Analysis of particular iris recognition stages

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Abstract. In this paper particular stages are analyzed present in the iris recognition process. First, we shortly describe available acquisition systems and databases of iris images, which can be used for tests. Next, we concentrate on features extraction and coding with the time analysis. Results of average time of loading the image, segmentation, normalization, features encoding, and also recognition accuracy for CASIA and IrisBath databases are presented.

Keywords: iris recognition, biometric, CASIA, IrisBath

1 Introduction

Identification techniques based on iris analysis gained popularity and scientific interest since John Daugman introduced in 1993 the first algorithm for the identification of persons based on the iris of the eye [1]. Then many other researchers presented new solutions in this area [2-10].

The iris is an element, which already arose in early phase of the human life and remains unchanged for a long part of life. Construction of the iris is independent of the genetic relationships and each person in the world, even the twins possess different irises. However, there are also many problems to be faced when encoding the iris such as a change of opening angle in the pupil depending on lighting conditions, covering a portion of its regions by the eyelids and eyelashes, or the rotation of the iris due to the inclination of the head or eye movement.

2 Acquisition of iris image and iris databases

There are several conditions that must be met to perform a correct image of the iris, which could serve to identify the person.

First, the iris picture has to be taken with a good resolution, as the photographed iris region is small, with a diameter of about 1 cm. The higher the resolution the more details will be visible. The method should also be not invasive or causing discomfort to the photographed person. It has to be stressed that too much light entering the eye can cause pain.

Second, the shooting area should be properly cropped in order to include an interesting part of the eye only.

Finally, the acquired image should have no or small number of reflections in the iris, as it difficult to overcome them.

Acquisition of the iris should be implemented in accordance with the standards. The application interface has to be built using ANSI INCITS 358-2002 (known as BioAPI™ v1.1) recommendations. Additionally, the iris image should comply with ISO/IEC 19794-6 norm [11].

One of the first systems for iris acquisition were developed using concepts proposed by Daugman [1] and Wildes [2]. Daugman's system performs image of the iris with a diameter of typically between 100 and 200 pixels, taking pictures from a distance of 15–46 cm, using a 330 mm lens. In the case of the Wildes proposal the iris image has a diameter of about 256 pixels and the photo is taken with a distance of 20 cm using a 80 mm lens.

Currently, several iris acquisition devices as well as whole iris recognition systems can be found on the commercial market. Because now this technology is not yet widespread in use, the prices of these devices are high and the access to purchase them is limited. As examples of the iris devices the following products can serve:

- IrisGuard IG-H100 – a manual camera for iris acquiring and verification; this camera can be held in the hand or can be mounted on a tripod or a desk, 8 pictures of the eye can be registered in time less than 3 s, the system is equipped with RS170 connector composite video (NTSC), pictures are monochrome with resolution 470 TVL
- IrisGuard IG-AD100®multi-modal capture device, this system makes it possible to combine face and iris recognition; dual iris capture takes below 4 seconds (normal conditions), a person eyes can be acquired anywhere within a range from 21 cm to 37 cm away from the unit and be perfectly authenticated within the range
- OKI IrisPass-M – this camera is designed for mounting on the wall to control access to secured areas or can be used in border control, or to register travelers [12]; it takes a picture of the iris at the time of 1 s or less (depending on lighting conditions), identifies the iris at the time of 1 s or less (depending on the configuration of the PC as a controller and the size of the iris database); false acceptance rate (FAR): 1/(1.2 M); shooting from a distance of 30–60 cm
- Panasonic BM-ET330 – designed for the access control to buildings, mounted on the wall [13]; iris recognition time of about 1 s, acquisition from a distance of 30–40 cm, the camera field of view: 115 degrees horizontal, 85 degrees vertical; the maximum number of irises in the database is 1000 and FAR 1/(1.2 M).

Experimental studies were carried out using the databases containing photos of irises prepared by scientific institutions dealing with this issue. Two publicly available databases were used during our experiments, as shown in Section 4. The first database was CASIA [14], coming from the Chinese Academy of Sciences, Institute of Automation, while the second IrisBath [15] was developed at the University of Bath. We have obtained also access to UBIRIS v.2.0 database [16] and the database prepared by Michael Dobeš and Libor Machala [17], which are currently undergoing testing by the contractors from WP7.

CASIA database is presented in three versions. All present photographs were taken in the near infrared. We used the first and third version of this database in our experimental research. Version 1.0 contains 756 iris images with dimensions 320×280 pixels carried out on 108 different eyes. The pictures in CASIA database were taken using the specialized camera and saved in BMP format. For each eye 7 photos were made, 3 in the first session and 4 in the second. Pupil area was uniformly covered with a dark color, thus eliminating the reflections occurring during the acquisition process.

The third version of CASIA database contains more than 22 000 images from more than 700 different objects. It consists of three sets of data in JPG 8-bit format. Section of CASI-IrisV3-Lamp contains photographs taken at the turned-on and off lamp close to the light source to vary the lighting conditions, while the CASIA-IrisV3 Twins includes images of irises of hundred pairs of twins.

Lately a new version of CASIA database has been created the CASIA-IrisV4. It is an extension of CASIA-IrisV3 and contains six subsets. Three subsets from CASIA-IrisV3 are: CASIA-Iris-Interval, CASIA-Iris-Lamp, and CASIA-Iris-Twins. Three new subsets are: CASIA-Iris-Distance, CASIA-Iris-Thousand, and CASIA-Iris-Syn.

CASIA-Iris-Distance contains iris images captured using self-developed long-range multi-modal biometric image acquisition and recognition system. The advanced biometric sensor can recognize users from 3 meters away. CASIA-Iris-Thousand contains 20 000 iris images from 1 000 subjects. CASIA-Iris-Syn contains 10 000 synthesized iris images of 1 000 classes. The iris textures of these images are synthesized automatically from a subset of CASIA-IrisV1.

CASIA-IrisV4 contains a total of 54 607 iris images from more than 1 800 genuine subjects and 1 000 virtual subjects. All iris images are 8 bit gray-level JPEG files, collected under near infrared illumination.

IrisBath database is created by a Signal and Image Processing Group (SIPG) at the University of Bath in the UK [15]. The project aimed to bring together 20 high resolution images from 800 objects. Most of the photos show the iris of students from over one hundred countries, who form a representative group. Photos were performed with resolution of 1280×960 pixels in 8-bit BMP, using a system with camera LightWise ISG. There are thousands of free of charge images that have been compressed into JPEG2000 format with a resolution of 0.5 bit per pixel.

3 Features extraction and coding

We can identify three successive phases in the process of creating the iris code [18]. They are determined respectively as: segmentation, normalization and features encoding as shown in Fig. 1.

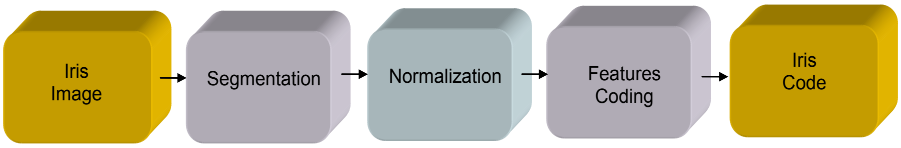

Fig. 1. Stages of creation of iris codes

3.1 Segmentation process

Separation of the iris from the whole eye area is realized during the segmentation phase. At this stage it is crucial to determine the position of the upper and lower eyelids, as well as the exclusion of areas covered by the lashes. In addition, attention should be paid to the elimination of regions caused by light reflections from the cornea of the eye.

The first technique of iris location was proposed by the precursor in the field of iris recognition i.e. by John G. Daugman [1]. This technique uses the so-called integro-differential operator, which acts directly on the image of the iris, seeking the maximum normalized standard circle along the path, a partial derivative of blurred image relating to the increase of a circle radius. The current operator behaves like a circular edge detector in the picture, acting in the three-dimensional parameter space (x, y, r), i.e. the center coordinates and radius of the circle are looked for, which determine the edge of the iris. The algorithm first detects the outer edge of the iris, and then, limited to the area of the detected iris, is looking to get its inside edge. Using the same operator, but by changing the contour of the arc path, we can also look for the edges of the eyelids, which may in part overlap the photographed iris.

Another technique was proposed by R.P. Wildes [2]. In this case also the best fit circle is looked for but the difference (comparing to the Daugman method) consists in a way of searching the parameter space. Iris localization process takes place in this case in two stages. First, the image edge map is created then each detected edge point gives a vote to the respective values in the parameter space looking for the pattern. The edge map is created based on the gradient method. It relies on the assignment of a scalar bitmap vector field, defining the direction and strength increase in the pixel brightness. Then, the highest points of the gradient, which determine the edges, are left with an appropriately chosen threshold. The voting process is performed at the designated edge map using the Hough transform.

In our experimental program [19] we also used the Hough transform, and to designate the edge map we used a modified Kovesi algorithm [20] based on Canny edge detector. An illustration of the segmentation process with the time analysis is presented in Fig. 2.

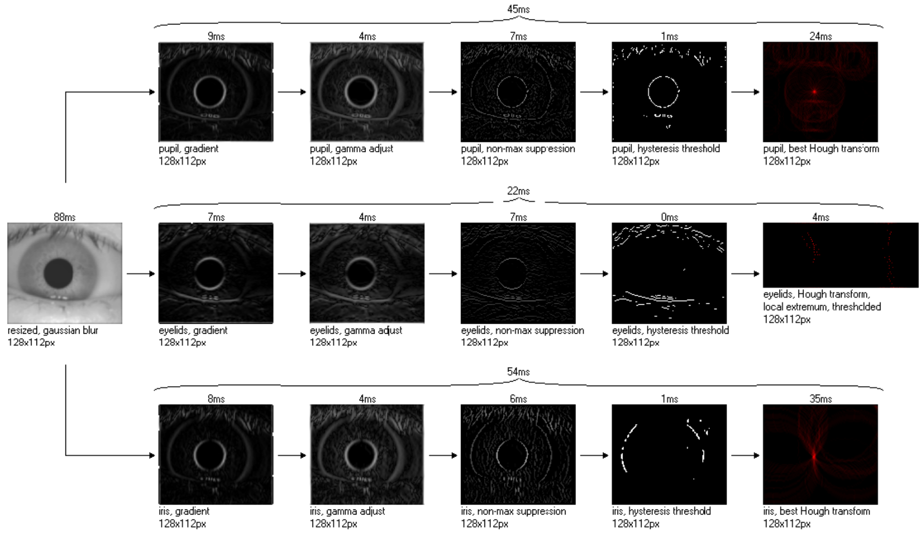

Fig.2. Example time-consuming analysis of segmentation process

3.2 Normalization

The main aim of the normalization step is the transformation of the localized iris to a defined format in order to allow comparisons with other iris codes. This operation requires consideration of the specific characteristics of the iris like a variable pupil opening and non coordinated pupil and iris center points. A possibility of circulation of the iris by tilting the head or as a result of the eye movement in the orbit should be noticed.

Having successfully located the image area occupied by the iris, the normalization process has to ensure that the same areas at different iris images are represented in the same scale in the same place of the created code. Only with equal representations the comparing two iris codes can be correctly justified. Daugman suggested a standard transformation from Cartesian coordinates to the ring in this phase. This transformation eliminates the problem of the non-central position of the pupil relatively to the iris as well as the pupil opening variations with different lighting conditions. For further processing, points contained in the vicinity of a 90 and 270 degrees (i.e., at the top and at the bottom of the iris) can be omitted, This reduces errors caused by the presence of the eyelids and eyelashes in the iris area.

Poursaberi [21] proposed to normalize just only half of the iris (close to the pupil), thus by passing the problem of the eyelids and eyelashes. Pereira [22] showed, in the experiment, in which the iris region was divided into ten rings of equal width, that the potentially better decision can be made with only a part of the rings, namely those numbered as 2, 3, 4, 5, 7, with the ring numbered as the first one, being the closest to the pupil.

During our tests, the Daugman proposal and the model based on its implementation by Libor Masek in Matlab [18] was used in the step normalization stage. At the same time we can select an area of the iris, which is subject to normalization, using both angular distribution and the distribution along the radius. The division consists in determining the angular range of orientation, which is made with the normalization of the iris. This range is defined in two intervals: the first includes angles from –90 to 90 degrees and the second – angles from 90 to –90 degrees (i.e., angles opposite to clockwise).

3.3 Features coding

The last stage of the feature extraction, which encode the characteristics, aims to extract the normalized iris distinctive features of the individual and to transform them into a binary code. In order to extract individual characteristics of the normalized iris various types of filtering can be applied. Daugman coded each point of the iris with two bits using two-dimensional Gabor filters and quadrature quantization.

Field suggested using a variety logarithmic Gabor filters, the so called Log-Gabor filters [23]. These filters have certain advantages over and above conventional Gabor filters, namely, by definition, they do not possess a DC component, which may occur in the real part of Gabor filters. Another advantage of the logarithmic variation is that it exposes high frequencies over low-frequencies. This mechanism approaches the nature of these filters to a typical frequency distribution in real images. Due to this feature the logarithmic Gabor filters better expose information contained in the image.

4 Time analysis

During our research we used the program IrisCode_TK2007 [19]. A multi-processing was used in order to automatically create iris codes for multiple files. The study involved two databases described in Section 2, namely CASIA and IrisBath.

Test results are presented in Table 1. Section "Information" includes the total number of files and the number of classes of irises. Section "Results" contains the results of the processed images. These are average times of individual stages and the total processing time for all files. Figure 3 shows the times of individual stages, expressed in percentage of the overall time for all tested databases (processed with Intel Core i7 CPU; 2,93 GHz).

Our program contains also an option "Multithreading", which a enables multithreaded processing on multiprocessor machines. Figure 4 presents the comparison of the processing times of various stages, when the option "Multithreading" was used or not (processed on Intel Core i7 CPU; 2,93 GHz) for IrisBath database. The total processing time for one processor was about 17 minutes. while for two processors was about 9 minutes.

Table 1. Processing times for two bases: IrisBath and CASIA

	Data base name	CASIA					IrisBath	All databases
		Iris Image Database (version 1.0)	IrisV3			Iris V4 Distance		
Information			Interval	Lamp	Twins			
	Number of classes of irises	217	498	822	400	142	22	2101
	Total number of files	756	2655	16213	3183	2572	432	25811
Results (times)	**The average time of image loading [ms]**	87	86	278	283	3956	1120	968
	The average time of segmentation [ms]	103	107	320	306	4404	1249	1081
	The average time of normalization [ms]	2	2	2	2	2	2	2
	The average time of features encoding [ms]	1	1	1	1	2	1	1
	The average total time coding [ms]	193	196	601	592	8364	2372	2053
	The average time of writing results on disc [ms]	6	5	6	6	8	5	6
	Total time database processing	**00:02:30**	**00:08:55**	**02:43:57**	**00:31:46**	**06:10:15**	**00:17:10**	**09:54:28**

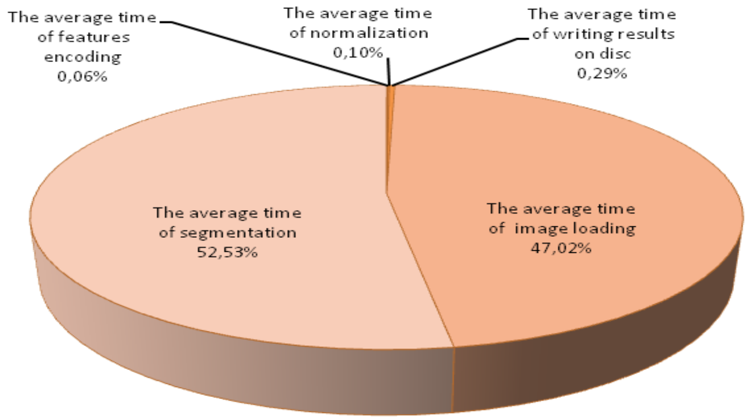

Fig. 3. Participation of individual stages, expressed in percentage, for all tested databases

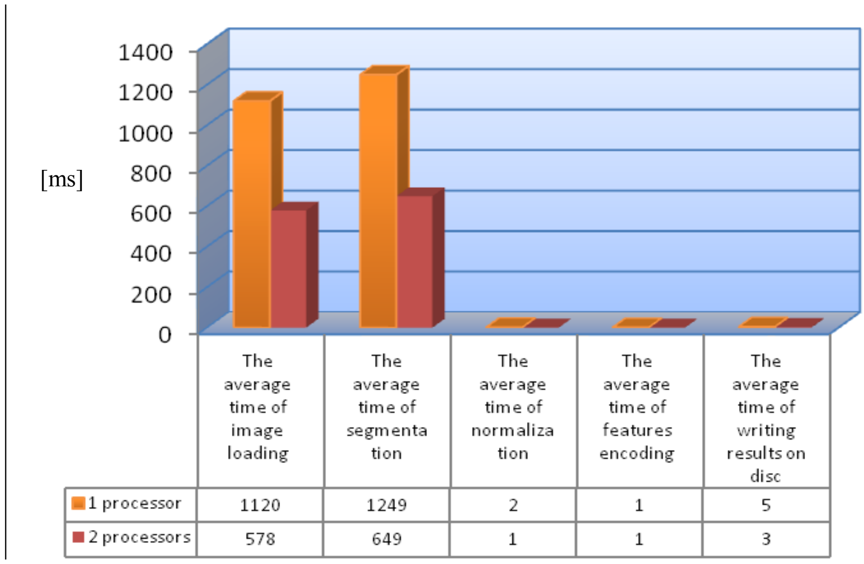

Fig. 4. Comparison of processing times [ms] of various stages (processed with Intel Core i7 CPU; 2,93GHz) for IrisBath database (time precision 1 ms)

5 Conclusions

The most important issue in the biometric identification process is recognition accuracy. The best result we received using the IrisBath database by means of the log-Gabor1D filter. The following results were obtained: FAR=0.351% (*false acceptance rate*) and FRR=0.572% (*false rejection rate*), which result in the overall factor of the iris verification correctness, equal to 99.5%. For the CASIA database v.1.0 the best result was obtained with the code size of 360×40 bits and the following results were obtained: FAR = 3.25%, FRR = 3.03%, and the ratio of correct verification of iris codes at the level of 97% [24].

It can be observed that the time of calculations is so short that the proposed iris recognition system can operate in real-time. However, an effective acquisition of the iris image remains a problem.

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