Iris Identification Using Wavelet Packets

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Abstract

In this paper, we present a new method for iris identification particularly convenient for visible light images. It relies on the use of packets of wavelets [8] for the production of an iris code. Experiments, conducted on a database of 700 iris images, acquired with visible light illumination, show an improvement of 2% of FAR and of around 11.5% of FRR with the proposed method relatively to the classical wavelet method [1]. The contribution of colour information is also studied with such method.

1. Introduction

Iris recognition is one of the most reliable biometric technologies but its acquisition is not straightforward; it demands specific devices allowing to capture the iris with a certain level of details. This is a difficult task because the iris is small and dark. Also, problems due to the spectacular spot reflection of the light on the iris are to consider [3].

Most authors propose to use a monochrome CCD camera with near infrared (NIR) illumination (invisible to humans) [1,4,6]. This way, the texture of the iris is well detected, specially for dark irises, and the acquisition is better accepted by the users. Others propose more complex devices in order to solve the problems of spectacular spot reflection [3]. In all cases, the suggested solutions are complex and expensive to set up, and sometimes intrusive for the users.

However, iris scan is a sufficiently mature biometrics so that it can be used for identification purposes. Indeed, Daugman’s approach [1,2], relies on the use of Gabor wavelets in order to process the image at several resolution levels. An iris code composed of binary vectors is this way computed and a statistical matcher (logical exclusive OR operator) analyses basically the average Hamming distance between two codes (bit to bit test agreement). Some recent works follow this direction [4][6].

Another approach, in the framework of iris verification, introduced by Wildes [3], consists of measuring the correlation between two images using different small windows of several levels of resolution. Also, other methods for iris verification have been proposed, in particular relying on ICA [6].

In this paper, our aim is to perform iris identification on images acquired in visible light with a standard camera, and in standard resolution and focus conditions. Indeed, even if we knew that in such conditions the quality of images would be degraded compared to that of near infrared images (NIR), our aim is to experiment to what extent iris authentication can still be performed despite of this degradation of the input images. Moreover, the color information, present in this type of images, contrary to what occurs in NIR, can be useful to adapt the classifiers or to pre-classify the different persons, thus improving the global quality of the system. In order to cope with the particularities of normal light images, we have introduced some modifications to the classical wavelet approach. In particular, we have found that the use of Gabor wavelet packets [8] allow a real improvement on this type of images compared to classical Gabor wavelets. Experiments have been conducted using two different databases: one from the National Laboratory of Pattern Recognition (NLRP) in China, that is the CASIA Iris Image Database [9] collected by the Institute of Automation of the Chinese Academy of Science, in which the images were acquired with a monochrome camera using NIR illumination; the second database was recorded at Institut National des Télécommunications (INT), in which the images were acquired using a standard camera and visible light illumination.

The content of this paper is as follows. Section 2 describes the similarities and differences between our approach (Wavelet Packets) and the classical Wavelet approach. Section 3 presents the results of applying both approaches on the different databases described above. Finally, conclusions and perspectives are provided in section 4.

2 Recognition approaches

A hybrid method is used for iris segmentation after binarization; a Hough transform [3,4,6] permits to localize the outer boundary of the iris, and integrodifferential operators [1,2] are used to detect the inner boundary of the iris.
2.1. Classical approach: Gabor wavelets

Several variants of the approach introduced by Daugman in [1] have been introduced by other authors, but the general idea remains the same. After iris localization, a wavelet analysis is performed. A Gabor wavelet, given in equation (3) is used for that purpose, with different width and frequency parameters in order to generate the iris code [2]. In (3), \( I(\rho, \phi) \) is the representation of the image in polar coordinates, \((r_0, \theta_0)\) represents the polar coordinates of the application point of the wavelet, \( \omega \) the wavelet frequency, and \( \alpha \) and \( \beta \) are the multi-scale 2D wavelet size parameters.

\[
\int_{\rho} \int_{\phi} e^{\frac{-i\omega \theta_0}{\rho}} e^{\frac{-i(\theta_0 - \phi)}{\rho}} \frac{\alpha}{\beta} \rho \, d\phi \, d\rho \tag{3}
\]

In the following, we call “wavelet’s base” a set of wavelets with various windows of analyses. A base is generally composed by one mother wavelet and \( N \) daughters wavelets, that is with \( N \) levels of resolution (in our case, three levels are consider). A daughter wavelet with resolution level \( N \), analyzes the image with a window which is \( N \) times smaller than that of the mother wavelet.

Then, 32 self-similar wavelets, with 4 scales and 8 orientations at each scale, are generated from the mother wavelets [1,2]. Each wavelet is convolved with 32 different spatial locations leading to a total of 1024 complex coefficients for each iris image. Each complex value is converted into 2 bits depending on the signs of its real and imaginary parts. Thus, each iris pattern is associated with a 2048 bits binary code. All the process of transforming an iris image into an iris code is illustrated in Figure 1.

2.2. Our approach: Wavelet packets

On one hand, the classical wavelet approach can be considered as performing more and more precise zooms on the iris. Therefore, if the initial quality of the image is not good enough, it will not be possible to perform a great number of such operations, since the quality of the “zoomed” images will get substantially degraded. A solution to this problem could be to increase the size of the initial window of the mother wavelet, but this would decrease the size of the code, thus implying a greater risk of errors at the recognition phase. For this reason, among others, we preferred to use, instead of classical wavelets, packets of wavelets; indeed, starting from the same analysis window and the same mother wavelet, the packets method involves more wavelets than the classical one, thus leading to an iris code of convenient size (see Figures 1 and 2). On the other hand, the whole image of the iris conveys information, even at very small scales; it is thus important to analyze the whole iris image also at low resolutions. The packets method also exploits equation (3), but involves several application points \((r_0, \theta_0)\) when changing of level of resolution, instead of a unique application point. In our case, for a given application point of the mother wavelet, we have 3 application points for the first level daughter wavelet, 5 application points for the second level daughter wavelet, and 7 application points for the third level daughter wavelet.

We used 832 wavelets with 4 scales and generated this way a 1664 bits code: in one half of the iris image, for each of the 16 levels of \( r \), 26 levels on \( \theta \) are considered (26 * 16 * 2 = 832).

2.3 Introduction of colour information

As all the irises available are colour images, we took into account this information in our Wavelet Packets Method. Initially, images are encoded in 16 million colours; we compressed colour information to 256 colours by exploiting the Adaptive Colour Reduction method [5]. We evaluate in the following whether colour information
improves the discrimination power of the identification system.

Figure 2. Wavelet packets decomposition of the sub-images and the corresponding binary code

3. Experimental setup

3.1. Description of the databases

In this work, we exploited 2 databases. The first database (B1) has been realized in our Institute. It contains 700 images from 70 persons (70 classes), and there are between 7 and 23 iris images per person. The images have been taken with a flash set at a distance of 20-30 cms; the camera used has a 23mm focus, and the captured irises have 120-150 pixels of radius. Also, some variations in lighting and position have been introduced in the database. We have chosen to capture only the left iris of each person. As the use of flash introduces a reflection in the right part of the iris, we only exploit the left part of the iris images; this divides of course the iris code by a factor 2 (from 2048 bits to 1024 bits for the classical method, and from 1664 bits to 832 bits for the wavelet packets method).

The second database comes from the National Laboratory of Pattern Recognition (NLRP) in China, that is the CASIA Iris Image Database [9] collected by the Institute of Automation of the Chinese Academy of Science, in which the images were acquired with a monochrome camera using NIR illumination. It is composed of 749 images from 107 different irises. For each iris, 7 images were captured in 2 sessions.

3.2. Results

Given an iris pattern, our goal is to find the person to which this pattern could be associated. To that end, we have at disposal a database of several iris shots of each person enrolled. We consider for each person a N-template, that is a set of N references (N iris codes).

To compare an iris code to a given N-Template, we compute a Hamming distance (XOR comparisons) between this iris code and each iris code in the N-template, and we keep the minimum of all these distances. If such distance is lower than a predefined threshold, the pattern is then considered as belonging to the corresponding person.

In database B1, 10 irises are available per person; 5 among them are randomly chosen to build the N-template. Following the same idea, as in database B2 only 7 irises are available per person, 4 among them are randomly chosen to build the N-template.

Results are given in terms of false acceptance rate (FAR) and false rejection rate (FRR) and also represented by the ROC curves. We consider that a false acceptance error was made by the system when an iris code and a N-template corresponding to two different persons lead to a Hamming distance lower than the threshold. In the same way, we consider that a false rejection error was made by the system when an iris code and an N-template corresponding to the same person lead to a Hamming distance higher than the threshold.

3.2.1. Classical Wavelet method vs. Wavelet Packets.

We notice that on database B1 that is in visible light, the classical wavelet approach performs poorly, as also remarked by other works [7, 11]. Indeed, in most cases, the classical method leads to false acceptances when the compared original iris images are blurred and have the same size. In this case, the packets method is more robust because it does not analyse only high frequencies. Also, in general, the classical method leads to false rejections when the eyelid covers partially the iris; in this case, the packets method is also more robust, since the original analysis window is bigger.

Figure 3: ROC curves comparing the Classical Wavelet method and Wavelet Packets on database B1
In NIR illumination (database B2), we see that the two methods are equivalent. These results do not reach state-of-the-art error rates because no enhancement was done on purpose, and no filter was applied on the iris code as well [2]. We notice that there are still some false rejections with both methods; this is due to the fact that there are some irises with very low contrast between the iris and the sclera, leading this way to segmentation failures. This will be avoided in the future by the “Iris Image Format for Data Interchange”, studied by ISO with standardization purposes, that will specify contrast standards.

<table>
<thead>
<tr>
<th>Databases</th>
<th>Type of errors</th>
<th>FAR</th>
<th>FRR</th>
<th>FAR</th>
<th>FRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Classical wavelet method</td>
<td>2%</td>
<td>12.04%</td>
<td>0.35%</td>
<td>2.08%</td>
</tr>
<tr>
<td>B2</td>
<td>Packets method</td>
<td>0%</td>
<td>0.57%</td>
<td>0.2%</td>
<td>1.38%</td>
</tr>
</tbody>
</table>

Table 1: Comparison of the different algorithms on databases B1 and B2

3.2.2. Grey-level vs. colour images. We notice that colour information is useful to the system; a global improvement ranging from 2% to 10% according to the threshold value is observed in Figure 4. We only studied the improvement on the FA rate, in order to evaluate whether colour information could enhance the discrimination power of the system on different persons. As expected, colour improves indeed the system regarding impostors.

![Figure 4: FA rate ROC curves comparing the Wavelet Packets method on grey-level and colour images on database B1](image)

4. Conclusions

In this paper, our interest was the processing of iris images acquired in visible light conditions. Very few researchers work in that context as most acquisition devices function in near infrared illumination. We have verified, as other authors [7, 11] that in visible light illumination, the use of the standard wavelet approach is not satisfactory in the context of blurred images and poor iris texture. In that normal light context, we have proposed the use of Wavelet Packets instead of the standard Wavelet approach. Experiments lead to good performances on a database of 70 persons, considering that no enhancement was done on purpose, and no filter was applied on the iris code as well [2]. Relatively good results were also obtained on near infrared images. Also, it was shown that colour information is useful in helping the system to be more discriminant regarding impostors.

In the future, we will introduce image enhancement before the pattern matching phase, which should improve results. Also, we are interested in working on a larger database containing both types of iris images (in visible light and in NIR illumination) as well as studying the limits of the system regarding to image quality degradation.

5. References

[9] [http://www.sinobiometrics.com](http://www.sinobiometrics.com)