفقی، تبدیل هاف دایره‌ای، زیست سنجش گوشی تلفن همراه.