Long Distance Iris Recognition System

Sheng-Hsun Hsieh[1], Shi-Wen Yang[1], Yung-Hui Li[2] and Chung-Hao Tien[1]
[1]Department of Photonics, National Chiao Tung University, Hsinchu Taiwan, 300
[2]Department of Information Engineering and Computer Science, Feng Chai University, Taichung Taiwan, 407

***Abstract*—Biometric signatures for identity recognition has been practiced for centuries. Recently, iris recognition system attracts much attention due to its nature of random and stable texture, high entropy density, and high independency across individuals (even for the twins) . In order to apply the iris identification in high turn-over-rate environments, such as custom security, court access or other high authentic management system, long working distance is necessary. Because the typical iris acquisition optics was constrained by its shallow depth-of-field, in this study, we employ the wavefront coding technique to engineer the point spread function insensitive to defocus. With adequate decoding filter and post processing, we can restore the intermediate iris image with adequate fidelity. The simulation and experimental results validated the proposed scheme, where the depth of field of the imaging system was extended 3X over the traditional ones, while keeping sufficient recognition accuracy.**

***Index Terms*—Extended depth of field, cubic phase mask, iris recognition.**

I. INTRODUCTION

Using biometric features for identity recognition has been practiced for centuries. Basically, the personal attributes used for a biometric identification system can be classified into two areas: the first one is based on physiological attributes, such as DNA, facial features, retinal vasculature, fingerprint, palm print, hand geometry and iris texture; the other one is dependent on behavioral attributes, like signature, keystroke, voice and gait style [1]. In many applications, biometrics recognition has become a key technology for identity management systems. Among these features, iris recognition is the most attractive one due to its nature of random and stable texture, high entropy density and noninvasive assessment.

The iris is an annular membrane between pupil and sclera in the eye. According to Daugman's algorithm, the probability of false identification is of the order of 10^{-10} [2-4]. Iris recognition system consists of three major parts, as shown in Fig. 1:

I. Iris image acquisition,
II. Iris image processing, and
III. Feature matching.

. At the front end, we must capture the iris image with possibly highest fidelity to ensure the accuracy of recognition. Second part is image processing, including iris segmentation, normalization and feature extraction. Iris segmentation is to find the centers and radii of the pupillary and limbic boundaries. Then iris image was normalized to transform the iris region from Cartesian coordinate to polar coordinate. After using Gabor filter to extract prominent feature in iris texture, the iris codes were matched via XOR operation.Iris template is matched to an existing database of previously enrolled irises to generate iris score by performing bit-wise XOR operation. The result of operation is presented as a measure of distance, called Hamming distance, which is a merit to judge the distinction between two iris images. An appropriate threshold value of Hamming distance was pre-determined so that a decision of acceptance or rejection can be made by thresholding the Hamming distance. In our experiment, the threshold is set to 0.3.

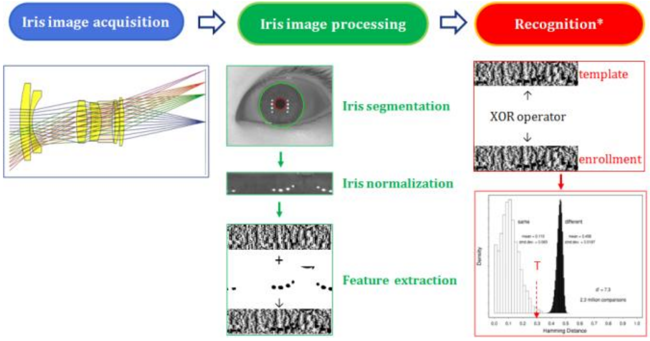

Fig. 1. Flow chart of iris recognition system.

II. OPTICAL SYSTEM PARAMETER

A. Image Resolution and Field of View

The major challenge or difficulty in long range iris acquisition lies in these two fundamental constraints (Fig. 2): the first one is the resolution limitation of the sensor. According to the algorithm proposed by Daugman, the resolution across the iris region should be higher than 150 pixels to ensure the accuracy for recognition [5]. Such requirement results in the magnification of the imaging system shall be larger than 0.1, corresponding 272 mm focal length. The other constraint lies in the field of view: size of capture facial image on sensor should be large enough to cover the entire ocular region, thus the computer can tell where the eye position is. That leads the magnification of the imaging system cannot not be larger than 0.16, unless we can find bigger CCD. Our image sensor size is 16 mm. The corresponding focal length shall be smaller than 413 mm. In order to meet these two requirements, we select a commercial available telephoto zoom lens, whose work distance can be large than 2.2 m with adjustable focal length or F-number. Here we set our operation focal length about 400 mm. The specification of sensor and telephoto lens are shown in Table I.

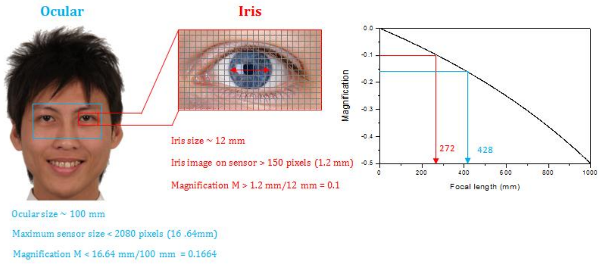

Fig. 2. Flow chart of iris recognition system.

TABLE I. SPECIFICATION OF SENSOR AND TELEPHOTO LENS

MV1-D2080 IR CCD		**Sigma APO 150-500 mm**	
Optical format	23.5 mm	Field of View	16-5 deg
Resolution	2080×2080	Minimum Distance	220 cm
Pixel Size	8 μm	Maximum Magnification	1:5.2
Dark current	0.65 fA/pixel	Caliber Diameter	86 mm

B. Depth of Field

The depth of field is the distance between the nearest and farthest object that appears an sharp image on the photo sensor. The depth of field is dependent on the circle of confusion, objective distance, focal length and entrance pupil size, respectively. Figure 3 schematically illustrates the concept of depth of field, where s_o s_i and f represent the object distance, image distance, and focal length, respectively. Here we use the size of circle of confusion c as the just distinguishable blurred spot in the recognition process. Let D_n and D_f represent the near and far limits of depth-of-field respectively. D_n and D_f can be defined by equation (1) and (2).

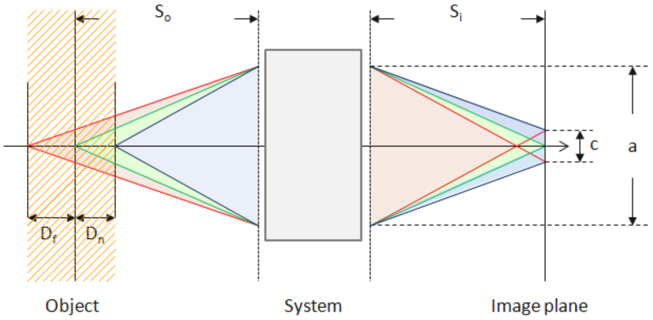

Fig. 3. The schematic diagram for depth of field formulas.

$$D_n = \frac{cs_o(f+s_o)}{fa - c(f+s_o)} \tag{1}$$

$$D_f = \frac{-cs_o(f+s_o)}{fa + c(f+s_o)} \tag{2}$$

It should be noted the definition CoC is dependent on the acceptable criterion. Traditional CoC depends on visual acuity, but in this paper CoC is defined as the Gaussian size which convolutes the original iris image. As long as the iris image, after convolved with Gaussian that defines CoC, can be successfully matched to its clear version, such level of CoC is acceptable in terms of the requirement of iris recognition. Here we set our CoC as 0.136 mm, the focal length as 400 mm and subject distance as 3000 mm of the iris capturing system. The pupil size approximates 86 mm of caliber diameter. The corresponding depth of field, after calculation, is about 60 mm. The range is really tight for typical iris acquisition especially for long-range system.

C. Wavefront coding

In order to extend the depth of field, we employ a wavefront coding technology. Unlike the conventional imaging system whose point spread function deteriorates due to the defocus, we place a coded phase mask on the pupil plane to engineer the point spread function insensitive to the defocus. The modified point spread function exhibits a triangle distribution over a certain working distance. With appropriate image post-processing technique such as winner filter,we can restore the intermediate image with adequate fidelity. The restored iris images can be used for recognition purpose in later stages. The phase profile is given by [6]

$$P(x,y) = \exp\left[i\alpha\left(x^3+y^3\right)\right] \tag{3}$$

where p(x, y) is the pupil and the indices x, y are normalized coordinates in the pupil plane, furthermore, the choice of α governs the overall strength of the mask. In other words, larger α causes high invariance but decreases modulation transfer function values. In order to design the profile with appropriate α value, we should carefully balance the tradeoff between modulation transfer function of the coded image and desired extended depth of field range. The optimal α value obtained in our system is approximately 42 .

D. Illumination

In order to validate the proposed methodology, we setup a near-IR iris acquisition system with extended depth of field technology. The subject is walking through a gate, and both sides of the gate are epuipped with near-IR LED arrays for environmental illumination. The iris images captured under near-IR wavelength reveal the most discriminative details of iris patterns for the purpose of iris recognition. With wavefront coding and optimized filter design, we can extend the original depth of field from about 60 mm to 200 mm, which is around three times larger than the original one. This is a huge improvement in iris image acquisition technology considering the fact that depth of field of current long-range recognition system is about 50-120mm [8]..

In additional to the imaging system, the irradiance consideraion is another big issue, which influence the image quality in certain level. In this case, we equip total 96 LEDs on both sides of the gate to keep sufficient irradiance on the subjects' faces. In general, the irradiance is the higher the better, but the minimum irradiance for acceptable SNR shall be larger than 3 mW/cm^2. On the other hand, the irradiance should not exceed ICNIRP rule whose IR safety guide for max irradiance about 100 mW/cm^2[7]. The adequate geometric layout and first-order optical design is used to offer the uniform irradinace as well.

III. EXPERIMENT

Captured image with and without extended depth of field can be shown in Fig. 4. Compared with the conventional imaging, the wavefront coding technique enable the image blur less sensitive to the defocus effect. The threshold operating range is about ±10 cm, above that, the point spread function is too large and cannot recover the intermediate image anymore.

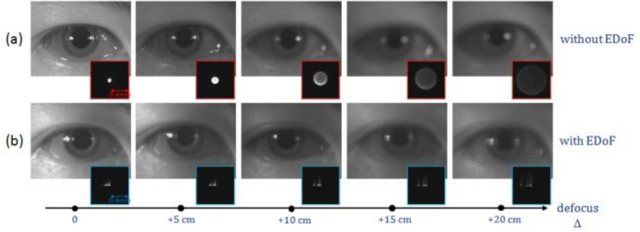

Fig. 4. (a) The iris image without cubic phase mask (b) The iris restored image by Wiener filter.

Figure 5. shows the Hamming distance with authentic comparison for iris images. Dot and square points represent the experimental data, where as blue and black curves are regression approximation. The Hamming distance of authentic comparison with and without extended depth of field exhibit different slope under different defocus. Taking 0.3 as the acceptance threshold of Hamming distance , the depth of field of conventional imaging device is about ±3 cm, where as that with cubic phase mask it can be extended to about ±10cm, which means the depth of field has been extended for more than three times.

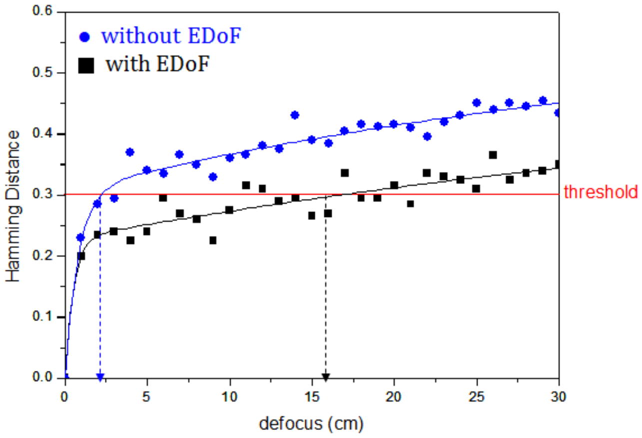

Fig. 5. The schematic diagram for depth of field formulas.

IV. CONCLUSIONS

In this study, we implemented a telephoto imaging system to acquire iris images from three meters away, which is practically useful for many applications which require high turnover rate. The computational imaging scheme can greatly increases the depth of field to be approximately three times the conventional imaging system, while keeping sufficient recognition accuracy. Future work includes synchronizing the camera system with continuous shooting function for better convenience for long-range iris image acquisition.

ACKNOWLEDGMENT

This work was supported by National Science Council of Taiwan under contract no. NSC-101-2221-E-035 -084.

REFERENCES.

[1] A. K. Jain, A. Ross, and S. Prabhakar, "An Introduction to Biometric Recognition," IEEE Transactions on Circuits and System for Video Technology, 14(1), 4-20 (2004).

[2] J. Daugman, "The importance of being random: statistical principles of iris recognition," Pattern Recognition 36, 279-291 (2003)

[3] J. Daugman, "High confidence visual recognition of persons by a test of statistical independence," IEEE Transaction on Pattern Analysis and Machine Intelligence 15(11), 1148-1161, (1993)

[4] J. Daugman, "How iris recognition works," IEEE Transaction on Circuits and Systems for Video Technology 14(1), 21-30, (2004)

[5] ANSI INCITS 379-2004: Iris Image Interchange Format

[6] E. R. Dowski, W. T. Cathey, "Extended depth of field through wavefront coding," Applied Optics 34(11), 1859-1866 (1995)

[7] ACGIH,2004 TLVs and BEIs (http://www.acgih.org)

[8] J. Matey, O. Naroditsky, K. Hanna, R. Kolczynski, D. LoIacono, S. Mangru, M. Tinker, T. Zappia, and W. Zhao, "Iris on the move: Acquisition of images for iris recognition in less constrained environments," Proceedings of the IEEE, vol. 94, no. 11, pp. 1936–1947, Nov. 2006.