21st International Conference on Pattern Recognition (ICPR 2012)
November 11-15, 2012. Tsukuba, Japan

Multimodal Biometric Authentication Based on Iris Pattern and Pupil Light Reflex

Vitor Yano[1], Alessandro Zimmer[2], Lee Luan Ling[1]
[1]*Department of Communications, FEEC/UNICAMP – Campinas, SP, Brazil*
[2]*Department of Electrical Engineering, UFPR – Curitiba, PR, Brazil*
vitoryan@decom.fee.unicamp.br, zimmer@eletrica.ufpr.br, lee@decom.fee.unicamp.br

Abstract

Biometrics-based authentication is a method of personal identification that has some advantages over the password and object-based ones, mainly for the user, who doesn't need to carry or memorize anything. However, this kind of identification is also subject to problems. Besides the technology-related possibilities of fraud, such as system invasion, database corruption or algorithm injection, some of the common used biometric features can be faked. Furthermore, most cases of false rejection are related to the quality of the acquired sample. This paper proposes a multimodal biometric authentication method which incorporates the use of dynamic features of the human reflex and the iris pattern recognition for a better performance. A prototype system has been implemented and tested with 59 volunteers. Experimental results presented an EER of 2.44%.

1. Introduction

There isn't a perfect biometric characteristic for all the needs of personal identification. Therefore, different kinds of biometrics are used for distinct purposes, in order to assure the best efficiency as possible for each application [1,2].

A biometric authentication system, as compared to a password or a smartcard one, has the advantage of requiring only the person itself to perform the identification, avoiding cases of impersonation due to sharing, or impossibility of verification because of a loss or forgetfulness [1].

Nevertheless, even a system based on a biometric feature can be spoofed. Besides the threats related to systems technology, such as database corruption, injection of malicious codes, among others [3], most of the biometric features themselves can be faked or simulated [3-8].

The use of more than one biometric feature for identification, in a so-called multimodal system, can prevent these kinds of attacks, making more difficult to defraud [2,4].

A recent attempt to make a "spoof-proof" biometric technology has been proposed by Nishigaki and Arai [9]. It uses information from the eyes saccade response and the blind spot position for user authentication. Tests with 10 subjects lead to results of 0% FAR and 0% FRR in the best case. The authors, however, warn that is still necessary to confirm the singularity and permanence of the blind spot position and the saccade response time. A practical use of this system would be void due to the complexity of the data acquisition setup.

Another human reflex that has important characteristics for biometric identification is the pupil light reflex (PLR). It's known that the movement of constriction and dilation that the eye pupil makes in reaction to a changing of light intensity has some properties which are different for each person [10-12] and, just like the saccade response, it is expressed automatically, mechanically and momentarily [9].

The singularity and permanence of this human reflex has also not been proven, but together with another biometric feature, could make an authentication method more difficult to spoof.

This work presents a new approach for a high security biometric authentication method, combining features from the iris pattern and the pupil light reflex (PLR). Due to its proven high level of singularity and permanence [13], the iris texture represents an ideal feature for this purpose.

2. Proposed system

In order to validate the hypothesis, a prototype system was developed. The method used in each step is described as follows.

Figure 1 shows a block diagram of the proposed system. Similar to an iris recognition system, this one uses a camera in order to acquire the samples in a non-invasive process.

The captured video is pre-processed for feature extraction. This step basically consists of noise reduction and contrast adjustment.

The characteristics of PLR, which will be named here as dynamic features, as well as those from the iris pattern, or static features, are then extracted from the images, generating independent feature vectors.

After that, each one of the vectors are compared to other stored on the database. This will result in scores which measure how much the person is different from the one that he claims to be.

Being a multimodal system, information from both biometrics needs to be fused to make a final decision. In the proposed system, this is done at score level due to the distinct nature of the data.

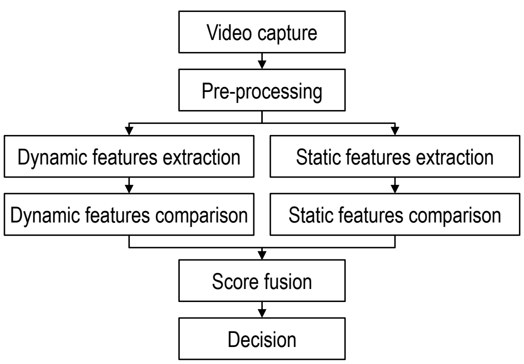

Figure 1. Block diagram of the proposed system

2.1. Video capture

A pupillometer device has been developed for the video capturing process (Fig. 2). It consists of an enclosure with a single aperture where the user positions his eyes so that an inner video camera can capture his iris image. This allows the light intensity over the pupil to be controlled. A short flash light is triggered to stimulate the movement of constriction and dilation of the pupil, while the PLR is recorded by the camera.

Figure 2. Pupillometer used for video capture

Internal illumination was provided by four infrared LEDs with peak wavelength of 850nm. This was done for two reasons: first, because the iris reveals richer patterns under this wavelength [14], and second, because this type of light, which is invisible for human eyes, doesn't affect the pupil constriction [15].

An infrared monochrome camera Basler acA640-100gm was used for the video recording. Six high-brightness white LEDs where arranged around the camera lens to generate the light stimulus.

2.2. Pre-processing

Due to the arrangement of the IR LEDs used for illumination, some specular reflexes over the eye surface generated high intensity regions on the images. These artifacts were removed by the same procedure as described in [16].

2.3. Dynamic features extraction

After the pre-processing step, the pupil size in each frame of the video needs to be measured for the dynamic features extraction. For that, an algorithm based on region growth was used, as described in [17].

A set of ratios between pupil and iris radius measurements describes the PLR signal $r_p'(t)$. Eight dynamic features extracted from it have been used, as follows.

The initial pupil radius (r_0) and the minimum pupil radius for the applied stimulus (r_{min}), given by Eq. 1 and 2, where t represents time since the flash triggers.

$$r_0 = r_p'(0) \tag{1}$$

$$r_{\min} = \min(r_p'(t)) \tag{2}$$

Latency time (t_L), which represents the period of time between the flash trigger and the start of constriction, determined by Bergamin and Kardon's method [12] (Eq. 3).

$$t_L = \arg\min_t \left(\frac{d^2 r_p'(t)}{dt^2} \right) \tag{3}$$

Constriction time (t_C) and constriction amplitude (Δr), given by Eq. 4 and 5.

$$t_C = \arg\min_t (r_p'(t)) - t_L \tag{4}$$

$$\Delta r = r_0 - r_{\min} \tag{5}$$

Recovery time (t_R), defined as the period of time starting at the maximum constriction until the pupil radius achieves a quarter of the constriction amplitude (Eq. 6).

$$t_R = \min(t) - t_C - t_L \ni \begin{cases} t > t_C + t_L \\ r_p'(t) > 0.25\Delta r + r_{\min} \end{cases} \quad (6)$$

Constriction (v_C) and recovery velocity (v_R), given by Eq. 7 and 8, respectively.

$$v_C = \frac{\Delta r}{t_C} \quad (7)$$

$$v_R = \frac{0.25\Delta r}{t_R} \quad (8)$$

Figure 3 represents how the features are associated to a PLR signal.

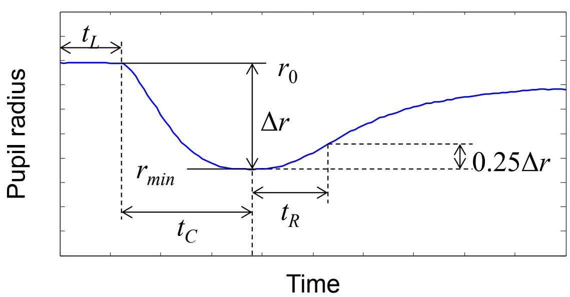

Figure 3. Features extracted from the PLR signal

To reduce correlation between features in the generated vectors, some of the possible parameters have been discarded. The form of feature vectors used to represent the PLR of an individual is showed in Eq. 9.

$$p = (r_0, r_{\min}, v_C, v_R) \quad (9)$$

Each element of the dynamic feature vector is normalized by the method of the normalized sum.

2.4. Static features extraction

Considering that the iris pattern is a static biometric measurement, a single image can be used to extract its features. In the proposed method, the video frame in which the pupil had the minimum radius was used. Only two sections of the iris texture were used for coding in order to avoid interference from eyelashes and eyelids. The regions used are illustrated in Fig. 4. The pupillometer built for image acquisition ensured that the eye was always in the same angular position.

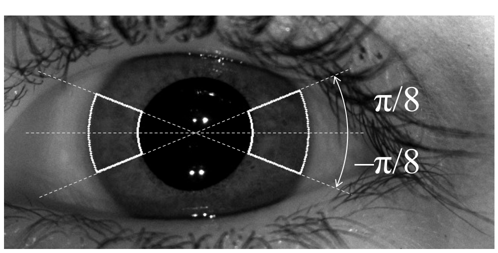

Figure 4. Iris regions used for features extraction

A border detection algorithm [18] was then applied to segment the iris texture area, and the feature extraction was done by texture coding using Gabor 2D wavelets, similar to Daugman's method [13].

3. Experiments

To assess the system performance, 59 volunteers have been recruited for experiments. From the total, 50 subjects had PLR and iris pattern recorded once, and the other 9 repeated the test five times each, generating 45 video sequences. The videos were acquired at resolution of 640x480 pixels and at sampling rate of 60 fps.

During the experiment, each person stayed 2 minutes with the eyes in the absent of visible light for pupil accommodation. After that, the image capture started and a 500μs flash light was triggered. The recording was stopped 3 seconds after the light pulse, allowing the use of 180 frames per video sample.

Dynamic and static features were compared separately. Euclidean distance has been used to compare vectors of dynamic features, resulting in score values S_{pupil}. As in Daugman's method [11], Hamming distance has been used for the static features, generating the scores S_{iris}. For multimodal authentication, a score level fusion has been used.

Each one of the first 50 videos had been compared to all others in order to simulate fake authentications. The other 45 videos were compared among those of the same person, being equivalent to authentic access attempts.

4. Results and discussion

Table 1 shows the Equal Error Rates for each method and for the multimodal system, and Fig. 5 shows the ROC curves for the three methods.

It can be seen that PLR can add information in cases where iris pattern features alone could produce errors.

Table 1. Experimental Equal Error Rates

Modality	**EER (%)**
Dynamic (PLR)	13.88
Static (iris)	5.47
Multimodal (fusion)	2.44

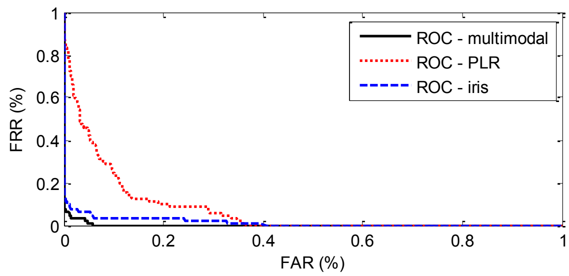

Figure 5. ROC curves for the three cases

These results show that, although the PLR features have low variability to be used alone for authentication, it can add biometric information to iris pattern features.

The Equal Error rates achieved by the proposed system are higher than traditional iris recognition methods, such as Daugman's [13] and Wildes' [19]. However, it wasn't considered Failure to Enroll or Failure to Acquire rates, which are not available for those systems. Also, in Daugman's system, the image must have at least 50% of the iris area visible to be considered a valid sample, all of the other images are simply discarded and didn´t count in the error rates obtained, while in the proposed work, just 25% of iris texture is used so that no images were discarded in this process. Low quality of iris texture can be compensated by PLR features.

Another important advantage of the proposed method is that it can avoid any "unalive" iris to be accepted. Daugman [12] proposes a liveness detection based on pupil hippus, but it can't associate the movement to a person, which could allow a video or even an imposter with contact lenses to be presented to the camera.

In some cases, the proposed system also can't authenticate a person only by its PLR, but it can reject an imposter with more than 97% of confidence, even if he uses contact lenses reproducing the iris pattern of another subject. The use of a single sensor to acquire both biometric features has also the advantage to be less expensive and more convenient to the user.

5. Conclusion

This paper presented a new approach for biometric authentication using human reflexes. A prototype system has been developed and tested. Promising results have been found, showing that PLR together with iris pattern can be used for a more secure biometric authentication system.

References

[1] A. Jain, A. Ross, K. Nandakumar. *Introduction to Biometrics*. Springer, Heidelberg, 2011.

[2] A. Ross, K. Nandakumar, A. Jain. *Handbook of Multibiometrics*. Springer, Heidelberg, 2006.

[3] C. Roberts. Biometric attack vectors and defences. *Computers & Security*, 26(1):14–25, Feb. 2007.

[4] Q. Xiao. Biometrics – technology, application, challenge, and computational intelligence solutions. *IEEE Computational Intelligence Magazine*, 2(2):5–25, May 2007.

[5] L. Thalheim, J. Krissler, P. M. Ziegler. Biometrische Zugangssicherungen auf die Probe gestellt. *c't Magazin für Computertechnik*, 11:114–123, May 2002.

[6] T. Matsumoto, H. Matsumoto, K. Yamada, S. Hoshino. Impact of Artificial "Gummy" Fingers on Fingerprint Systems. *Proceedings of SPIE*, 4677:275–289, Jan. 2002.

[7] H. Chen, H. Valizadegan, C. Jackson, S. Soltysiak, A. K. Jain. Fake Hands: Spoofing Hand Geometry Systems. In: *The Biometric Consortium Conference*, 2005.

[8] B. Toth. Biometric Liveness Detection. *Information Security Bulletin*, 10(8):291–297, Oct. 2005.

[9] M. Nishigaki, D. Arai. A user authentication based on human reflexes using blind spot and saccade pesponse. *International Journal of Biometrics*, 1(2):173–190, Aug. 2008.

[10] V. Pamplona, M. M. Oliveira, G. V. G. Baranoski. Photorealistic models for pupil light reflex and iridal pattern deformation. *ACM Transactions on Graphics*, 28(4):106.1–106.12, Aug. 2009.

[11] A. Yasukouchi; T. Hazama, T. Kozaki. Variations in the light-induced suppression of nocturnal melatonin with special reference to variations in the pupillary light reflex in humans. *Journal of Physiological Anthropology*, 26(2):113–121, Mar. 2007.

[12] O. Bergamin, R. H. Kardon. Latency of the pupil light reflex: sample rate, stimulus intensity, and variation in normal subjects. *Investigative Ophthalmology & Visual Science*, 44(4):1546–1554, Apr. 2003.

[13] J. Daugman. How iris recognition works. *IEEE Transactions on Circuits and Systems for Video Technology*, 14(1):21–30, Jan. 2004.

[14] Yuqing He, Jiali Cui, Tieniu Tan, Yangsheng Wang. Key Techniques and Methods for Imaging Iris in Focus. In: *International Conference on Pattern Recognition*, 557–561, 2006.

[15] F. Fotiou, K. N. Fountoulakis, A. Goulas, L. Alexopoulos, A. Palikaras. Automated standardized pupillometry with optical method for purposes of clinical practice and research. *Clinical Physiology*, 20(5):336–347, Sep. 2000.

[16] V. Yano, G. Ferrari, A. Zimmer. Using the Pupillary Reflex as a Diabetes Occurrence Aid Tool through Neural Networks. In: M. Kamel, A. Campilho (Org.). *Image Analysis and Recognition*. 6754:40-47, Springer Verlag, Heidelberg, 2011.

[17] V. B. L. Ibanez, V. Yano, A. Zimmer. Automatic pupil size measurement based on region growth. In: *ISSNIP Biosignals and Biorobotics Conference*, January 2012.

[18] H. Scharr. Optimal Filters for Extended Optical Flow. In: B. Jähne, R. Mester, E. Barth, H. Scharr (Ed.). *Complex Motion*. 14–29, Springer, Heidelberg, 2007.

[19] R. P. Wildes. Iris recognition: an emerging biometric technology. *Proceedings of the IEEE*, 85(9):1348–1363, Sep. 1997.