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Daugman's Algorithm Enhancement for Iris Localization

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Abstract. Iris localization is considered the most difficult part in iris identification algorithms because it defines the inner and outer boundaries of iris region used for feature analysis. Several researches were taken in the subject of iris finding and segmentation. The main objective here is to remove any non-useful information, namely the pupil segment and the part outside the iris. Duda and Hart used Hough transforms to detect the contours and curves. Daugman proposed an integro-differential operator to find both the pupil and the iris contour. Daugman's method is claimed to be the most efficient one. This paper proposes an implementation for Daugman's algorithm, which was found incompatible with visible light illuminated images. Then this paper proposes algorithm enhancement for solving this problem.

Introduction

The human iris begins to form in the third month of gestation and the structure is complete by the eight month, even though the color and pigmentation continue to build through the first year of birth. After that, the structure of the iris remains stable throughout a person's life, except for direct physical damage or changes caused by eye surgery. The iris hence parallels the fingerprint in uniqueness but enjoys a further advantage that it is an internal organ and less susceptible to damages over a person's lifetime [1]. It is composed of several layers which gives it its unique appearance. This uniqueness is visually apparent when looking at its rich and small details seen in high-resolution camera images under proper focus and illumination. The iris is the ring-shape structure that encircles the pupil, the dark centered portion of the eye, and stretches radially to the sclera, the white portion of the eye (XFig. 1), it shares high-contrast boundaries with the pupil but less-contrast boundaries with the sclera.

The iris identification system must automatically recognize the identity of a person from a new image by comparing it to the human iris patterns annotated with identity in a stored database [2]. A general iris recognition system is composed of four steps. Firstly, an image containing the user's eye is captured by the system.

Then, the image is preprocessed to normalize the scale and illumination of the iris and localize the iris in the image. Thirdly, features representing the iris patterns are extracted. Finally, decision made by means of matching. The iris identification system must automatically recognize the identity of a person from a new image by comparing it to the human iris patterns annotated with identity in a stored database [2].

There are four key parts in the iris recognition system: iris image acquisition, preprocessing, feature extraction, and classifier design [3].

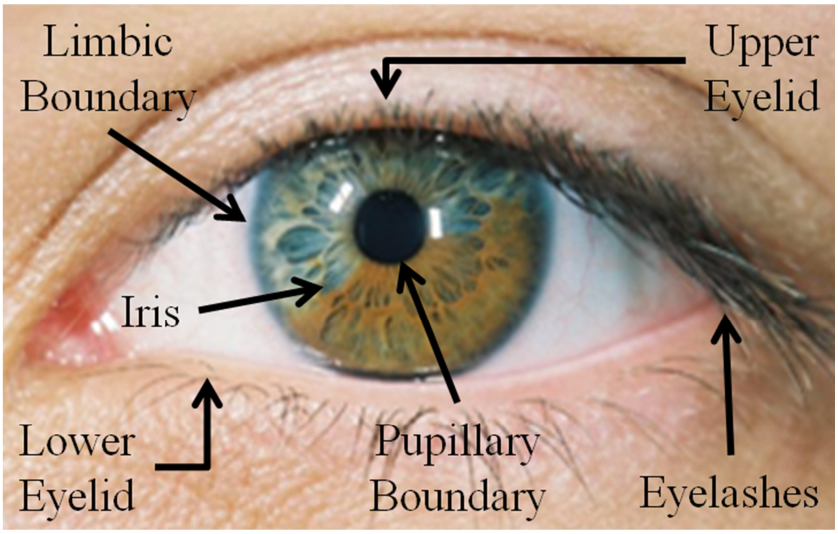

Figure 1. Eye image that used in the iris recognition system

In a world where we will increasingly do business with parties we have never met, and might never meet, authentication will become as integral a part of the transaction as the exchange of goods and tender. The robustness of iris recognition makes it ideal for authenticating parties to commercial transactions, to reduce fraud in applications like check-cashing and ATMs, unauthorized activity in applications like treasury management, and in future, to ensure non-repudiation of sales, or to provide Letter of Credit and other authentication services in an electronic commerce environment [4]. Daugman has shown that iris patterns have about 250 degrees of freedom, i.e. the probability of two eyes having the same iris texture is about 1 in 7 billion. Even the 2 irises of an individual are different thereby suggesting that iris textures are independent of the genetic constitution of an individual. Iris recognition has been deployed successfully in many large scale and small scale applications. Iris localization is considered the most difficult part in iris identification algorithms because it defines the inner and outer boundaries of iris region used for feature analysis [5]. The main objective here is to remove any non-useful information, namely the pupil segment and the part outside the iris (sclera, eyelids, skin). Hough transforms used to detect the iris contour [6, 7]. Daugman proposed an integro-differential operator to find both the pupil and the iris contour. Daugman's algorithm is claimed to be the most efficient one. We analyze The Daugman's iris locating and pointing out the some limitations of this algorithm such as bright spot on pupil, see Fig.2, this paper proposes Daugman's algorithm enhancement for iris localization and overcome to bright spot problem.

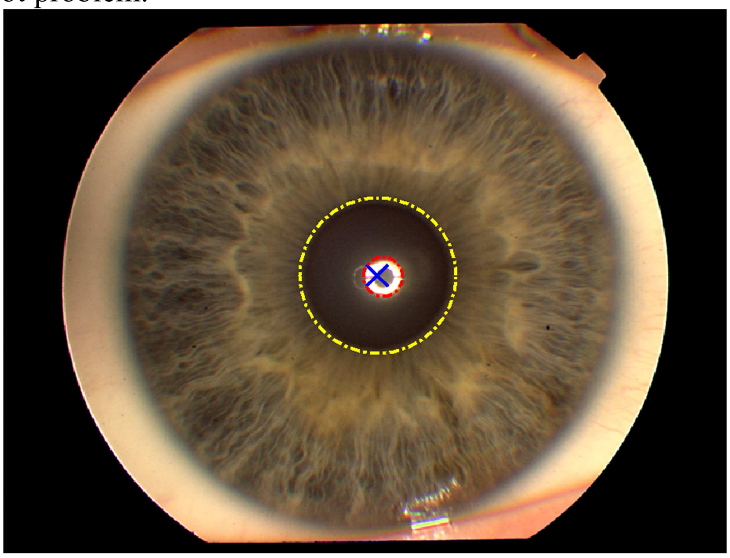

Figure 2. Bright spot problem in iris locating with Daugman's algorithm

Used methods

Daugman's algorithm. Daugman's algorithm is based on applying an integro-differential operator to find the iris and pupil contour [1]. The equation is as follows:

$$\max(r, x_o, y_o)\left|G_\sigma(r) * \frac{\partial}{\partial r}\oint_{r,x_o,y_o} \frac{I(x,y)}{2\pi r} ds\right| \tag{1}$$

Where x_0 ,y_0 ,r_0 are center and radius of coarse circle (for each of pupil and iris), $G_\sigma(r)$ is Gaussian function, Δ_r is radius range for searching for, and $I(x,y)$ is original iris image. $G_\sigma(r)$ is a smoothing function, the smoothed image is then scanned for a circle that has a maximum gradient change, which indicates an edge. The above algorithm is done twice, first to get the iris contour then to get the pupil contour [1]. It worth mentioning here the problem is that the illumination inside the pupil is a perfect circle with very high intensity level (nearly pure white). Therefore, we have a problem of sticking to the illumination as the max gradient circle. So a minimum pupil radius should be set. Another issue here is in determining the pupil boundary the maximum change should occur at the edge between the very dark pupil and the iris, which is relatively darker than the bright spots of the illumination. Hence, while scanning the image one should take care that a very bright spot value could deceive the operator and can result in a maximum gradient. This simply means failure to localize the pupil. The following experimental results have been getting using UPOL database [8].

Gray Projection. The gray projection algorithm, bases on the principle of statistics that accumulates each pixel by row or column in gray scales [9-12]. The process is described as follows.

Given a $M \times N$ gray image $I(i,j)$, which denotes the gray scale of the pixel with the coordinates (i,j), the horizontal and vertical gray projection can be defined as (2) [12].

$$H(i) = \frac{\sum_{j=0}^{N-1} I(i,j)}{N} \quad , \quad V(j) = \frac{\sum_{i=0}^{M-1} I(i,j)}{M} \tag{2}$$

Description of Approach

Pupil segmentation. Pupil part is obviously different from the rest in the gray scale eye image. One typical specialty is darkness of pupil, which results in low gray scales in gray image. Fig.3 (a) is a gray scale eye image, while Fig.3 (c) shows the corresponding gray histogram of it. A wave range clearly marked by a red rectangle that can be seen in Fig.3 (c) which mostly distinguishes the pupil area from the rest of the eye image.

Therefore, the part of pupil can separate simply by classifying the pixels of the eye image with the gray threshold selected according to Fig.3 (c). The pupil part is found through image segmentation.

Segmentation isn't enough for finding pupil area. By calculating the maximum value of curves in the (2), exact boundary box of pupil area can be defined as (3).

$$\mathrm{bin}(i,j) = \begin{cases} \underset{\text{For } 1 \le j \le n}{255} & \text{if } j > fv \;\&\; j < bv \\ \\ \underset{\text{For } 1 \le i \le m}{255} & \text{if } i > uh \;\&\; i < dh \\ \\ 0 & other \end{cases} \tag{3}$$

Where bin(i,j) is the binary image, bv, fv, dh and uh are right, left, down and up sides of the pupil boundary box respectively. As a result, The Fig.3 (b) is binary image of pupil that exactly shows pupil area.

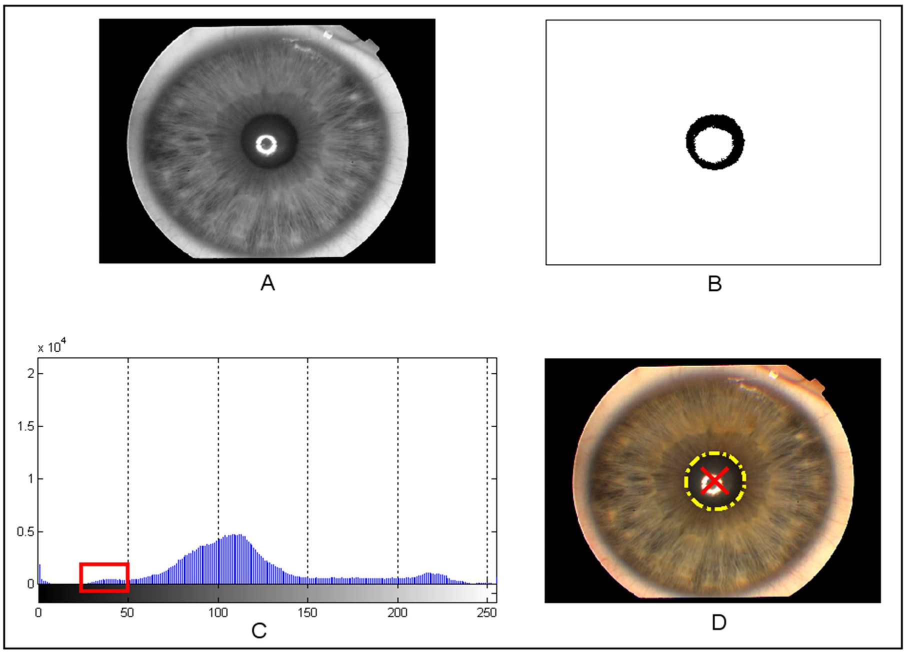

Figure 3. (a) Original gray image (b) Pupil segmentation image
(c) Image gray histogram (d) Exact pupil area

As we mention in section II, bright spot may cause failure to localize the pupil and Fig. 2 show this situation. By applying gray projection, we can find boundary of pupil, hence, it does not need Daugman's algorithm search for pupil boundary from inside of pupil that means bright spot can't cause any problem for pupil boundary localization. Fig. 4 show result of applying gray projection and you can see pupil boundary clearly found and bright spot was ignored.

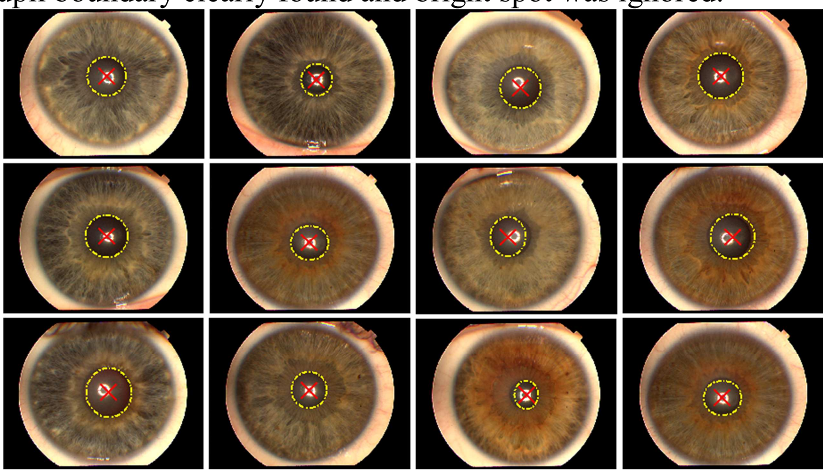

Figure 4. Result of applying gray projection on some images

Iris positioning. Because of the fact that radius of iris is bigger than pupil radius, we can choose minimum radius for searching limbic boundary (iris localization) greater than radius of pupil. This can help us to overcome bright spots of the illumination inside the pupil because it doesn't need to search in pupil boundary box, hence bright spots hasn't influence on iris positioning. Moreover, this algorithm enhancement speeds- up iris detection process. Our algorithm enhancement flowchart is shown in Fig. 5. Yellow and orange rectangles in this flowchart show our enhancement on Daugman's algorithm.

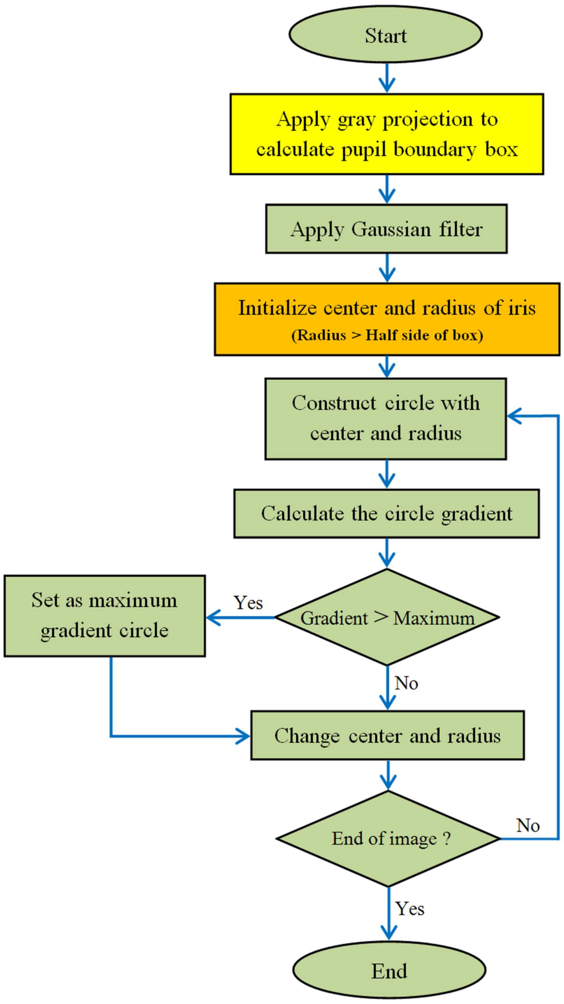

Figure 5. Daugman's algorithm flowchart with our enhancement on it

Performance Analysis

Our algorithm is implemented on a PC with Intel Core 2 Due E4600 240 GHz CPU and 2 GB of RAM, with a Microsoft Windows XP operating system and has been developed and tested in *MATLAB R2008a* on UPOL database that includes about 384 images for 64 persons.

Fig. 6 shows some of experiments results and you can see in TABLE I that our enhancement on Daugman's algorithm cause to speed up pupil and iris boundary detection and have better accuracy in true detection.

TABLE I. Exprimental results

UPOL database	Original Daugman's algorithm	Optimized Daugman's algorithm In [12]	Daugman's algorithm with our enhancement
Accuracy	82%	93%	97%
Average Time	6 Sec	4.6 Sec	3.3 Sec

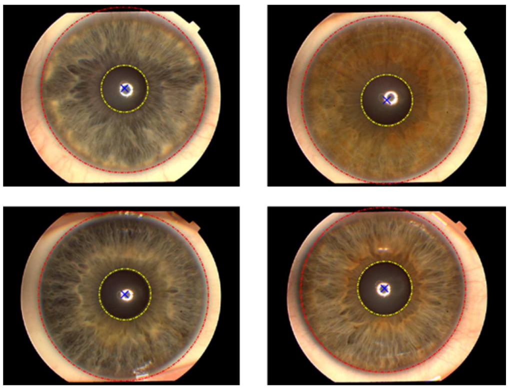

Figure 5. Expriment results

Conclusions

The above studies show that the iris locating algorithm based on integro-differential operator suffers from bright spots of the illumination inside the pupil , so our Daugman's algorithm enhancement overcome this problem and decrease average time of calculation for searching pupil and iris boundaries and our enhancement gives a successful results for iris localization process.

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