How to Make Iris Recognition Easier?

Wenbo Dong, Zhenan Sun, Tieniu Tan
Center for Biometrics and Security Research (CBSR) &
National Laboratory of Pattern Recognition (NLPR)
Chinese Academy of Sciences, Institute of Automation (CASIA)
{wbdong,znsun,tnt}@nlpr.ia.ac.cn

Abstract

Iris recognition is regarded as the most reliable biometrics and has been widely applied in both public and personal security areas. However users have to highly cooperate with the iris cameras to make his iris images well captured. In this paper, we aim to discuss whether and how we can make iris recognition easier. Firstly the restricting factors of iris image acquisition are analyzed and the optical formulas are derived. Then the solutions of state-of-the-art iris recognition systems are reviewed and summarized. Finally, we propose two novel iris recognition systems with good human-computer-interface but with two different strategies which respectively meet the requirements of low-end and high-end market.

1. Introduction

Does an iris recognition system work well? It depends on many aspects. The most important one is certainly the recognition algorithm, and the other one is whether it can capture on-focus iris images fast and comfortably. For the former, much valuable work [1][2][3] has been done and state-of-the-art iris recognition algorithms have been very accurate, robust and fast, but for the latter, it seems that there is no perfect system by now. Most systems need user's cooperation to finish the task. The question is whether and how we can make iris image acquisition easier?

In this paper, we first discuss why the iris image acquisition is so difficult. Here, special formulas of iris imaging in the digital sensor are derived and based on that, the factors constraining the camera capture volume are analyzed from the theoretical point of view.

Then we review the solutions of state-of-art iris recognition systems and sum up advantages and disadvantages of their strategies. The good human-computer interface (HCI), high-resolution cameras, and control techniques such as auto-focus and auto-tracking are all useful to make iris recognition systems easier.

Finally, we propose two novel iris systems developed by us. One is a double-eye device based on LCD screen feedback like a magic mirror, and the other is a long-distance device on the high-resolution camera, long-focus lens, and pan-tilt-zoom unit. They both make iris recognition more comfortable and have high performance-price ratio.

2. Why iris image acquisition is difficult?

In this section, we summarize the geometrical optics for iris image capturing and analyze the factors restricting this volume based on that. That will explain the difficulty to capture iris image with a single camera.

2.1. The geometrical optics for iris imaging

In fundamental geometrical optics, we define the lens focus as f, the object distance as u, the imaging distance as v , the object's width and height as W and H respectively, the image width and height as w and h respectively, the object-image ratio as β, then we have the following formula:

$$1/f = 1/u + 1/v \quad (1)$$

$$\beta = W/w = H/h = u/v \quad (2)$$

Based on equation (1) and (2), we have $f = u/(\beta+1)$. It can help us choose the focus of lens.

In a digital optical sensor as seen in Figure 1, we define the digital sensor's (CCD or CMOS) width and height as w_p and h_p respectively, sensor pixel size as σ and object-pixels ratio as λ, so

$$\begin{cases} w_p \cdot \sigma = w \\ h_p \cdot \sigma = h \\ \lambda = W/w_p = H/h_p = \beta \cdot \sigma \end{cases} \quad (3)$$

978-1-4244-2175-6/08/$25.00 ©2008 IEEE

The depth of field (DOF) means the area that objects can be imaged in focus [4]. We can calculate the system's depth of field (DOF) by Equation (4). Here, D is the DOF, F is aperture value, which equals to f divided by focus aperture diameter.

$$D = \frac{2F\sigma f^2 u^2}{f^4 - F^2\sigma^2 u^2} \quad (4)$$

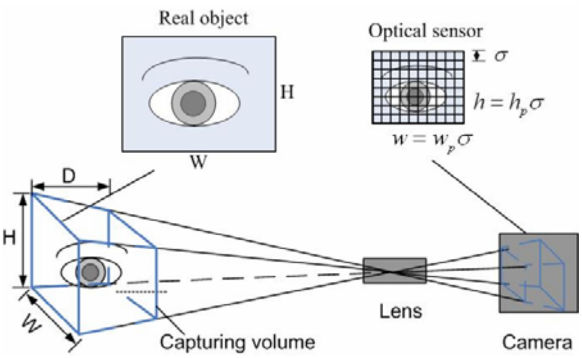

Figure 1. Iris imaging in digital sensor through an optical lens

In iris image acquisition systems, the average iris diameter is averagely 10 millimeters, and the required pixel number in iris diameter is normally more that 150 pixels. (International standard [5] regulates that 200 pixels is "good quality", 150-200 is "acceptable quality" and 100-150 is "marginal quality".) So, the iris image with smaller λ is considered as better quality image and bigger λ as less quality image. We take λ_0 =1/15 (mm/pixel) as a standard value.

In equation (4), f and u have the relationship as $f = u/(\beta+1) = u/(\lambda/\sigma+1)$. And when f is more than 25 mm and F is less than 20, we can roughly think $f^4 \gg F^2\sigma^2u^2$, so equation (4) can be simplified to

$$D \approx 2F(\lambda+\sigma)^2/\sigma \quad (5)$$

As a conclusion, the camera's capture volume for iris imaging can be summarized as

$$\begin{cases} W = \lambda \cdot w_p \\ H = \lambda \cdot h_p \\ D = 2F(\lambda+\sigma)^2/\sigma \end{cases} \quad (6)$$

2.1. Analysis of the restricting factors

a) From Equation (6), λ is the most important parameter, which is proportional to W and H, and its square approximately proportional to D. However, λ can not been set as big as expected, because the big λ value causes low image quality. For example, Daugman has proposed λ value of 1/15 to 1/22 (150~220 pixels in iris diameter) for good performance [1], that's to say, the biggest λ value may be 1/15.

b) The digital camera parameters w_p, h_p and σ are vital to the capture volume, but they are restricted by the camera design techniques. On the other hand, higher resolution $w_p \times h_p$ will bring lower image transfer speed, which is unfit for real time image processing. For example, normal 32-bit PCI bus can only transfer maximum 15 frames of 2000 × 2000 images or 5 frames of 4000×3000 images per second. Another parameter σ is approximately inverse proportion to the depth D, but the current sensor technique can not make σ smaller than several micro meters.

c) The only method to extend the capture depth is to reduce the aperture size (enlarge the F value). But when the aperture is too small, little photons can come into the sensor, so we need enhance the outer illumination, or enhance the camera's exposing time. However, too intensive illumination may hurt human eyes. (The normal infrared lamp intensity should be less than 2.5mw/cm2. [6]) But if the illumination can not be increased too much, exposing time must be increased, which means to make more motion-blurred images. In one word, the capture depth extend by reducing aperture is also limited.

As a conclusion, we can not enlarge the capturing volume as much as we imagine. Even with the best cameras, lens and high-power light, one single camera's capturing volume is still very small.

3. How to make iris recognition easier

From Section 2, the single camera's capture volume is so difficult to extend, but are there any other ways to make iris image acquisition easier? We can see the solutions of state-of-the-art iris recognition systems and sum up strategies to make this mission possible.

8.1. Application of high-resolution cameras

For example, Sarnoff's IOM system [7] uses the Pulnex (JAI) 4200 camera, which is 2000×2000 pixels, and we have used the Dalsa 4M60 with 2352×1728 pixels. They have data format of 8/10 bit and frame rate of 15 or 30 frames per second.

They are all off-the-shelf cameras with good performance, but also very expensive. We have surveyed other top digital camera companies and optical sensor companies. Their best product properties for real-time iris image acquisition, such as resolution and frame rate are no better than the above.

IOM system also applies a camera array made up with 3 cameras, which can get 3 times capturing volume of the single camera. This is a good idea, but too many cameras, lens, sampling cards and computers will cost too much in hardware, and also two many cameras cost too much computer resource in software.

8.1. Application of auto-control techniques

The auto-adaptive devices are broadly tried out to help image acquisition, such as pan-tilt unit and auto-focus lens. For example, Mitsubishi [8], Yongsei Univ. [9], and ours [10] have all used the pan-tilt unit to track people's eyes. Mitsubishi [8] and ours [10] use another wide-angle camera to detect face, while Yongsei use the laser projector to help find people's position.

For extending the capturing depth of field, Yongsei Univ.[9], ours[10] and many institutes have used the auto-zoom or auto-focus lens. Some of them regulate the focus by evaluating images' high frequency, and others use the special information such as the light spot's size on iris images.

By these auto-adaptive devices, we can find the iris in a large scale and make users non-cooperative to the iris camera, but the question is that the tracking and zooming process takes too much time.

8.1. Application of human computer interface

A good HCI is absolutely required in a successful product. The typical strategy is to use the indicator voice, lamps, or other signals, as well as the half-transmitting mirrors or the feedback of LCD screen. They are broadly used in current commercial systems, such as OKI, LG, Panasonic [11][12][13] and so on.

Good HCI will make devices better to use, but the question is that not all users like to do under the machine's instructions. Everyone expect a fully-automatic and more convenient machine.

As a conclusion of this section, we can use high-resolution cameras, control techniques and good HCI to solve this problem. We also need recognize that that is not only a problem of engineering, because the better machine will take higher costs.

4. Our proposed iris recognition systems

Here we describe two novel iris recognition systems with high performance-price ratio. One is the low-cost products for common use, and the other is the ideal fully-automatic system for advanced use. These two types of iris recognition systems will respectively satisfy the market's low-end and high-end need.

4.1. Double-eye system with "magic mirror"

A double-eye system based on LCD feedback is designed as seen in Fig. 2. This is an embedded system with two cameras and a LCD screen. The novelty is that people can see their eyes in the LCD, just as they see them in a magic mirror. But the real cameras just below the LCD are invisible behind a half-transmitting mirror, so people can not see them. Moreover, when people enter camera's depth of the field, LCD's image will become green, otherwise it will become red. So people can regulate himself to easily find the right position and enter into this narrow field. Also the double eye recognition can also make higher false reject rate (FRR).

The product has been developed by us for real applications, such as attendance check, access control, customs clearance and so on.

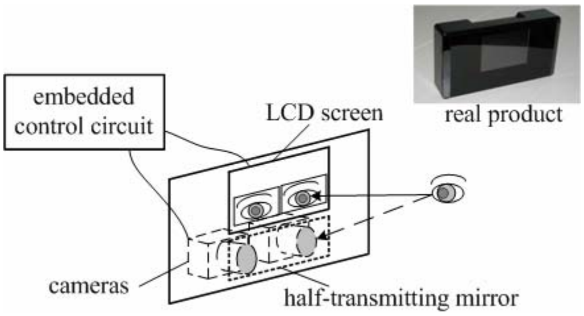

Figure 1. Double-eye system with LCD mirror

4.2. Long distance iris recognition system

A long-distance iris recognition system of future-oriented is designed, for the purpose that people can perform iris recognition comfortably from 3 meters away. A prototype has been designed as Figure 3. People need to pass a gateway and stop for 2~3 seconds for identification. Some details of image acquisition and image processing are shown as below.

4.2.1. Iris image acquisition. Firstly, we use a camera with resolution of 2352×1728 pixels and transfer speed of 15 frame per second, as well as an 300 mm focus lens. They can capture in-focus iris images in a range of 16mm$\times$12mm in real time from 3 meters away.

Secondly, a pan-unit is used to automatically adapt to different heights of people and another motor-assisted unit is used to turn the lens focusing. People's face is detected by another video camera and then the iris camera is regulated to aim at the detected position and automatically focus.

Thirdly, a front LCD, sound indicator and a ground mark is used to lead users into the capture volume. The infrared lamps is setup on the both sides of the gateway and can been switched on or off by automatically.

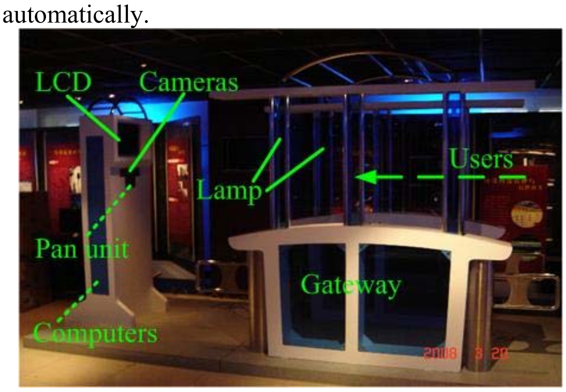

Figure 3. The prototype of long-distance iris recognition system

4.2.2. Image processing. We use image processing method of 3 steps to select the best images from the real-time high-resolution video sequence and then segment iris images for identification.

Firstly, we evaluate the image brightness to judge whether an object is entering. Secondly, eye images are detected by existed haar-like feature cascade classifier. Then we segment eye images and select 3 best candidates for identification by assessing the image's focus value. At last, we adopt our existed algorithms [3] to finish the iris recognition..

Experiments show that the whole process of image acquisition, image processing and iris recognition takes average 3~5 seconds with high recognition rate. This results is worthy of its high cost and complicated design.

Compared with other iris systems as described in Section 2, in this system we have integrated all available methods together, which make this system fully automatic and very convenient to use at a distance. We are planning to push it to practical usage.

5. Conclusion

In this paper, we have mainly discussed the question of iris image acquisition. The equations of iris camera's capture volume are formulated and the factors restricting iris image capturing are analyzed. The state-of-the-art iris recognition systems are reviewed and their strategies are summarized. Two novel iris systems have been developed by us including a double-eye system and a long-distance system. We hope that our works are valuable to all people engaged in the development of iris recognition system.

Acknowledgement

This work is supported by the National Basic Research Program of China (Grant No. 2004CB318100), the National Natural Science Foundation of China (Grant No.60736018, 60335010, 60702024, 60723005), the National Hi-Tech Research and Development Program of China(Grant No.2006AA01Z193, 2007AA01Z162), and the Chinese Academy of Sciences.

References

[1] Daugman, How iris recognition works, IEEE Trans. Circuits Syst. Video Technol., 14(1): 21-30,2004

[2] R. P. Wilds, Iris Recognition: An Emerging Biometric Technology, Proc. IEEE, 85(9): 1348-1363, 1997

[3] L. Ma, T. Tan, Y.Wang and D.Zhang, Personal dentification based on iris texture analysis, IEEE Trans. PAMI, 25(18): 1519-1533, 2003

[4] Y. He, J. Cui, T. Tan and Y. Wang, Key Techniques and Methods for Imaging Iris in Focus, Proc. ICPR, 4: 557-561, 2006

[5] Biometric Data Interchange Formats - Part 6: Iris Image Data, ISO/IEC, 19794-6, 2005

[6] Safety of Laser Products – Part 1: Equipment classification Requirements and User's Guide, IEC 60852-1, 2001

[7] J. R. Matey, O. Naroditsky, K. Hanna, etc., Iris on the move: Acquisition of Images for Iris Recognition in Less Constrained Environments, Proc. IEEE, 94(11): 1936-1947, 2006

[8] G. Guo, M. J.Jones, A System for Automatic Iris Capturing. Mitsubishi Electric Research Laboratories, http://www.merl.com/publications/TR2005-044, 2005

[9] S. Yoon, H. G. Jung, ect., Non-intrusive iris image capturing system using light stripe projection and pan-tilt-zoom camera. CVPR'07: 1-7, June 2007

[10] W. Dong, Z. Sun, T. Tan, Self-Adaptive iris image acquisition system, Proc. of SPIE, 6944: 694406, 2008

[11] T, Oda, Y. Ohta, inventors; Oki Elec. Ind., assignee, Photographing device iris input device and iris image input method, US patent 6850631, 2005

[12] W. H. Lee, A. Yang, J. j. Chae, inventors; LG Elec., assignee, Apparatus and method for adjusting focus position in iris recognition system, US patent 7095901, 2006

[13] T. Nakaigawa, K. Ikoma, inventors; Matsushita Elec. Co., assignee, Iris image pickup apparatus and iris authentication apparatus, US patent 7068820, 2006