Extraction and selection of dynamic features of the human iris

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Abstract

The personal identification through iris texture analysis is a highly efficient biometric identification method. Some algorithms and techniques were developed, taking into consideration the texture features of the iris image in the human eye. Nonetheless, such features, due to the fact that they are static, they are also susceptible to fraud. That is, a picture can replace the iris in an analysis. For that reason, this paper proposes a method for extracting the texture features of the iris during the pupil contraction and dilation, in addition to the dynamic contraction and dilation features themselves. Therefore, it was developed a new image acquisition system through NIR (Near Infra-Red) illumination, considering the Consensual Reflex of the eyes. The features are measured according to a dynamic illumination standard controlled by the software and are afterwards selected by means of data mining. Then it is possible to increase the safety in the biometric recognition devices of people through their iris, for only living irises can be utilized. The results show a significant precision index in determining such features, despite being inferior to the ones obtained by means of static methodology.

1. Introduction

The analysis method of the human iris was initially proposed by Frank Burch in 1936. It was only in 1993 that John Daugman patented a computer algorithm based on wavelet transform and Gabor filter, consisting of a sequence of 256 bytes named as “iris code” [1] [2] [3].

Since then, several methods were developed for recognition, based on iris features. Most of the systems were based on the algorithm created by Daugman [1].

The identification techniques are extremely precise, completing the process in a split second. However, all literature-known methods are applied to static images. That is, the recognition is done in an image obtained under special NIR illumination conditions [4] or even under visible light illumination. This process is fast and offers the necessary precision in order to identify a person.

By observing the current methods, it is verified that they do not guarantee that the individual being evaluated is actually present or if the captured image is a photograph, prosthesis or some type of digital image, which may serve as entry data to the recognition system for frauds.

So far, methods having assessed the known iris features jointly with the eye movements under illumination alteration conditions are unheard of.

2. Objectives

Due to the increasing safety needs, this paper proposes a new approach to the biometric recognition through the human iris. The proposed approach allows for the evaluation of the static features of the iris. That is, texture features observed during the pupil movements – involuntary contraction and dilation movements – due to alterations in the illumination conditions. These features present behavior standards which vary from person to person when the eye is submitted to illumination pulses. Therefore, this paper intends to demonstrate that other features – dynamic ones – can be utilized with great efficiency in the biometric recognition through the human iris, and with great performance regarding resistance to frauds. Conversely, this paper does not intend to apply the tests which confirm such resistance, but to demonstrate the usage possibilities of these dynamic features to the biometric recognition.

3. Methodology

The human eye is sensitive to visible light. That is, the light within the violet-red range causes some type of reaction to the eye, from the cones and rods up to the sclera (the white outer part). For example: the pupil contracts and dilates under the effect of the visible light, and the iris and the sclera exceptionally reflect within this range. In order to capture an image of the human iris by using visible light, there is a problem: how to keep the natural reflexes on the globe of the eye, iris and sclera surfaces from affecting the quality of the digitalized image? Several techniques are employed by professional photographers in order to deviate the light beam, by appropriately positioning the camera. Still, to acquire iris images at a good resolution – thus allowing for the extraction of features aiming at the biometric recognition – the photograph techniques cannot be utilized because, in general, the camera must be placed frontally to the iris and at a short distance. Some examples of the iris with visible light reflex can be seen in figure 1. These images do not provide enough quality for a dependable biometric recognition.

Figure 1 - Visible light reflexes on the iris.

The systems for the acquisition of human iris images – aiming at their recognition – have somehow solved this problem by using images obtained by infra-red light (NIR) [4], because the human eye is not sensitive within this range of the electromagnetic spectrum. The eye is therefore, frontally lit with LEDs operating in the near infra-red range, by digitalizing an image with a camera sensitive to the infra-red light, according to figure 2.

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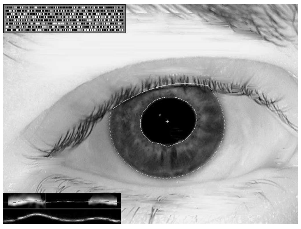

Figure 2 - NIR illumination images [5].

The NIR illumination generates good resolution and definition images. However, due to the fact that they are not "visible" to the human eye, they do not allow for the necessary stimuli so that the pupil can perform the contraction and the dilation movements. The "visible light" offers the necessary stimulus. Nevertheless, the image quality is compromised, thus making the extraction of features difficult.

Some bases to iris images, utilized in the Biometrics literature – such as CASIA from the Automation Institute and Chinese Science Academy [6] [7] or UBIRIS from SOCIA Lab. from the Beira Interior University, Portugal [8] – are static images and they record pictures of individuals at different moments using NIR illumination.

In short: how to capture images without visible light reflexes, but controlling the pupil contraction and dilation? Better: how to capture images with NIR illumination using visible light to contract and dilate the pupil, without causing reflexes on the iris, thus extracting the dynamic features?

The answer is in the human optic system anatomy [9]. The eye captures through the cones and rods the light stimuli taken to the brain by the optic nerve, so that vision can be processed.

In the transmission of the stimuli by the optic nerve, they pass through an area named optic chiasm, according to figure 3. In this area, the mixture of the medium fibers of the optic nerve takes place. Fibers of the right optic nerve mix with the left ones and vice-versa. This causes the eyes to be "connected", that is, the reflexes to stimuli applied to one of the eyes are presented in both. Such physiological function is denominated "Consensual Reflex". This reflex is responsible for the "synchronism" of the movements for both eyes.

Therefore, based on the "Consensual Reflex", a device for the acquisition of iris images was developed. It is shown in figure 4.

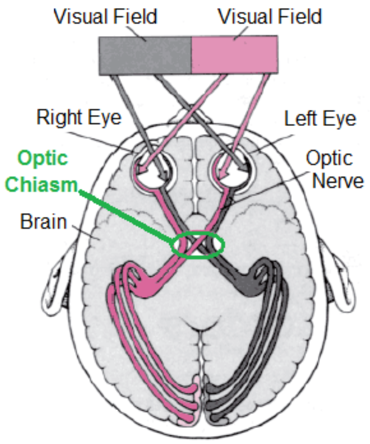

Figure 3 - Detail of the optic chiasm area in the human optic system.

This device performs different and independent tasks in each one of the eyes. The left eye receives visible light stimuli (white) in specific periods of time, controlled by the software developed, whereas the right eye image is digitalized in a video sequence, under NIR illumination.

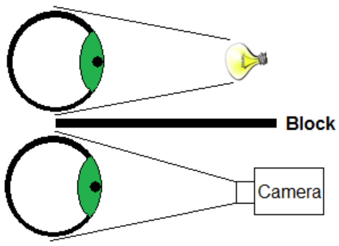

Figure 4 - Device developed to capture iris images.

The acquisition device, connected to a computer, allows for the software to control the illumination on an eye, applied to in specific periods of time, whereas the image of the other eye is digitalized, thus forming a video sequence. This video sequence – obtained by NIR – is synchronized along with the visible light pulses applied to the other eye. Then it is possible to extract the frames features during the pupil contraction and dilation, without the interference of the light reflexes on the iris, pupil and sclera. These movements are produced by the controlled stimulus of the other eye and repeated by the eye whose image is being digitalized, due to the Consensual Reflex, without the interference of the visible light reflexes.

3.1 Definition of the stimuli periods.

With the purpose of extracting the dynamic features of the iris, the intervals of illumination alteration used were (1 – 209; 210 – 419; 420 – 629; 630 – 839; 840 – 1000). That is, from frame 1 to frame 209, the right eye is digitalized by using NIR illumination, and without any application of illumination to the left eye. From frame 210 to 419, the right eye is digitalized, whereas the left eye receives visible light during the entire interval. That is, the visible light pulse starts in frame 210 and finishes in frame 419. This procedure is repeated in the other intervals, forming a video sequence of 1,000 frames.

In order to validate the dynamic features extracted from the biometric recognition through the iris, videos from 111 people were captured – 5 videos of each – recorded across different days and times, totaling 555 videos. Each video contains 1,000 frames.

3.2 Pre-processing

Unlike the bases in which the images are captured, in controlled and previously processed environments [6][8], the images captured for this paper presented noises, due to the involuntary movements of the participants' eyes. It demanded a pre-processing action, so that flawed frames could be discarded.

To discard inadequate frames, the proposed algorithm verifies the location of the pupil and the quality of the image, by using the methodology proposed by MA et al [10].

The frames to be used are equalized, and seeds are “planted” in the pupil area, enhancing its presence and identifying its core. Finally, the major axis, the minor axis and the pupil circularity are calculated.

The pupil, in most of the cases, is not a perfect circumference. Due to the fact that it is a muscle-filled organ (trabeculae) [9], the contraction and dilation movements distort more and more this pseudo-circumference. This distortion rate is one of the dynamic biometric features to be extracted and used in the recognition.

The ring corresponding to the iris is segmented for purposes of texture information analysis. The upper and lower part of the frame is discarded, as well as the eye’s left and right side. These areas are discarded because they contain occlusions which may compromise the extracted features, such as the eyelashes, eyelids and also the sclera.

3.3 Feature Extraction

In order to enable the evaluation of the behavior of each one of the features due to the illumination alteration conditions, five analysis periods are established. The first one is composed of the entire video (1,000 frames). The other periods are defined to record the precise period of illumination transition. This way, the periods comprise the following frames:

1st period – average of the 1,000 frames;

2nd period – average between the frames 210 and 220;

3rd period – average between the frames 420 and 430;

4th period – average between the frames 630 and 640;

5th period – average between the frames 840 and 850;

Twelve different dynamic features are extracted:

1) Pupil circularity;
2) Pupil diameter;
3) Pupil contraction/dilation time;
4) Pupil contraction/dilation rate;
5) Average of the gray levels of the segmented iris;
6) Standard deviation of the gray levels of the segmented iris;
7) Variation coefficient of the gray levels of the segmented iris;
8) Correlation;
9) Angular Second Moment (ASM);
10) Entropy;
11) Contrast;
12) Inverse Difference Moment (IDM);

These twelve features above form the base to generate a feature vector, and for each one of them the average is calculated within each period.

It was observed that the features of contraction and dilation of the pupil have some person-to-person differences, both during the contraction time (visible light on) and the dilation time (visible light off). Then, it is supposed that the pupil circularity, diameter, contraction/dilation time and contraction/dilation rate be individual features and have discrimination power between different individuals.

The circularity and the diameter are extracted in each one of the 5 periods of time. The time and the contraction/dilation rates are measured under illumination alteration conditions.

Figure 5 presents a variation graph for the diameter of the pupil during an example video sequence. The pupil contracts more in the first light pulse – between frames 210 and 220 – than between frames 630 and 640. The individual average for this variation is utilized as positions of the feature vector.

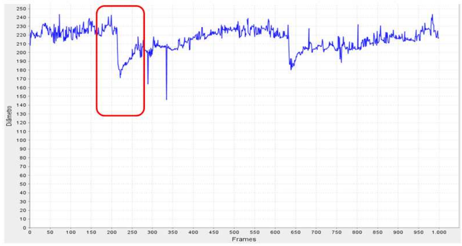

Figure 5 - Pupil diameter variation.

The features of the iris gray levels, which compose the vector, are the gray levels average, the standard deviation and the variation coefficient. These features are usually employed in the literature, in static images of the iris [7][10]. According to the authors' approach, these features are measured in the intervals, taking into consideration all the frames across a specific period (contracted or dilated pupil) and there is one measurement for each period and for each iris segment.

The area formed by the segmented iris is divided in two parts (A Sector = left and B Sector = right) due to the cuts performed, according to figure 6.

Figure 6 - Segmented iris.

Each one of these parts is utilized to extract the gray levels and the texture [11]. The iris texture has also been commonly used in the static image identification [7][10]. As the pupil dilates/contracts during the periods mentioned, these features present a dynamic standard behavior during its movement. The following texture parameters are considered in this paper: correlation, angular second moment, entropy, contrast and inverse difference moment.

The texture features, in each iris segment, are obtained on the co-occurrence matrices generated by the variation in the gray levels, in the following directions: 0º, 45º, 90º and 135º.

After measurement normalization, the feature vector is generated with 248 elements, according to Table 1.

Table 1 - Dynamic features of the iris – NE = Number of Elements

Features	NE
Pupil circularity	5
Pupil diameter	5
Pupil contraction/dilation time	4
Pupil contraction/dilation rate	4

Gray levels average	10
Standard deviation	10
Variation coefficient	10
Correlation	40
Angular Second Moment	40
Entropy	40
Contrast	40
Inverse Difference Moment	40
Total of features	**248**

3.4 Feature Selection.

The tests performed with the 248 features confirmed the proposal feasibility. However, it is important to know – among the proposed dynamic features – which ones are the most discriminative. The selection of the most discriminative and dynamic features was performed through *Data Mining* [12]. For this reason, the Weka (*Waikato Environment for Knowledge Analysis*) software was utilized [13].

In order to select the attributes, the options **CfsSubsetEval** and **BestFirst –D 1 –N 5** were used. Weka indicated that, among the 248 features, the 17 ones presented in Table 2 are the most discriminative.

Table 2 – Most discriminative dynamic features of the iris

1 – Pupil dilation time in the interval between frames 420 and 430
2 – Pupil contraction / dilation rate in the interval between frames 630 and 640
3 – Pupil contraction / dilation rate in the interval between frames 840 and 850
4 – Gray levels average of the B sector of the segmented iris for all the 1,000 frames of the video
5 – Gray levels average of the B sector of the segmented iris in the interval between frames 420 and 430
6 – Gray levels average of the B sector of the segmented iris in the interval between frames 630 and 640
7 – Correlation of the A sector in the 90º angle of the co-occurrence matrix for all the 1,000 frames of the video
8 – Correlation of the B sector in the 0º angle of the co-occurrence matrix in the interval between frames 210 and 220
9 – Correlation of the B sector in the 90º angle of the co-occurrence matrix in the interval between frames 630 and 640
10 – Correlation of the B sector in the 135º angle of the co-occurrence matrix in the interval between frames 840 and 850
11 – ASM of the A sector in the 0º angle of the co-occurrence matrix in the interval between frames 630 and 640
12 – ASM of the A sector in the 90º angle of the co-occurrence matrix in the interval between frames 630 and 640
13 – ASM of the B sector in the 135º angle of the co-occurrence matrix in the interval between frames 840 and 850
14 – Entropy of the A sector in the 135º angle of the co-occurrence matrix for all the 1,000 frames of the video
15 – Contrast of the A sector in the 45º angle of the co-occurrence matrix in the interval between frames 840 and 850
16 – Contrast of the B sector in the 45º angle of the co-occurrence matrix in the interval between frames 210 and 220
17 – Contrast of the B sector in the 45º angle of the co-occurrence matrix in the interval between frames 630 and 640

4. Results

In order to evaluate the performance of the dynamic features extracted and selected in the biometric recognition, two distance metrics were utilized: Euclidean Distance and Hamming Distance.

Figure 7 presents the Recall x Precision graph for all video sequences. It is observed that the Euclidean distance presents slightly superior results compared with the Hamming distance. The precision is also maintained above 80% for the search for up to 4 videos of the same individual, thus demonstrating the discrimination capacity of the dynamic features of the iris proposed in this paper, for biometric recognition. It is important to highlight that the 17 features selected improved the results previously obtained from the 248 proposals.

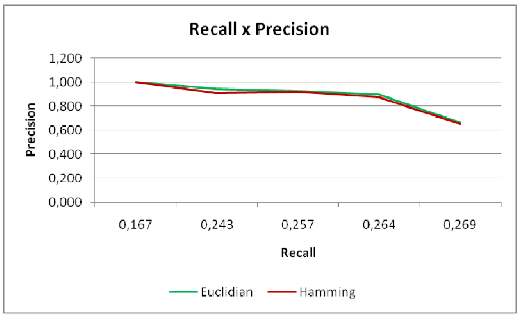

Figure 7 - Recall x Precision with search for up to 5 similar videos.

5. Conclusions

The biometric recognition through the iris with static images presents precise indices above 90%, according to Table 3.

Table 3 – Precision of the static methods

Method/Author	Recognition Rate
Daugman[1][5]	100%
Li Ma[10]	99.43%
Boles[14]	92.64%

Despite the high performance indices of the methods proposed by Daugman, Li Ma and Boles, all of them use static images. However, none of them discusses the resistance of their methods regarding frauds. Despite the fact that our method was not evaluated regarding this aspect, it is supposed that it is more fraud-resistant, due to the methodology employed. For instance, if one attempts to fraud our approach, the individual to be identified should use a video sequence with the periods of time between pupil contraction and dilation, synchronized with the image digitalization.

As the definition for the amount of intervals – as well as the beginning and the end of each one of them – is entirely deterministic, biometric recognition systems can be generated. These will operate solely in the presence of a "living iris". That is, if the individual to be recognized responds to the illumination stimuli applied.

The image acquisition device and the methodology proposed to extract the features are completely innovative and, for this reason, impossible to be compared with other extraction and biometric recognition techniques through the iris.

The recognition precision, by using dynamic iris features, approached the traditional methods (>90%), in its search for similarity of up to 3 videos of the same individual.

Despite the fact that the prototype constructed to image acquisition has not been improved yet, the methodology presented optimal results, thus demonstrating its feasibility.

The authors intend, for further works, to develop a two-camera device enabling the digitalization of both eyes (iris) in different or simultaneous moments. The behavior evaluation for each iris may increase the discrimination power of the dynamic features in the biometric identification, thus improving the system precision.

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