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Iris identification method using only a section of the pattern

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Iris based authentication methods are popular due to their reliability and dependability. This paper proposes the method of the iris recognition that instead uses only two fragments of the pattern. The presented method allows for a simpler iris extraction, as it does not use a complex conversion of an iris pattern from a circular to rectangular shape. The results obtained from this experiment show similarities to other previous ones. Importantly, the proposed method may be treated as an alternative solution. The experiment confirmed the validity of the concept for the proposed iris recognition method. Moreover, this method is quicker in comparison to the others. The additional merit of the proposed solution is the elimination of the distortion which comes from the eyelids and eyelashes at the beginning of the iris image processing. Moreover, this method does not require using additional techniques to eliminate disturbances.

Keywords: biometrics, iris recognition, iris pattern extraction.

1. Introduction

Nowadays, it is becoming increasingly popular to use biometrics in advanced technologies and security systems. These advanced security systems are used in a variety of places, for example: border controls, airports, banks, security zones, criminal investigations, *etc*. [1]. They exploit biometric patterns such as voice, face image, fingerprint, iris patterns, hand geometry or retina. The methods are popular due to their effectiveness and acceptability by the user. Among the various methods, iris recognition is most favourable because of the uniqueness of the biometric pattern.

There are numerous person's identification techniques based on a iris. The first major work on this topic is the article of DAUGMAN [2]. He proposed the algorithm for iris location that implements operators to detect the pupil edge. Next, the iris image is converted to the rectangular coordinate system. The iris features in the form of the binary iris code which is obtained from a transformation of two-dimensional Gabor wavelets. Hamming distance is used for measurement and recognition. BOLES and BOASHASH [3] proposed a technique that engages the zero crossing wavelet transform, and PATIL and PATIL KULKARNI [4] showed a similar method that also used a wavelet transformation. WILDES [5] describes a segmentation method that implements the Hough transform and an edge detection operator. A circular Hough transform segments the iris with edge detection which was used by MASEK [6]. MONRO *et al*. [7] presented an algorithm for the iris coding using discrete cosine transform for features extraction. The surface matching for iris recognition is proposed by WEIQI YUAN and BINXIU GAO [8]. Whilst DONG-MEI WU and JIANG-NAN WANG [9] presented their own surface matching algorithm that used the difference of illumination intensity.

SIBAI *et al*. [10] proposed the method which used a genetic algorithm and artificial neural network. A neural network is used for recognition, and the genetic algorithm is used to optimise the neural networks parameters. ALI *et al*. [11] presented a method which used a support vector machine.

The above methods are used to recognize the entire image of the iris. Such systems which use the entire pattern of the iris, are challenging in computing and are also computationally expensive. They require a complex extraction process and normalization of the pattern, which is transformed from a radial to rectangular system. Moreover, a problem with the visibility of the entire image of the iris occurs as the eyelids obscure the upper or bottom fragment of the image. Interferences originating in the eyelashes are another problem. However, solving this problem was drawn up through thresholding.

In this work, we propose the method of the iris recognition which uses only two fragments of the pattern. This method does not require the extraction of the entire image of eye's iris and converting the pattern from the system radial to rectangular. Moreover, fragments used for the recognition are not usually obscured by eyelids which allow for a major simplification of the identification system.

2. Proposed method

The algorithm of the proposed method of iris recognition consists of the following:

1. Normalization of eye image;
2. Iris localization;
3. Pattern extraction;

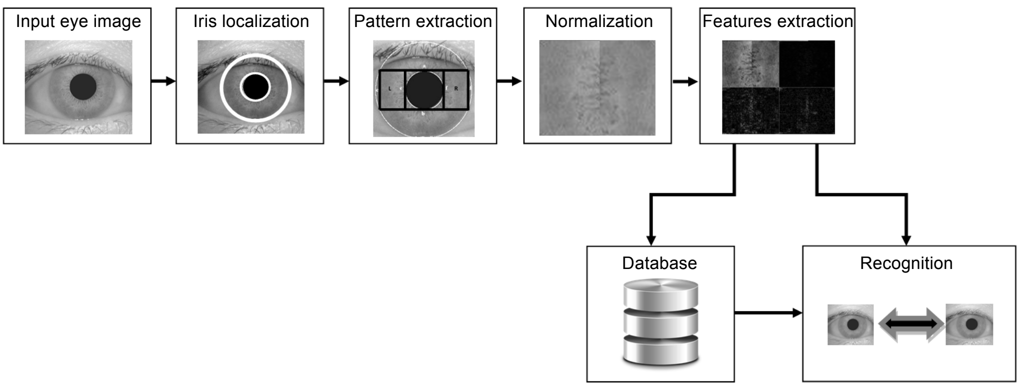

Fig. 1. Scheme of the proposed iris recognition method.

4. Normalization;
5. Features extraction with wavelet transform;
6. Matching of a pattern.

Input images were taken from the image file in either a BMP or JPG format with a different colour map and resolution. In the case of a colour image, it is converted to a greyscale. These iris images do not contain specular reflections. In the second step, the iris localization based on Hough's method is used to point the area of interest. Furthermore, in this step the iris image is normalized. The next step is pattern extraction, which uses two circles and delimitation of the parts of the iris that are normalized in the fourth stage. In the next phase, we extract the features with wavelet transform. The last step consists of the decision about storing the features to the database to create future recognition (Fig. 1).

3. Normalization of the eye image

The first step of our method is the normalization of the eye image. This process consists of geometric and visual normalization. This stage is necessary for the method to be invariant to rotations of an eye. To do this, we determine the corners of the eye [12] and the line between them. Then, we calculate the angle α between the line and the horizontal line. The next step of this procedure is rotation of the eye image by the angle $-\alpha$ (see Fig. 2). The last stage of this process is intensity and contrast normalization using histogram equalization. It provides a sophisticated method for modifying the dynamic range and contrast of an image by changing the image until its intensity histogram has a required shape. The redistribution of pixel values in an image is obtained so that each range contains approximately the same number of pixels. This improves the quality of the image and increases a recognition rate.

4. Iris extraction

The second step of iris recognition is to extract the iris region in an eye image. The iris region may be determined by two circles, one for the iris boundary and the second for the pupil boundary. The eyelids and eyelashes often cover the upper and lower parts of the iris area. Sometimes, light reflections may appear within the iris region disturb-

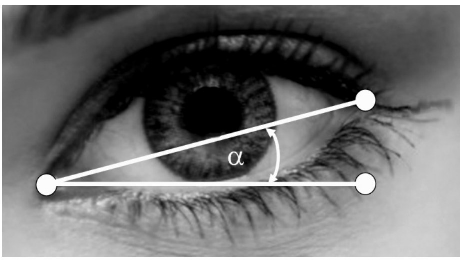

Fig. 2. Normalization procedure of the eye image.

ing the iris pattern. Hence, an effective method is required to isolate the circular iris region in spite of the interferences [13]. The most common technique for determining the iris area is the Hough transform. This transform may be used to determine the parameters of simple geometric objects, such as circles presented in the image. It may be applied to numerous computer vision problems, as images contain objects with geometric edges which may be described by regular curves. The main quality of the Hough transform is the tolerance towards gaps in the boundary of an object. As described by CHERABIT *et al.* [15], Hough transform is a projection of the N-dimensional image space to a parameter of space with dimension M. The two spaces are related by the mathematical model $y = f(x)$. So the aim is to find parameters of the shape that will be detected. The simple case of Hough transform is detecting straight lines $y = mx + b$, represented as a point (b, m) and defined as:

$$r = x\cos(\theta) + y\sin(\theta) \tag{1}$$

where r is the distance from the origin to the closest point on the straight line, and θ is the angle between the x axis and the line connecting the origin with that closest point [15].

The circular Hough transform can be used to detect the radius and central coordinates of the pupil and iris regions. Similar to WILDES [5], we used an automatic segmentation algorithm based on the circular Hough transform. Firstly, an edge map is created by computing the derivatives of intensity values in an image of an eye, then the next step is thresholding. Subsequently, votes in a circular Hough space are analysed in order to estimate three circle parameters: centre (x_0, y_0) and radius r. The parameters of the circle are described by the following equation:

$$(x - x_0)^2 + (y - y_0)^2 = r^2 \tag{2}$$

The three coordinates (x_0, y_0, r) for which the value of Hough space is highest will become the coordinate of the centre and radius of the circle. In this way, we obtain the boundaries of the iris (Fig. 3). In our case, the values of the thresholds were 0.19 and 0.20; r – the value of initialization was 30 pixels. We select the two highest peaks in the accumulator matrix, and we assume there are two circles in the input image.

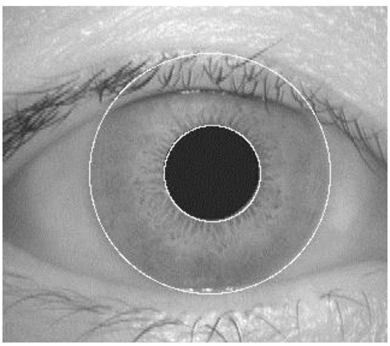

Fig. 3. The boundaries of iris appointed with circular Hough transform.

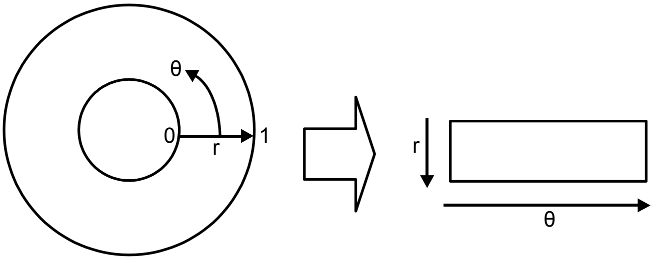

Fig. 4. Rubber sheet model [6].

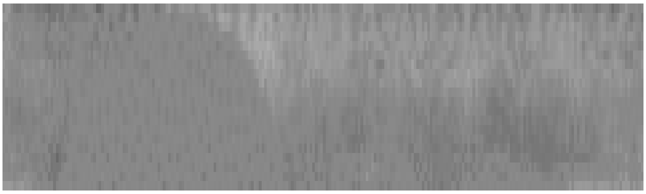

Fig. 5. Traditional iris pattern – size 628 × 55 pixels (34540 points).

The next step in the pre-processing of an iris is normalization. In most methods for iris identification, the homogenous rubber sheet model is used [2]. This model remaps each point within the iris region to a pair of polar coordinates (r, θ) where r is on the interval [0, 1] and θ is the angle [0, 2π] (Fig. 4). The result of this process is a rectangular iris pattern (Fig. 5).

The above way of separating the iris in the person's identification is very common. Unfortunately, it is burdened with interferences, which originate from eyelids and eyelashes which obscure the pattern of the iris. Furthermore, it causes problems in the identification process, as it also requires applying additional techniques to eliminate these disruptions. Methods of removing these disruptions are not always fully effective and can cause a decrease in the level of identification. Due to the recalled defects, we propose our method for the extraction of the fragment of the iris pattern (Fig. 6). After

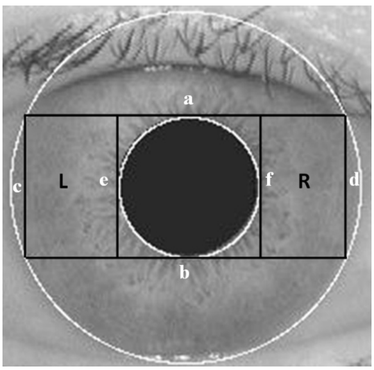

Fig. 6. The iris areas used for identification.

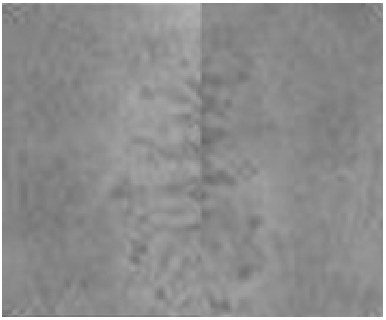

Fig. 7. Our pattern – size 100 × 75 pixels (7500 points).

determining the circles defining the outer limits of the pupil and iris, two parallel horizontal lines are determined. The lines are tangent to the upper and the lower point of the circle, which define the edge of the pupil. The length of these lines are limited by the circle defining the edge of the iris (lines *a* and *b*). After, the ends of these lines are connected with the segments *c* and *d*. Next, they are plotted to the tangents segments on the left and right pupil edge (lines *e* and *f*). In this method, two areas are formed, *L* and *R*, that contain a fragment of the iris. These areas are allocated from the entire image and joined to each other. There is a pattern for the identification coming into existence – in this way (Fig. 7). The obtained pattern is normalized by scaling to the equal size of 100 × 75 pixels. The advantage of the method of an allocation pattern is a smaller number of points for processing, and as shown in the experiment, it is sufficient for a successful identification of a person. An additional advantage of this method is that the obtained sample, as a rule, has no interference in the form of the eyelids and eyelashes.

5. Features extraction

In order to ensure precise recognition of data, the iris image must be extracted. Most iris identification methods use a pass-band decomposition of the iris image to create a biometric pattern. Many techniques exist for distinguishing features, however the out of use in recognizing the iris, Gabor filters, and a wavelet transform are the most commonly applied.

6. Wavelet transform

The two-dimensional wavelet transformation allows for the analysis of images. The pattern image is decomposed through low- and high-pass filters to four sub-images (Fig. 8). Ultimate images have a different energy; still, an LL sub-image has the largest amount and is a reduced copy of the authentic image. However, the remaining sub-images LH, HL, and HH extract the changing components of the image, appropriately in the horizontal, vertical and diagonal direction (Fig. 9). In the two-dimensional signal processing,

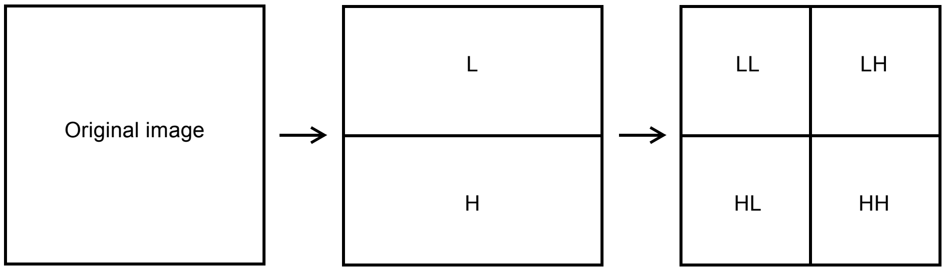

Fig. 8. Scheme of one-level two-dimensional wavelet transform.

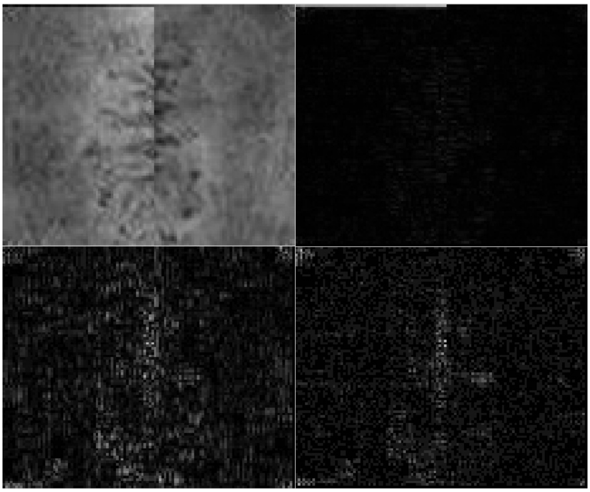

Fig. 9. Wavelet transform of the iris pattern.

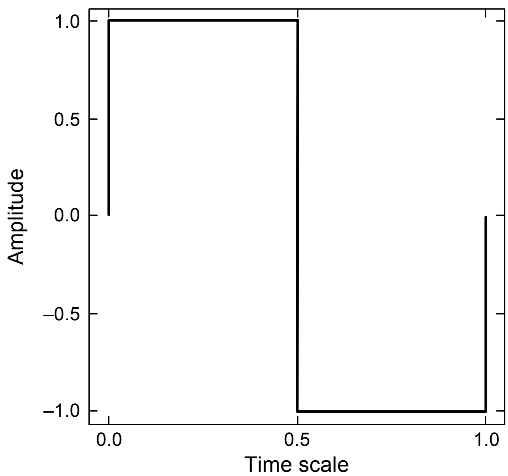

Fig. 10. Haar wavelet function.

an assigned bank of filters is applicable for conducting the transformation. A pair of filters is usually used – as a high- and low-pass. The convolution with the low-pass filter gives the so-called image approximation A_1, though the convolution with the high-pass filters returns images with allocated details in set directions: horizontal D_1, vertical D_2, and diagonal D_3. Wavelets may be used to decompose the data in this iris region into components that appear at different resolutions. The output of wavelets applying is then encoded in order to provide a compact and inaccurate representation of the iris pattern [3, 16]. We used a two-dimensional discrete wavelet transform of the first level in our method. As a wavelet function, we used Haar function (Fig. 10). The sample image of the wavelet transform of the iris pattern is shown in Fig. 9. The pattern used for the recognition (comparison) is the whole result of the wavelet decomposition of the first level.

7. Matching of a pattern

The researchers usually use one of two matching techniques in iris recognition methods. Namely, they are the Hamming distance or the weighted Euclidean distance. We have chosen the weighted Euclidean distance as the matching technique in our iris recognition method. The recognition rate that was higher and over two times lower affected the choice of the matching technique for the weighted Euclidean distance.

8. Weighted Euclidean distance

The weighted Euclidean distance (WED) is used to compare two patterns, particularly if the pattern is composed of integer values. The weighted Euclidean distance gives a measure of how similar a collection of values is between two templates [4, 6]. This metric is described as:

$$\mathrm{WED}(k) = \sum_{i=1}^{n} \frac{(f_i - f_i^k)}{(\delta_i^k)^2} \tag{3}$$

where f_i is the i-th feature of the unknown iris, and f_i^k the i-th feature of iris pattern k, and δ_i^k is the standard deviation of the i-th feature in iris pattern k. The unknown iris pattern is found to match iris pattern k, when weighted Euclidean distance is a minimum at k.

9. Experiment

In the first part of our experiment, we used the image database CASIA-IrisV1 [17]. Iris images from the database were captured with uniform illumination, meaning that all eyes were adequately illuminated. The database includes 756 iris images from 108 eyes. For each eye, 7 images are captured in two sessions, where three samples are collected in the first session and four in the second session. All images are saved in BMP file with resolution 320 × 280. The iris images in the first session were taken as a training dataset, and those from the second session were used for testing. Images in the CASIA Iris Image database do not contain specular reflections due to the use of near infrared light for illumination. We chose three datasets (A, B, and C), each consisting of 100 eyes in order to verify the method, and for each individual, we chose one image for learning and one for testing.

In the second part of our experiment, we used iris images from the UBIRIS.v1 database. The detailed description of images from this database may be found in [18]. UBIRIS database is composed of 1877 images collected from 241 persons in two separate sessions through one month. Images are saved in JPG file with resolution 800 × 600 pixels and 24-bit colour. Its most significant feature is to include images containing several noise factors, simulating less controlled image acquisition environments. This enables the evaluation of the robustness of iris recognition methods. We chose two datasets, D and E, each of them for 100 eyes.

The parameters of the testing platform were as follows: processor Intel Core-i5 – 4 cores and 4 threads 3.3 GHz, 8 GB RAM 1600 MHz, graphics card Nvidia GeForce GT 430 and Windows 7 64 bit.

The results of the experiment are presented in Table 1. Our method achieves the following results: FAR = 2.33%, FRR = 2.11%, and the average recognition rate at the

Table 1. Results of experiment.

Dataset	Number of images	Recognition rate [%]
Dataset A	100	99
Dataset B	100	97
Dataset C	100	98
Dataset D	100	98
Dataset E	100	98
	Average	98

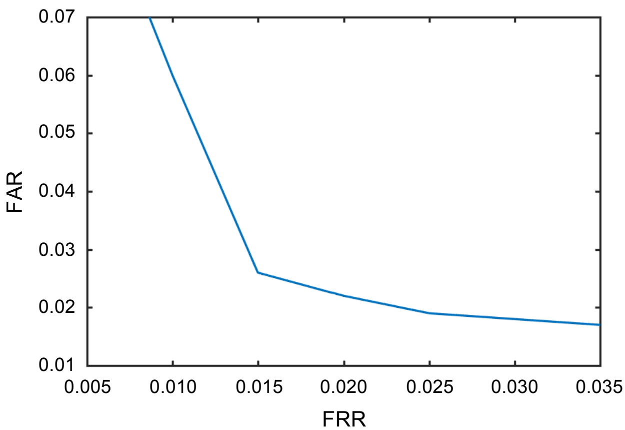

Fig. 11. ROC of the proposed method.

T a b l e 2. Comparison to other methods.

Method	Number of images	Recognition rate [%]
Hamming distance [2]	300	99
SVM [11]	300	100
Wavelet [19]	300	99
ICA [20]	60	90
Contourlet transform [21]	150	99
Orientation field [22]	370	96
Our method	300	98

T a b l e 3. Average time of features extraction [ms].

Method	Iris extraction	Iris extraction + encoding
Our method	49	53
Masek [6]	53	56
SVM [11]	–	71
ICA [20]	–	93

level 98% (Fig. 11). The comparison to the other methods is shown in Table 2. The comparison of calculation time is shown in Table 3.

10. Conclusion

This paper presents the conception of the new method for iris recognition. The presented method allowed for simpler iris extraction, because it did not use a complex conversion of the iris pattern from a circular to rectangular shape. As shown in the experiment, only a section of the pattern is necessary for correct identification, as in [23]. The obtained results of the experiment were similar to the other method, and the proposed method may be an alternative solution to the others. The experiment confirmed the validity of the concept of the proposed iris recognition method. Moreover, our method was faster in comparison to the others. The additional merit of the proposed solution was the elimination of the distortion which comes from the eyelids and eyelashes at the beginning of the iris image processing. What is more, it did not require using extra techniques to eliminate these disturbances. To conclude, the research results indicate that this method may be used in biometric systems. Other methods have a slightly superior recognition rate, but our method is faster, which could be a decisive factor in the processing of large amounts of data.

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