Real-time Iris Localization for Iris Recognition in Cellular Phone

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Abstract

With the increasing need of guaranteeing the security in case of using bank transaction service by using cellular phone, it is required to apply biometrics for the security of cellular phone. Especially, iris recognition is good for cellular phone security because of its reliability and accuracy compared to other biometrics such as face, fingerprint and voice recognition. In this paper, we propose a new pupil and iris localization algorithm, which is apt for cellular phone platform based on detecting dark pupil and corneal specular reflection by changing brightness & contrast value. In addition, we lessen the processing time by excluding floating point operation in our algorithm, which is not apt for ARM CPU of CDMA cellular phone. Results show that our algorithm can be used for real-time iris localization for iris recognition in cellular phone.

1. Introduction

Traditional methods for personal identification include the token-based methods that use specific things such as ID cards or physical keys for authentication and the knowledge-based methods that use something you know such as password for identification. However, those methods are not usually reliable. For example, token may be lost and knowledge may be forgotten. Therefore, a new method for personal identification named as biometrics has been more and more attractive [1]. Biometrics aims to recognize a person using the physiological or behavioral characteristics such as fingerprints, face, iris, voice, gait, signature, and so on. Since physiological or behavioral characteristics aren't easy to being used by stealth, copying, modifying and losing, biometrics is good for security.

Iris recognition is to recognize a person by using unique iris patterns, which exist in iris region between white sclera and black pupil as shown in Figure 1. The conventional iris patterns are randomly generated after almost three months of birth and it is reported that they are not changed all the life long [2]. Iris recognition shows good performance for accuracy and safety compared to other biometrics such as face, fingerprint, voice recognition and so on. Also it is non contact method and user's refusal feeling is small compared to other contact method such as fingerprint and hand vessel recognition.

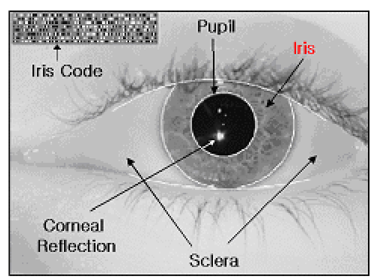

Figure 1. The structure of human iris

With the increasing need of guaranteeing the security in case of using bank transaction service by using cellular phone, it is required to apply biometrics for the security of cellular phone. In previous research and product, they adapted fingerprint recognition for cellular phone such as LG-KP3800 made by LG Electronics [3]. However it requires an additional fingerprint image acquisition sensor and DSP chips for finger-print recognition. This causes the cost and size of

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cellular phone to be increased. So, we aim at developing the iris recognition system in cellular phone only by using built-in mega-pixel camera and S/W without additional H/W component.

However, the CPU processing power of cellular phone is very small (for example, ARM 9 has the processing power of about 200 MHz [4][5]) and ARM CPU does not have an internal floating point processor. So, the complicated algorithm using floating point operation takes much processing time in cellular phone. So, we propose a new pupil and iris localization algorithm, which is apt for cellular phone platform based on detecting dark pupil and corneal specular reflection by changing brightness & contrast value. In addition, we lessen the processing time by excluding floating point operation in our algorithm. Experimental results show that our algorithm can be used for real-time iris localization for iris recognition in cellular phone.

2. Conventional Iris Recognition System

Conventional iris recognition is composed of two steps. In the first step, the iris region is localized and in the second step, unique iris codes are extracted from the detected iris region [2][6]. Also, conventional iris recognition camera has the IR-Pass filter (through which IR-LED (Infrared Light Emitting Diode) light is passed to camera sensor and the visible light is cut off) in front of camera lens and IR-LED illuminators are used because the human iris patterns are shown in details with the light of the wavelength of 750nm~880nm [7].

2.1. Previous Iris Localization method [2][6]

In previous iris localization method by Daugman, he uses the pyramid searching based circular edge detection algorithm to detect the inner and outer boundaries of iris [2][6]. Daugman's method shows accurate iris localization performance, but it takes much processing time as shown in Table 1 [2][6]. In Table 1, we can see that total 102 ms(= 90+12 ms) is taken to detect iris and pupil region in 300 MHz RISC processor. The conventional ARM 9 (which is used for CDMA cellular phone) processor has the low processing power of 200 MHz [4][5]. Especially, in cellular phone, because about 30% of processing power are always used as dormant mode (during which the cellular phone is waiting for telephone connection), actual processor power is reduced to about 140 MHz. From that, we can analogize the processing time of Daugman's method in cellular phone as 219 ms (=102 ms*(300 MHz/140 MHZ)). In addition, as mentioned before, the ARM 9 CPU does not have floating point processor and the processing time is more increased than 219ms because the Daugman's method of pyramid searching based circular edge detection algorithm has so many floating point operation.

Table 1. Execution Speeds of various stage in the iris recognition process on a 300MHz RISC processor [2][6]

Operation	Time
Assess image focus	15 msec
Scrub Specular reflection	56 msec
Localize eye and iris	**90 msec**
Fit Pupillary boundary	**12 msec**
Detect and fit both eyelids	93 msec
Remove lashed and contract lens edges	78 msec
Demodulation and IrisCode creation	102 msec
XOR comparison of tow IrisCodes	10 μsec

Another solution for reducing process time is to send the captured iris image from cellular phone to server by network. Conventional CDMA cellular phone in Korea uses CDMA 1xEVDO(Evolution Data Only) network for data communication, which has the characteristics of transmission speed of 2.4 Mbps (from server to cellular phone user), but lower speed of 144kbps (from cellular phone user to server) [8][9]. Conventionally, an image for iris recognition is 8 bit gray 640 x 480 pixels and one image size is 307,200 bytes (=2.46Mbit), consequently. From that, we can know that it takes about 17 sec (=2.46Mbit/144kbps) for transmitting one image from cellular phone to server. Even if we use the compression scheme such as JPEG with compression rate of 6:1 or less (Annex E - Iris Image [10]), it takes about 2.83 sec to transmit one iris image and the total processing time is large for iris recognition. Another solution is to use additional DSP chip for iris recognition inside the cellular phone, but it increase the total cost of cellular phone.

So, we propose a new iris localization algorithm, which is apt for cellular phone platform based on detecting dark pupil and corneal specular reflection by changing brightness & contrast value. In addition, we lessen the processing time by excluding floating point operation in our algorithm.

2.2. Proposed Method

2.2.1. Changing brightness & contrast and pupil detection. Because the pupil has the hollow structure inside of cornea [11], the gray level of pupil in input image is very low compared to other region such as iris, sclera and skin as shown in Figure 2. So, by simple binarization [11], we can discriminate the pupil and the other region such as iris, sclera and facial skin.

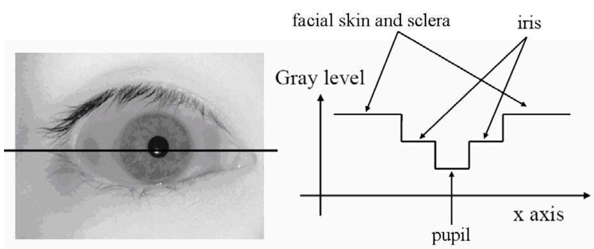

Figure 2. Horizontal gray level profile of facial skin, sclera, iris and pupil

However, some dark regions such as shaded facial skin or iris are also represented as same gray level (0) and it is difficult to discriminate them from pupil only by binarization. So, we propose the new method of changing decoder value (brightness and contrast).

Typically, NTSC analog output from CCD camera sensor has the data range of 10 bits (0 ~ 2^{10-1}). However, A/D (Analog to Digital) conversion by frame grabber has the data range of 8 bits (0 ~ 2^{8-1}) [12]. Some expensive pro-video applications use the A/D conversion range of 10 bits, but conventional consumer applications (which are commonly used in cellular phone) adopts that of 8 bits inputs [12]. So, the NTSC signal in low saturated range (such as the pupil) and the other region (such as shaded facial skin and iris) can be represented as same image gray level (0), which makes it difficult to discriminate the pupil region and the other region only by digital image processing algorithm as shown in Figure 3(a). Figure 4 is an example which can explain such phenomenon.

However, the NTSC level of pupil is lower than that of other dark region such as shaded facial skin and iris, because the pupil has the hollow structure [11].

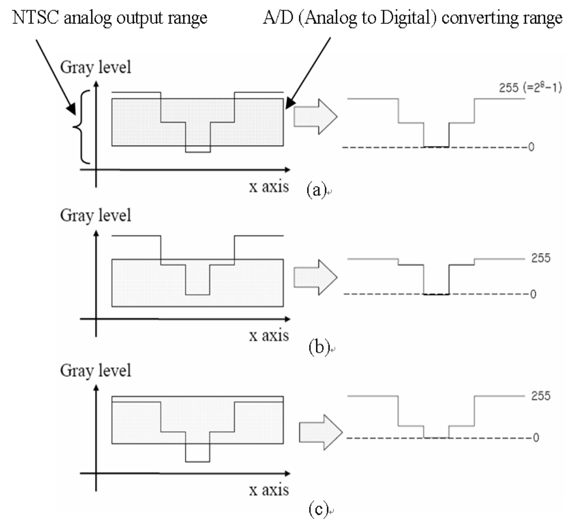

Figure 3. A/D converted input image according to various A/D converting range

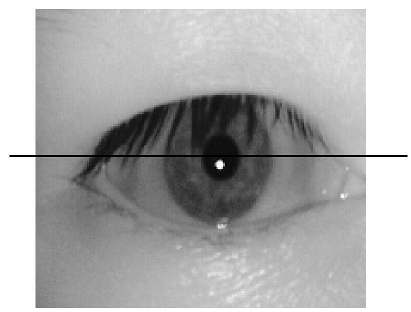

Figure 4. Low saturated pupil and other iris regions

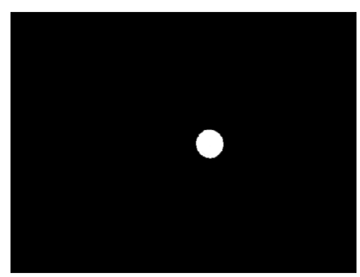

Figure 5. Pupil region in binarized image

So, if we make the brightness and contrast value of frame grabber lower (which corresponds to making the image brighter) as shown in Figure 3(b), there is no low saturated region and the pupil can be discriminated from other dark region. From that, we can select the binarization threshold easily to detect the pupil region and get clear pupil region in binarized image as shown in Figure 5. However, some dark region such as eye brow is still represented as same grey level to pupil in input image as shown in Figure 6.

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So, we use the method of detecting corneal specular reflection in order to solve such problem.

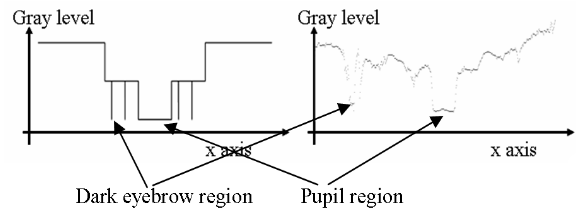


Figure 6. . Horizontal gray level profile of pupil and dark eyebrow region

2.2.2. Detecting pupil region by using corneal specular reflection. Conventional iris camera uses the IR-LED illuminator, which illuminates user's iris region. So, the reflected region named as corneal specular reflection happens at the pupil as shown in Figure 7. As shown in Figure 7, the gray level of corneal specular reflection is higher other region such as facial skin. That is because the reflectance rate on cornea is greater than that on facial skin [13][14]. From that, we can detect the corneal specular reflection easily by simple binarization. To determine the threshold of binarization more easily, we make the brightness and contrast value of frame grabber higher (which corresponds to making the image darker) as shown in Figure 3(c) similar to the method of section 2.2.1.

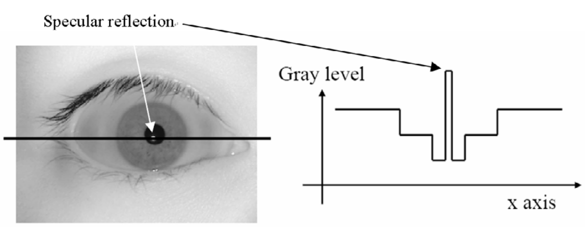


Figure 7. Horizontal gray level profile of corneal specular reflection and other facial skin

However, in case that specular reflections on glasses surface exist as shown in Figure 8, the A/D converted gray levels of specular reflection on cornea and glasses surface are represented as same level (255). So, to solve such problem, we combine the in-formation of detected pupil region as shown in section 2.2.1 and that of detected corneal specular reflection, because the corneal specular reflection exist in pupil region. In detail, after we detect the pupil region as shown in Figure 6 and Figure 9(a), then we check whether the detected corneal specular reflection (as shown in Figure 8 and Figure 9(b)) exists in the detected pupil region. If so, we determine the detected pupil region is genuine one, vice versa.

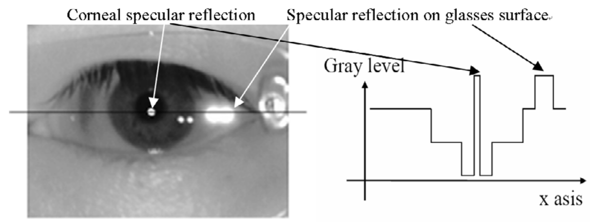
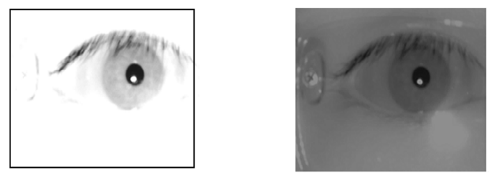


Figure 8. Horizontal gray level profile of corneal specular reflection and specular reflection on glasses surface



(a) Pupil image with high brightness&contrast (b) Pupil image with low brightness&contrast

Figure 9. Pupil images with high and low brightness & contrast

2.2.3. Detecting accurate pupil region by region-restricted labeling. However, in some case that the specular reflection on glasses surface exist in dark eye brow, such a region may be accepted as pupil region by the method of section 2.2.1 and 2.2.2. To overcome such problem, we verify whether the detection pupil region is genuine one by using restricted region-based labeling [11].

In detail, we perform the component labeling only about the pupil candidate region having corneal specular reflection. The processing speed for labeling is fast because it is performed only for restricted pupil candidate region. And we check the size and the horizontal diameter ratio to vertical one for the pupil candidate region. In general, the radius of iris is from 10.7mm to 13mm and that of iris in input image is from 100 to 134 pixels (the focal length of our camera is 49.5mm and the Z operating distance (in which, we can get focused iris image and iris recognition can be performed) is from 48 to 53 cm) in 640*480 pixels image. The conventional size of pupil is from 0.1 to 0.8 times of iris [2]. So, we can assume the radius of pupil is from 10(=100*0.1) to 107(=134*0.8) pixels. From that, we can also know the pixel counts of genuine pupil is from 314(=10*10*3.14) to 35,950(=107*107*3.14) pixels. In addition, we know the pupil is almost circle and define the horizontal diameter ratio to

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vertical one for the pupil candidate region is from 80 to 120%. From that, we can detect the genuine pupil region at fast speed. Experimental results for 1000 test images (from 20 persons) shows the processing time is almost 10ms in ARM 9 CPU of 140 MHz. Also, the method of detecting pupil region does not have the floating point operation and the processing speed is fast, consequently.

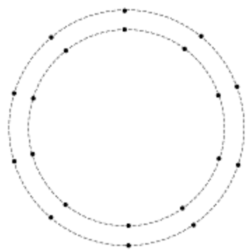

Figure 10. 10 inner and outer circle points between which the edge differences are calculated

2.2.4. Detecting iris region by modified circular edge detection. Now we detect iris outer boundary using modified circular edge detection. In Daugman's method, he uses the pyramid searching based circular edge detection for detecting pupil and iris region [2][6]. It shows accurate iris localization performance, but takes much processing time as mentioned before. In addition, it has many floating point operations and it is the main cause of increasing processing time. So, we use modified and integer-based circular edge detection method as shown in Figure 10. Based on the detected pupil center and radius as shown in section 2.2.3, we define the iris candidate region and perform the circular edge detection. As shown in Figure 10, the edge difference values between 10 inner and outer circle points are calculated and summed with the movement of the circle center position and the change of circle radius. The angle between each point is 36 degree. Among the calculated and summed difference values, the position having maximum value is the accurate iris position. To prevent the degradation of processing speed due to floating point operation, we save the positions of 10 inner and outer circle points with the change of circle radius in program code (Not calculating dynamically) and obtain the moved positions of 10 inner and outer circle points only by integer calculation (add operation). Each points has 4 bytes size and total 400 bytes(=4*10*2*5) are required to save the inner and outer circle points with the change of circle radius(we use 5 steps for the change).

3. Experimental Result

As mentioned before, we control the camera brightness & contrast twice to detect the pupil and iris region. Figure 11 shows the timing diagram of proposed method and Daugman's method. In our iris camera, the image capturing speed is 30 frames per second and 33 msec is taken to capture one image frame (640*480 pixels). As shown in Figure 11, if the calculated focus value meets the predefined threshold (in this case, we use the focus ckecking method proposed by Daugman [10]), we control the camera brightness & contrast and capture 2 image frames and perform our algorithm to detect pupil and iris region. Experimental results show that total processing time of our algorithm is about 160 ms in ARM 9 CPU of cellular phone. However, Daugman's method takes total 340 ms. As mentioned before in section 2.1 and Table 1, Daugman's method is expected to take 219 ms by theoretically, but it takes additional time (121ms) to detect pupil and iris. That is because his algorithm includes so many floating point operations and it is the main cause of reducing processing speed in ARM 9 CPU.

Table 2. Time table of proposed method

	time
Image capture	33 msec
Control brightness & contrast	33 msec
Image capture	33 msec
detect the pupil and iris region	60 msec
Total	About 160 msec

In next experiment, we measure the accuracy of our algorithm. About 1000 test images (from 20 persons). In this paper, we captured the iris image by using Samsung SPH-S2300 cellular phone [15]. It has the 324M pixels CCD camera with optical 3 times zooming functionality. The internal IR cut filter was removed and additional halogen lamp was used for capturing iris image.

The accuracy of our algorithm is measures with calculating the RMS error between the detected pupil(iris) center & radius and those manually picked. Experimental results show that the RMS error of iris center position is about 1.2 pixels and that of pupil center position is 0.6 pixels. And results show that the error of iris radius is 2.2 pixels and that of pupil radius is 0.55 pixels. In

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case of using Daugman's method [2][6], it shows the RMS error of iris center position is about 1.17 pixels and that of pupil center position is 0.6 pixels. And Daugman's method shows that the error of iris radius is 2.21 pixels and that of pupil radius is 0.53 pixels. From that, we can know our algorithm shows almost same performance, but shows better processing speed (less than 180ms) compared to Daugman's algorithm for detecting iris and pupil region.

Table 3. RMS error of pupil & iris center position

	pupil	Iris
Proposed Method	0.6	1.2
Daugman's Method	0.6	1.17

Table 4. Error of pupil & iris radius

	pupil	Iris
Proposed Method	0.55	2.2
Daugman's Method	0.53	2.21

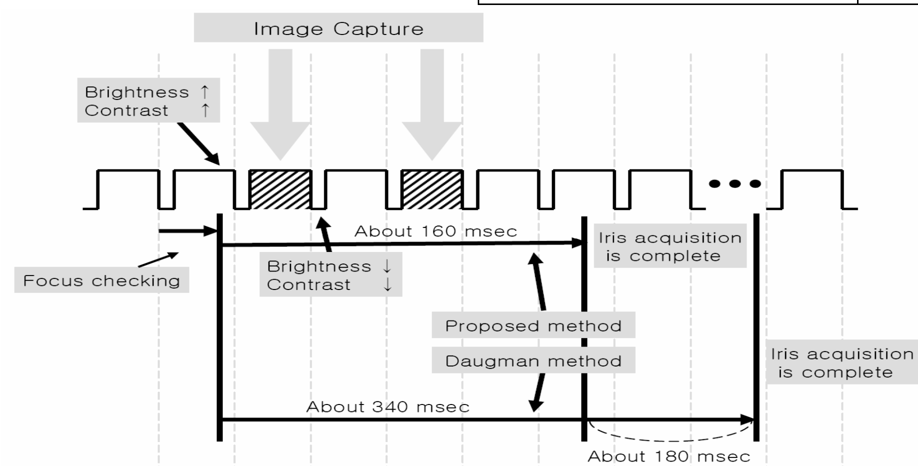

Figure 11. Diagram of proposed method and Daugman's method

4. Conclusion

In this paper, we propose a new pupil and iris localization algorithm, which is apt for cellular phone platform based on detecting dark pupil and corneal specular reflection by changing brightness & contrast value. In addition, we lessen the processing time by excluding floating point operation in our algorithm, which is not apt for ARM CPU of CDMA cellular phone. Experimental results show that our algorithm can be used for real-time iris localization for iris recognition in cellular phone. However, in case of severely blurred input image, our algorithm shows the degraded performance to detect iris boundary. In the near future, it is required to enhance the localization performance for more various input image including blurring, occluded by eyelash, etc.

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