Implementation of an Identification System Using Iris Recognition

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Abstract

In this paper, we propose a probable solution to implement a security system using an iris recognition technique. The implemented system acquires images with an infrared camera. It extracts a 2D code through scale-space filtering and concavity. Experiments are then performed using a set of 272 iris images taken from 18 persons. The results show that the iris feature patterns obtained can be clearly discriminated from person to person.

Keywords: *iris, human identification, biometrics, scale-space filtering*

1. Introduction

Biometric identification systems, which rely on physical and structural features of the human body to identify a human-being, are used in various areas that require a high degree of security due to the superiority of its reliability and stability. Among these various methods, iris recognition is regarded as being the most distinct, consistent, and stable option. The appearance of an iris pattern is highly randomized with extremely data-rich physical structures that differ from person to person, even between monocular twins. In addition, there are some 450 degrees of freedom on which to base a statistical analysis and comparison. Moreover, the human iris reacts so sensitively to light that its shape and size change continuously. This makes counterfeiting or copying extremely difficult.

A viable iris identification system was first introduced in 1993[2] and a US patent soon followed [3]. According to the patent, extracting 128 features of the iris and placing them in a 256-byte code has theoretically reduced identification errors to 1 in 800,000,000 [4, 5]. Several other methods were developed using isotropic bandpass decomposition [6, 7, 8, 9] and multi-channel Gabor filtering [10]. Another approach using zero-crossings in a wavelet transformation was also presented [11, 12]. Unfortunately, no physical recognition system incorporating these techniques successfully has been introduced. By contrast, a scale-space filtering approach [13] was introduced and proven to work efficiently for rapid and automatic human identification with a high degree of reliability and confidence.

Recently, iris recognition research has focused on reducing the antinomic relationship between the False Acceptance Ratio (FAR) and the False Rejection Ratio(FRR). The algorithm to extract iris features by Iridian is extremely efficient. Through the adjustment of the threshold value its 256-byte iris code can be used to identify a particular person from one in 26 million to 1013 persons theoretically [4, 5]. In this paper, we introduce a probable solution to implement an iris recognition system using a scale-space filtering technique. The proposed method can retrieve a 2-dimensional binary iris code which measures the Hamming distance. The performance results presented herein are comparable to those of Iridian's [5].

2. Iris Identification Algorithm

2.1. Segmentation

To identify the iris correctly in a given image, its inner and outer boundaries need to be located. To define the inner boundary, the center of the pupil is determined by examining its radius. The image value changes across the pupil's outer border with the iris. The outer boundary can be located similarly. Most methods use a geometric approach for boundary detection. Since the pupil is very simple in shape, the efficiency of the algorithm depends on computational speed rather than accuracy.

In this paper, the region corresponding to the pupil is first segmented as in earlier works [13, 14] using brightness thresholding. The threshold value is obtained from an image histogram by applying a K-means clustering algorithm. After finding the center of the pupil, the outer boundary of the iris is then located. A 5X10 mask is used which moves pixel by pixel in a horizontal fashion with respect to the estimated center of the pupil. The outer boundary of the iris can be found where the average gray level of the pixels in a 5X10 subregion changes abruptly. Once the centers of the pupil and the iris are located, the original image is transformed to a polar coordinate image. Since the pupil and the iris are not concentric, the newly created Cartesian coordinate image is revised using bilinear interpolation when converted to a polar coordinate representation. Figure 1 shows an example of a transformed polar coordinate iris image.

Figure 1. Iris image in a polar coordinate system

It should be noted that even if an image is taken with the highest precautions, it usually contains unwanted aspects such as eyelashes and external light sources. Therefore, disregarding inaccurate or unclear information will cause fewer misidentifications. For example, when visual data in a particular region seems to be ambiguous, it is better to exclude that particular image rather than to make arbitrary corrections. A statistical approach can be taken to discriminate regions that have a high probability of being noise. For the purpose of this study, a 16x16 window is applied at an 8-pixel interval. Areas whose standard deviation is less than one half the average are considered to be noise and are thus ignored [13].

2.2. Extraction of Binary Iris Codes

The iris is a complicated specimen to examine by itself, not to mention that the color and brightness differ from person to person. There are many ways of extracting features from an image. Literature shows that most iris identification techniques use space-frequency analysis such as wavelet and Gabor transformation. In this work, variations in the directional properties of image brightness are used to describe iris features. A derivative of the grey level is investigated to determine whether the rate of grey level change is continuously increasing (concave-down) or decreasing (concave-up). Only the direction of concavity, not the magnitude, is considered. This approach can be easily applied, since the direction inverts at the zero-crossing of second derivatives. Zero-crossing is a well known image processing technique used for edge detection. A value of 1 is assigned to a pixel with positive second derivatives while 0 is given to negative second derivatives. This method has the advantage of dealing with various eye colors or brightness factors pliably.

Since the derivatives are very noise-sensitive, it is difficult to extract iris features consistently. In order to fully conserve the original information while minimizing the effect of noise, a scale-space filtering technique is applied as introduced previously in [13]. However, even though this approach works efficiently well with a high identification rate, more than 400,000 arithmatic operations are required to retrieve a 256 byte 2D iris code. In this paper, a modified algorithm is proposed, one which is more cost effective.

Let the one-dimensional iris signature $f(\theta)$, denote the gray values on a virtual concentric circle of an arbitrary radius. The iris signature $f(\theta)$ is composed of various frequency components and additive noises. In general, noise can be removed by low frequency filtering. However, the high frequency components may also be filtered out. Iris patterns are very complicated with a variety of frequency components. Thus, if only low frequency filtering is used to reduce noise, a significant number of detailed patterns may also be blurred. To cope with this problem, a scale-space filtering technique is applied to lessen the sensitivity of the derivatives to noise while conserving the concavity of the original signal as much as possible.

Concavity is investigated in a scale-space domain. Let $F(\theta, \sigma)$ be the result of the scale space filtering of $f(\theta)$ at the scale σ, such that

$$F(\theta,\sigma) = \frac{\partial^2}{\partial\theta^2}\int_{-\infty}^{\infty} f(\xi) g_\sigma(\theta-\xi) d\xi \tag{1}$$

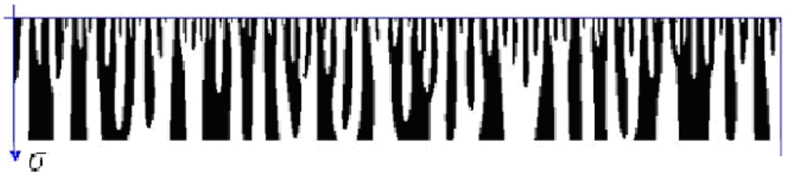
where $g_\sigma(\theta)$ represents the Gaussian with a standard deviation.

It is important to note that scale-space filtering [13, 14] is a method that describes a signal qualitatively, managing the ambiguity of the scale in a systematic way. The signal is first expanded through convolution using Gaussian masks over a continuum of sizes. Contours in the scale-space image represent the points of zero-crossings in the scale space. Passing through such a point, a pair of opposite signs appears in the smoothed signal.

Let $I(\theta, \sigma)$ be defined as the two-dimensional feature pattern in the scale space. $F(\theta, \sigma)$ takes 1 or –1 for a positive or negative value of $F(\theta, \sigma)$, *i.e.*, $F(\theta, \sigma)$ = sgn $\{F(\theta, \sigma)\}$. Only sign information is used for feature extractions. Figures 2 (a) and (b) show an example of a one-dimensional iris signature and a corresponding two-dimensional feature pattern in the scale space respectively.

As shown in Fig.1, extremal points appear and disappear at singular points as σ varies. Additional zeroes may appear but existing ones do not in general disappear. Normally, a scale-space filtering technique [13, 14, 15] is very effective for personal identification, however, it is also computationally expensive. It requires more than 400,000 multiplications to extract one 256X8 iris code from a 640X480 grey iris image. Fortunately, computation costs, a common flaw of previous works, can be reduced by analyzing the Fourier spectrum of the iris images and selecting an appropriate scale, σ. Figure 3 shows an example of an extracted feature when applying scale-space filtering on the polar coordinates of an iris image when σ= 4.5.

(a) 1D Cross-section of an iris image, $f(\theta)$



(b) Feature extraction in a scale-space domain, $I(\theta,\sigma)$

Figure 2. Example of feature extraction

Figure 3. Iris image in a polar coordinate system

A 2 dimensional iris code can be obtained by subsampling the extracted feature. The sampling interval is determined by the size of the desired codes. For personal identification, two iris codes are XOR-ed to each other and the degree of mismatch is then measured. To prevent non-iris artifacts from influencing iris comparisons, AND operation is also applied as in other methods [3, 13]. The Boolean XOR operation detects disagreement between any corresponding pair of bits, while the Boolean AND operation prevents non-iris artifacts from influencing recognition during iris comparisons. The norms of the resultant XOR-ed bit patterns and AND-ed mask vectors are obtained in order to compute a fractional Hamming Distance, HD, as follows:

$$HD = \frac{\|(codeA \oplus codeB) \cap (maskA \cap maskB)\|}{\|maskA \cap maskB\|} \quad (2)$$

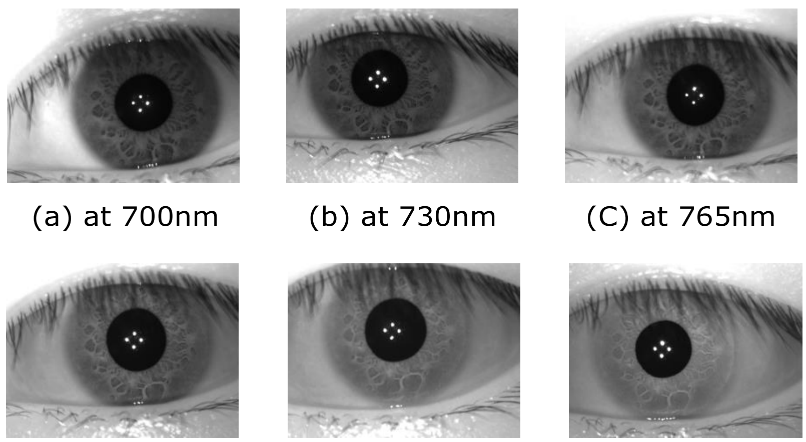
where $\oplus$ represents XOR operator.

The Hamming Distance is a similarity measure and represents the fraction of bits that disagree between two given codes. While 50% of the bit patterns extracted from different people theoretically match, HD between codes belonging to the same eye is greater than 80%.

3. Implementation of the Iris Recognition System

The proposed iris recognition system can be implemented cost effectively using ordinary equipment easily encountered in everyday life. A low-priced standard 640X480 USB Camera is chosen to interface with a Window based computer system through a USB port commonplace with most computers. A D2 web-camera from Alphacam is used. To obtain a clear iris image at a 20~30 cm distance, a 1/3” 9.8° 35mm lens is selected following an operational test.

White light, which is frequently used in recognition systems for lighting, was deemed to be unsuitable for our purpose due to its level of brightness. To acquire a clear iris image, the eye must be illuminated directly. A glaring light source generally makes people feel uncomfortable. Moreover, the reflection of a bright light source off the iris acts as noise and causes problems during the recognition process. Instead, a near-infrared LED is selected to minimize light reflection and user repulsion. Experiments were performed to identify the appropriate LED infrared-wavelength able to conserve meaningful iris features or patterns, while minimizing the effect of reflection. When a 700 nm wavelength (close to a visible ray) LED is used, details of the iris pattern can be conserved; however, the noise can not be effectively reduced. Likewise, with a wavelength of 940 nm, the border between the iris and the sclera is not clearly visible, making it difficult to extract an iris image. To minimize reflection, 4 less dazzling LEDs instead of 1 high powered LED are used for illumination. Figure 4 shows the images under various illuminations with different wavelength LEDs. After careful consideration, an infrared LED wavelength of 850 nm is adopted as a light source with an IR bandpass filter for illumination.



(a) at 700nm (b) at 730nm (C) at 765nm

(d) at 850nm (e) at 880nm (f) at 940nm

Figure 4. Iris images under various illuminations

4. Recognition Performance

Experiments were performed on a photographic database of eye images to analyze the recognition performance of the proposed approach. An ordinary Window-based computer was used for the simulation. 1,000 sheets of 640x480 gray scale images were acquired from 50 different pairs of human eyes using our prototype as shown in Figure 4. This represents 10 images taken from each eye.

Each image was preprossed. Once the center and radius of the iris was located, the iris region was then transformed into a polar coordinate iris image. Contaminated regions that might contain ‘possible noise’ were removed. A scale-space filtering technique was used to retrieve iris features and to generate an iris code image. The generated binary code image contained approximately 45% 1's and 55% 0's on average. From the code image, 16 different sizes of two-dimensional binary iris code were extracted for analysis. The iris codes were XOR-ed to each other to compare their degree of similarity (or mismatch). Any region assumed to be contaminated was excluded as noted in Eq. 2. For the analysis, 49,500 code pairs from different people were randomly selected and XORed to retrieve the HD.

The performance of a given biometric identification scheme can be characterized by a graph superimposing two fundamental histograms of HDs: One histogram, we define as a histogram of authentics, is obtained from pairwise comparisons between codes extracted from the same eye; the other histogram, we define as a histogram of imposters, is obtained from pairwise comparisons of codes from different eyes.

It is clear that the mean of the imposter HDs is almost 0.5 (theoretically 0.5). The mean of the authentics on the other hand is much higher than 0.5. In addition, the standard deviation of the imposters is much smaller than that of the authentics. Therefore, by setting the threshold properly and measuring the HD of the code pairs one can determine whether any two codes are of the same or different eyes. The two fundamental distributions should ideally be well separated, as any overlap between them will cause decision errors.

To analyze the distribution of similarity, a histogram of measured HDs was examined. The HD distribution of the imposters resembled Gaussian, whereas the HD distribution of the authentics did not. Subsequently, the best-fit formula for Gaussian distribution was applied to properly model the histogram of imposters. FARs and FRRs with different threshold values were examined. The FARs were obtained from the histogram of imposters and the FRRs were obtained from the histogram of authentics. Since FAR is crucial for security and FRR is important for convenience, FAR was used to set the threshold value and FRR was measured for further analysis. Since the histogram of authentics was modeled as a Gaussian, a standard normal distribution table was used to determine the FARs at different thresholds.

FARs and FRRs were examined at different threshold values. To set the proper threshold, a maximally acceptable FAR was anchored at a value of 0.1X10-14. It should be noted that sufficient performance can be obtained with an FAR setting as low as 0.0001% (1.0X10-7) for newly released high-performance fingerprint scanners. Thus, by using a value of 0.1X10-14, the FAR can effectively perform two times better than these existing fingerprint scanners. The threshold value was determined around the point where the FAR was below 0. 1X10-14.

Table 1 shows the results of each code according to variations in size. Figure 5 shows a particular histogram of imposters of 128x16 Bit Code. These results show that the proposed approach is highly effective. For example, as noted in Table 1, if the threshold is set for 0.62 with a 128X16 code, a person can be identified at FAR 0.2232X10-15 and FRR 0.0542. This means the chance of misidentification is limited to 2.2 cases per 1016 attempts.

Table 1. FAR & FRR with Different Code Sizes

Code Size (bits)	Threshold (%)	FAR	**FRR**	Code Size (bits)	Threshold (%)	FAR	FRR
64*8	71	0.6159E-15	0.3644	256*8	69	0.2146E-15	0.3013
64*16	64	0.1675E-15	0.1402	256*16	65	0.343E-16	0.1567
64*32	63	0.1820E-15	0.1227	256*32	64	0.9361E-15	0.1293
64*64	63	0.4874E-15	0.1082	256*64	65	0.1587E-16	0.1447
128*8	66	0.2881E-16	0.1520	512*8	69	0.2331E-15	0.3184
128*16	62	0.2232E-15	0.0542	512*16	65	0.1202E-15	0.1769
128*32	62	0.2531E-15	0.0555	512*32	64	0.2331E-15	0.1502
128*64	61	0.4140E-15	0.0391	512*64	65	0.3715E-16	0.1616

This is an appropriate level considering that the world’s population is roughly 7 billion. In addition, an FRR value of 0.0542 means that approximately one in 20 persons might be falsely rejected as an imposter. Subsequently, reexamination would be required.

Since the FAR and FRR values are very small, this implies that the two histograms overlap slightly. This also means the risk of misidentification is relatively insignificant and negligible.

As seen in Table 1, a code size of 128x16, 128x32, or 128x64 bits would be advisable for commercial applications due to the low FRR. It should be noted as well that during about 50,000 experimental trials conducted using 128x16 bit code, not one single false acceptance occurred.

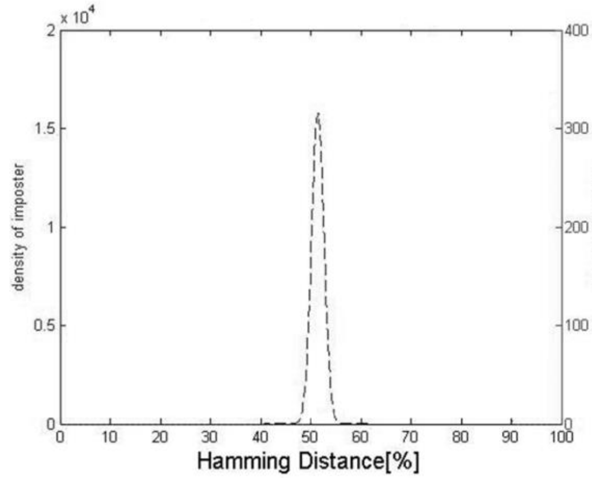


Figure 5. Histogram of Imposters of 128x16 Bit Code System

5. Conclusion

Advances in hardware and software have made it possible to implement highly reliable compact personal identification systems using the iris of the human eye. The iris has more discriminators than any other biometric feature including the commonly used finger print. In addition, the image structure of the iris remains stable throughout a person's lifetime and can be acquired without any contact. In this paper, an implementation scheme is introduced which emphasizes the importance of not only performance but also implementation cost. The proposed method can be applied easily to ordinary articles in daily use, such as safety latches and automobile starting devices. To achieve this, a 2 dimensional code is extracted using the direction of concavity from a given image. A scale-space filtering technique is used to overcome the noise sensitivity related to the second derivatives. The proposed approach can resolve misidentification problems caused by variations in color and brightness among people under a variety of illumination conditions.

The resulting iris code can also be used to develop a reliable system for rapid and automatic personal identification. Since two iris codes are XOR-ed to each other and only the degree of mismatch, *i.e.*, the Hamming distance, is measured for personal identification, the proposed scheme is computationally cost-effective. These experimental results demonstrate the feasibility of a highly reliable iris recognition system. Furthermore, the simulation results are comparable to those presented by Daugman [2, 3, 5]. Considering that existing commercial iris identification systems take several images and select the best one, the proposed approach provides an effective method of iris recognition. "This work was supported by 2011 Hongik University Research Fund."

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