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Iris recognition: a biometric method after refractive surgery*

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Abstract: Iris recognition, as a biometric method, outperforms others because of its high accuracy. Iris is the visible internal organ of human, so it is stable and very difficult to be altered. But if an eye surgery must be made to some individuals, it may be rejected by iris recognition system as imposters after the surgery, because the iris pattern was altered or damaged somewhat during surgery and cannot match the iris template stored before the surgery. In this paper, we originally discuss whether refractive surgery for vision correction (LASIK surgery) would influence the performance of iris recognition. And experiments are designed and tested on iris images captured especially for this research from patients before and after refractive surgery. Experiments showed that refractive surgery has little influence on iris recognition.

Key words: Biometric, Iris recognition, Refractive surgery, LASIK, Myopia
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INTRODUCTION

Biometric technique is an alternative method for personal identification based on physical and behavioral characteristics of the human body such as fingerprint, face, iris, signature, voice, etc., instead of the traditional means of key, password or ID card. Among various biometric methods, it is proved that iris recognition yields higher accuracy: iris recognition has no false matches in over two million cross-comparisons according to biometric product testing Final Report (Mansfield *et al.*, 2001). Moreover iris recognition has the ability to handle very large populations at high speed.

Fingerprint recognition is the most widely used and least expensive biometrics technology, but it can be counterfeited easily by a “rubber finger”. The face may change much when an individual gains weight or ages, and may be modified by hair, beard or accessories as well. Iris, instead, is the only visible internal organ of human; it is stable and very hard to be altered throughout the whole life of a human being. Moreover its physiological response to light (pupil vibration and dilation) provides a natural test against fake irises.

But what if eye surgeries must be done to some individuals? For example, those who had undergone eye surgery for cataract or uveitis etc. may be rejected by iris recognition system as imposters because the iris pattern was altered or damaged somewhat during surgery. A correct match cannot be made with the iris template enrolled before surgery. In this situation, the system should be alerted and the iris should be re-enrolled after surgery to ensure the genuine iris template will not be rejected as the imposter.

Till now, little research has been done on these special situations except for research on iris recognition after cataract surgery (Roizenblatt and Schor, 2004). In this paper, we originally explore whether refractive surgery for vision correction, especially LASIK surgery, would have any influence on the performance of iris recognition. In order to do this research, iris images were collected from hospital

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before and after surgeries, and a recognition procedure was designed for the recognition task.

This paper is arranged as follows. Section 2 is a brief introduction of some related terms, such as myopia, refractive surgery etc. In Section 3, an iris recognition procedure is designed and introduced. In Section 4, experiments are made and results are shown and analyzed. Finally, conclusions are made in Section 5.

REFRACTIVE SURGERY

The structure of the eye is shown in Fig.1. As light enters the eye, it first passes through the cornea, which is the clear outer portion of the eye. Because the cornea is curved, the light rays bend, allowing light to pass through the pupil to the lens. The iris regulates with the ciliary muscles the amount of light that enters the eye. These muscles cause the pupil to contract when exposed to excess light or to dilate when there is too little light. When light hits the curved surface of the lens, it is refracted, providing proper focusing power on the retina.

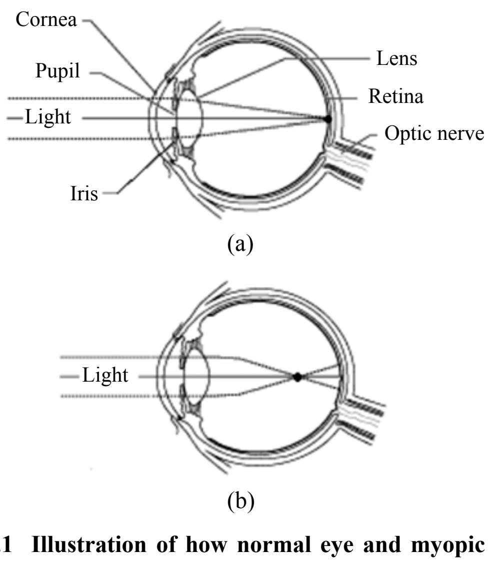


Fig.1 Illustration of how normal eye and myopic eye work. (a) Normal eye, where the light focuses right on the surface of the retina; (b) Myopia situation, where the light focuses at a point in front of the retina

Myopia, also known as near-sightedness, is caused by faulty light refraction in the eye. It occurs when the eyeball is slightly longer than usual from front to back. This causes light rays to focus at a point in front of the retina, rather than directly on its surface. Subsequently, distant images cannot focus clearly on the retina and what we see is a blurred image.

Myopia may be corrected by glasses, contact lenses, or refractive surgery, which is used to change the way light refracts, or bends, as it enters the eye. The most common refractive surgery is LASIK surgery. LASIK stands for "Laser Assisted in SItu Keratomileusis". The LASIK surgery involves reshaping the cornea using a laser beam. First a flap is cut in the cornea, and then the cornea is ablated by a special laser, as shown in Fig.2. Then the flap is re-covered on the modified cornea and heals by itself. The result is shown in Fig.3. Once healed, the way light refracts is changed, the newly-shaped cornea allows light to focus onto the retina properly, resulting in clearer vision.

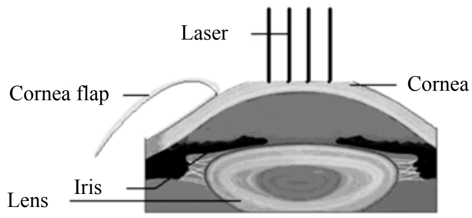


Fig.2 Illustration of how LASIK surgery works. A flap is cut in the cornea, and then the cornea is ablated by laser

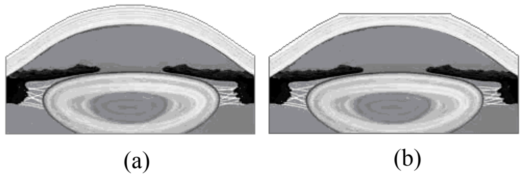


Fig.3 The eye before (a) and after (b) the refractive surgery

It is natural to doubt whether the external appearance of the iris pattern is distorted after LASIK surgery because the iris is just behind the modified cornea. Would this distortion or other side effects affect the iris recognition results? If so, how much will it affluence iris identification. Our motive in this research is just to resolve these doubts by experiments.

IRIS RECOGNITION PROCEDURE

In our research, a procedure is designed for iris recognition. In this procedure, four main steps are needed to make a final decision of "accept" or "reject":

(1) Iris localization: iris is defined as the annular area between the pupil and the sclera. The iris's inner boundary and outer boundary are approximated by circles. The inner circle (pupil margin) is detected according to the gray-level distribution of the eye. The pupil is the biggest connective dark area in the eye, so it can be segmented from the other part of the eye by bisecting with the optimal threshold. Then morphological operators are applied to get rid of the influence of eyelids and eyelashes occlusion (Yuan and Shi, 2004). The outer circle is localized with the well-known Daugman's Integro-differential operator (Daugman, 1993; 2003).

$$\max_{(r,x_0,y_0)}\left|G_\sigma(r)\cdot\frac{\partial}{\partial r}\oint_{r,x_0,y_0}\frac{I(x,y)}{2\pi r}\mathrm{d}s\right|, \quad (1)$$

where $I(x, y)$ is the iris image; G_σ is a smoothing function such as a Gaussian of scale σ; (r, x_0, y_0) are the circle parameters.

(2) Iris normalization: remap the annular iris image $I(x, y)$ from raw Cartesian coordinates (x, y) to a dimensionless pseudo-polar coordinate system (r, θ) with Daugman's "rubber sheet" model. It is meant to account for iris image translation, overall scaling of the iris texture and dilation of the pupil.

(3) Iris feature extraction and encoding: firstly, the normalized iris pattern is broken into 1D signals row by row. Then these 1D signals are convolved with 1D Log-Gabor wavelets:

$$G(f)=\exp\left(\frac{-\left(\log(f/f_0)\right)^2}{2\left(\log(\sigma/f_0)\right)^2}\right), \quad (2)$$

where f_0 represents the center frequency, and σ is the bandwidth of the filter.

Then the phase information from the output of filtering is extracted, and quantised to four levels to encode the unique iris pattern into a bit-wise iris code (Masek, 2003).

(4) Matching: the Hamming distance is employed as the matching metric. Recognition is performed in verification mode, i.e. in one-to-one fashion. Every test iris sample is labelled with its true classification. Then matches should be made with the template iris image to make a decision of "accept" or "reject".

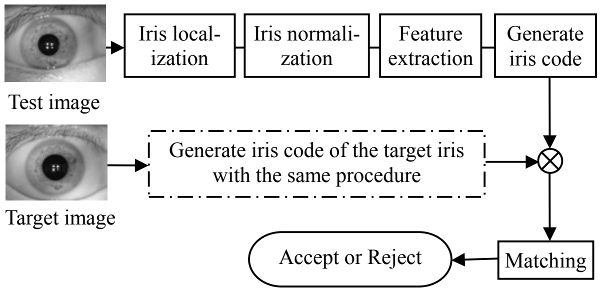


Fig.4 Framework of the whole recognition procedure

EXPERIMENTS AND ANALYSIS

The test data we used are iris images collected especially for this research from hospitals. The images were captured with our self-made patented sensor (Shi *et al.*, 2003). Due to specialized imaging conditions using near-infrared light, features in the iris region are highly visible and there is good contrast between pupil, iris, and sclera regions. Fourteen myopic eyes to be corrected were chosen and ten images were captured for each eye before and after their refractive surgeries respectively. So totally 14×2×10=280 eye images were collected for surgery eyes. We name the images captured before surgery as Iris Set I, and after surgery, Iris Set II. Moreover, another 1000 eye images that belong to 200 classes (5 images in each class) of normal eyes were collected, which is named as Iris Set III. Some samples in each iris set are shown in Fig.5.

First, the whole recognition procedure is implemented on Iris Set III to test whether the recognition procedure itself is available and what its overall performance is. The result curve is plotted with solid line in Fig.6, which shows the False Match Rate (FMR) against the False Non-Match Rate (FNMR) with the varying match threshold.

The FMR is defined as the expected probability that a sample will be falsely declared to match a single randomly-selected "non-self" template. Correspondingly, the FNMR is the expected probability that a sample will be falsely declared not to match a template of the same measure from the same user supplying the sample (Mansfield and Wayman, 2002).

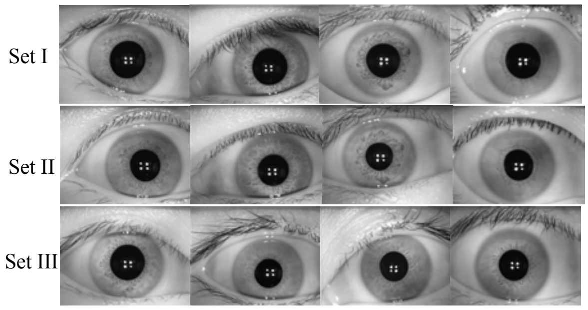


Fig.5 Some samples in each iris set

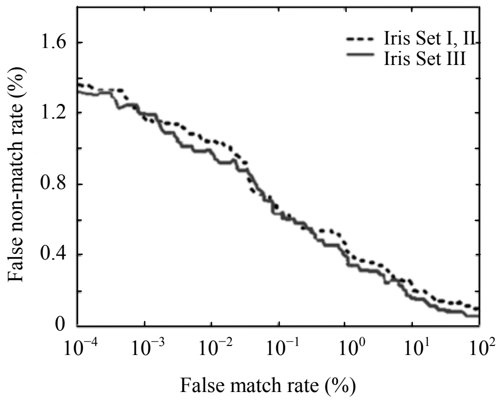


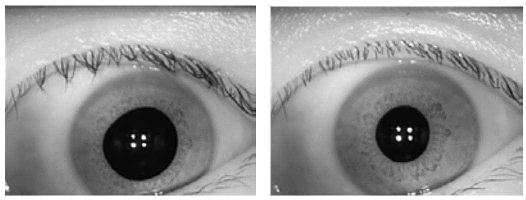
Fig.6 Verification result on both iris sets

The "equal error rate" (EER) is defined as the point on the ROC where the false match and false non-match rates are equivalent. It can serve as a measure to explicitly evaluate the overall performance of a recognition system. The smaller the EER is, the better is the system. Table 1 shows that the EER of our recognition procedure is encouraging compared with EERs of other famous methods [reported in (Ma *et al*., 2004)]. It should be noted that due to the bimodal nature of the genuine distribution, sometimes the statistic is flawed as a measure of biometric identification devices (Wayman, 1999).

Then, identification is performed to test whether the iris pattern can still be accepted after refractive surgery. For each iris class, we choose three samples taken from Set I (before surgery) for training and all samples of Set II (after surgery) serve as test samples. This is also consistent with the widely accepted standard for biometrics algorithm testing (Mansfield *et al*., 2001). The experiment result is also shown in Fig.6 with dotted line. It can be shown that it is not deviated much from the verification result tested on normal eye without surgery. And in identification mode, all test images can still be identified correctly except one that failed. The failed sample is shown in Fig.7. It may because that it is still in the recovering phase and is sensitive to light, so the external illumination makes its pupil react and change much. Moreover, its pupil's contour deviates much from an exact circle, which also induces failure in its correct identification.

Table 1 Comparison of our recognition procedure with other methods on EER

Methods	EER (%)
Daugman	0.08
Wildes	1.76
Boles	8.13
Tan	0.57
Proposed	0.78



(a) (b)

Fig.7 The failed iris sample
(a) Before surgery; (b) After surgery

According to the experiments and analysis, we make the conclusion that the LASIK surgery has little influence on iris recognition. However, still much more samples are needed and more experiments should be made in the future to further validate this conclusion.

CONCLUSION

In this paper, we originally discuss about whether refractive surgery for vision correction, especially LASIK surgery, would have any influence on the performance of iris recognition. Experiments were designed and tested on iris images captured from the patients before and after surgery. Conclusion is made based on the experiments that refractive surgery has little influence on iris recognition. However, many more samples are needed to validate this conclusion, and more optimization should be made to improve the whole identification procedure.

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