Iris-based human verification system

A research prototype

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Abstract—**The biometric person authentication technique based on the human iris is well studied to be applied in any access control system requiring a high level of security. In this paper a system for personal verification based on iris patterns is presented. This includes a problem of biometric systems, required knowledge of the anatomy of the human eye, what is verification based on the iris patterns and algorithm operating principle. In the middle part, we present the verification algorithm, which consists of image processing to obtain iris information, iris normalization, feature extraction, and person verification. Gabor filter was used for feature extraction. From such result iris bit template sequence is encoded. Then the Hamming distance is calculated from the iris template, which gives the estimate of the match in the verification process. The results of the algorithm were obtained on CASIA iris database, where a decision threshold for the Hamming distance was set to 0.427, which gives 0% false acceptance rate and 11.584% false rejection rate on the test set. As we were developing a prototype system with the goal to build a foundation for possible improvements and for a real test system, we were very satisfied with the achieved results.**

Keywords-biometric systems; verification; eye anatomy; iris; feature extraction; Gabor wawelets; Hamming distance

I. INTRODUCTION

Traditional methods for personal verification are based on what this person has in his possession (identification document, key etc.) or what this person has remembered (passwords and similar). Every one of this methods has its own weakness, keys can be lost, identification documents forged, passwords forgotten [4].

Advantages in modern information technology today allow us to access different private information, banking services, and protected information, but simultaneously bring much greater vulnerability to the systems and the data against intruders. Thus the increased pressure for the privacy and security of the data led to the rapid development of intelligent personal identification systems in the field of biometrics [5].

A. Biometric systems

Biometric systems provide automatic identification of individuals based on their unique physiological or behavioral characteristics, which the person has in the possession. Commonly used biometric features are facial features, fingerprints, voice, facial thermograms, iris, posture/gait, palm print, hand geometry etc. [5]. A sample of these characteristics is then transformed by various mathematical functions and methods into a biometric template. The essential features contained in this template are then compared with other templates to identify (Who is this person?) or verify (Is it really that person?) the person. Of all these biometric characteristics the verification based on fingerprint received special attention and was successfully applied in to law enforcement applications. In the past 30 years systems based on face and sound recognition were also researched, while the iris recognition approach is newer [5]. The recognition based on iris is known to be one of the most reliable in the field of biometric systems. The probability of two people with identical iris is very close to zero [5,6]. It is for this reason that the recognition based on iris became an important biometric solution. Compared with other biometric characteristics iris is the most stable and hence the most reliable biometric characteristic over the period of a lifetime.

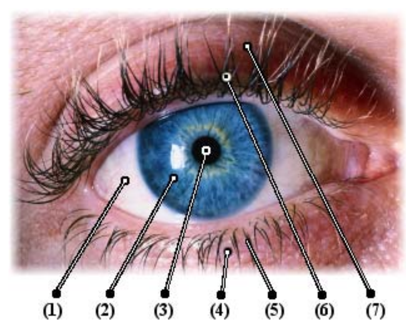


Figure 1. Human eye, where (1) is sclera, (2) iris, (3) pupil, (5,6) eyelashes and (4,7) eyelids.

B. Eye anatomy

The human eye is the organ of vision, which transmits the picture trough the visual paths into the brain. The structure of this organ is very complex. The part that we are interested in is only the visible outer part as shown in Fig. 1. It has a round shape of different colors surrounded by sclera, which is normally white. For an image of an iris it is very likely to be covered by the upper and lower eyelid and eyelashes. At the center of the iris there is a black circle named pupil, which controls the amount of light that passes into the eye and further into the brain processing center.

Information gained from research shows that the diameter of a human iris ranges somewhere between 10 mm to 12 mm, on the other hand, there is difficult to determine the diameter for the pupil since it varies both with age as well as with the current mental state of a person. Usually, it is between 2 mm and 5 mm [2].

A good property of the iris as the inner organ is that its complex structure is visible externally and protected with a transparent layer of the cornea from damage. It is also positive that the iris from the first year of age maintains its complex structure unchanged throughout its lifetime [6,7].

C. Recognition operating principle

An iris-recognition algorithm first has to identify the approximately concentric circular outer boundaries of the iris and the pupil in an image of an eye. The set of pixels covering only the iris is then transformed into a bit pattern that preserves the information that is essential for a statistically meaningful comparison between two iris images. The mathematical methods are then used for recognition. In the case of Daugman's algorithm [7,8], a Gabor wavelet transform [9] is used in order to extract the spatial frequency range that contains one of the best signal-to-noise ratio considering the focus quality of available cameras. The results are a set of complex numbers that carry local amplitude and phase information for the iris image. In Daugman's algorithm all amplitude information is discarded, and the resulting 2048 bits that represent an iris consist only of the phase information. Discarding the amplitude information ensures that the template remains largely unaffected by changes in illumination, and it also neglect the iris color, which contributes significantly to the long-term stability of the biometric template. To authenticate via identification (one-to-many template matching) or verification (one-to-one template matching) a created template is compared to a stored template in a database. If the Hamming distance [7] is below the decision threshold, a positive authentication has effectively been made.

A practical problem of iris recognition is that the iris is usually partially covered by eye lids and eyelashes. In order to reduce the false reject risk in such cases additional algorithms are needed to identify the locations of eye lids and eyelashes, and exclude such bits in the resulting bit template from the comparison [3].

D. Today's best solutions

The algorithms for iris recognition are now used in many devices for different purposes. Companies such as Sandia Labs, OKI, EyeTicket, IBM, Siemens, Iritech, LG, L-1 Identity Solutions, Sagem etc. are using iris recognition technology for governmental bodies, in medicine, aviation, immigration procedures, as well as for commercial and test purposes.

A big credit indeed goes to Daugman's algorithm [7], which is widely used mainly on the country border controls, where the robustness of the technology is under the strong pressure from the wrong confirmation, especially nowadays, since a large number of mass comparisons can be made on large databases. It is also worth mentioning L-1 Identity Solutions [10] (it also encompasses Iridian Technologies; see Tab. I), which is among the companies with an enviable development of iris-based recognition.

II. USED APPROACH

Our approach is based on Daugman's iris recognition algorithm [7]. The iris images used in our research are from the CASIA v1.0 database (756 images, 108 eyes) [11].

A. Segmentation

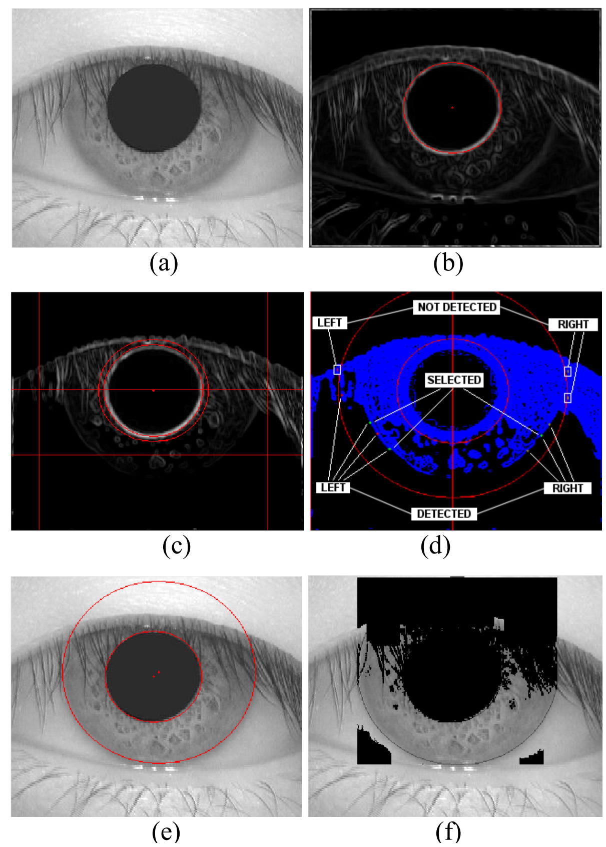


Figure 2. Input image (a), detected pupil edge (b), image illumination (with the region of interest border lines at the outer edge of the iris according to the CASIA database characteristics [11]) (c), outer edge points of the iris found on the principle of locating three points that define the circle (d), image segmentation output (e), and iris mask that excludes eyelids and eyelashes found on the basis of color information (f).

The first step in the iris verification biometric system is the segmentation of the iris image that includes important features for verification as well as unnecessary and noisy parts. The aim of iris segmentation is to eliminate iris part from a digital image of an eye. Iris part shown in Fig. 1 can be described with two circles. The first one divides sclera and iris, while the second one divides iris and pupil. It has to be noted that these two circles are not concentric. Another specific that has to be taken into account is the presence of the upper and the lower eyelid as well as eye lashes, which may cover smaller or larger portions of iris. This fact may influence the quantity and quality of the obtained information. For image edge detection Sobel edge detection operator [3] was used, which is widely used and very effective. We started by locating pupil edge that is easier detected because of the high level of contrast in the transition between the pupil and the iris. The outer circle represents a slightly heavier task due to the lower contrast between the sclera and the iris. To detect this edge it is necessary to carry out some additional operations of image illumination and smoothing [3], which contribute to better detection of the outer edge with the Sobel operator.

The whole process of segmentation is outlined in Fig. 2 and is not described in [7] (it is an independent work of the authors). Output information from segmentation strep gives both the inner and outer edge of the iris (Fig. 2e), and the associated iris mask, which defines useful, therefore uncovered parts of the iris (Fig. 2f).

B. Normalization

Pupil size varies with dependence on the quantity of light that comes into it, which in turn also affects the shrinkage and stretching of the elastic surface of iris. This can drastically affect the comparison of two irises of the same eye. We have to convert the area of iris to a fixed two-dimensional space based on the Dougman's homogeneous rubber sheet [7], which enables us to compare two irises (Figure 3).

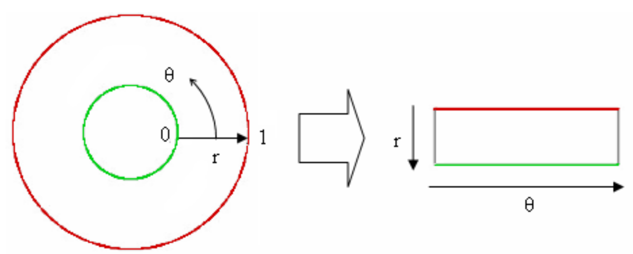


Figure 3. Dougman's model for mapping the iris into rectangular shape (polar coordinates) with marked edges.

C. Feature extraction

After we get normalized iris, we have to extract features from it. Selection of features from polar normalized iris image is carried out with the transformation of the image with 2D Gabor wavelet, which gives the optimal results of the spatial frequencies of the signal in the 2D space [9]. The result of the transformation is a set of complex values, which can be divided into real and imaginary part. In every point of the image we calculate the phase angle from these two values. Based on the angle and the phase transformation (Figure 4), we then create a bit template, where each angle generates two bits of the template as evident from Figure 4.

The bit template (Fig. 5) is thus twice the size of the polar normalized iris image.

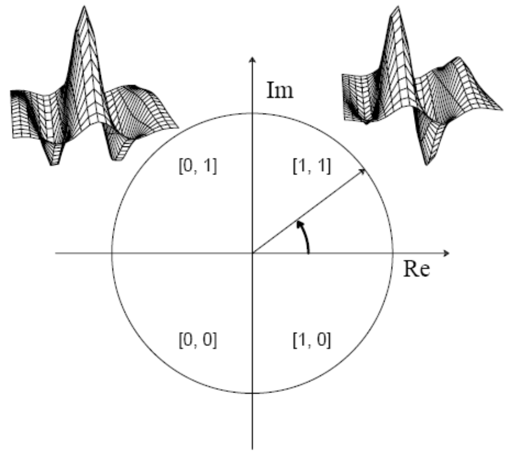


Figure 4. The phase transformation used to convert the angles into iris template [8].

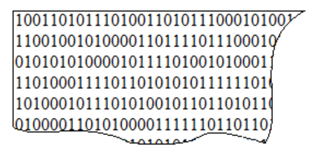


Figure 5. Sample of the iris bit template.

D. Comparison of the iris templates

Iris benchmarking is carried out with a Hamming distance (HD) [7], which contains the logical operator XOR (exclusive or), and gives us a certain degree of matching of two irises. We repeat the comparison of irises through the calculation of the HD in three cases (Fig. 6) due to the possible rotation of the eye. The HD with a minimum value is then used as the result of the comparison. In practice, the expected movement of the HD value for two different irises is around 0.5 [12].

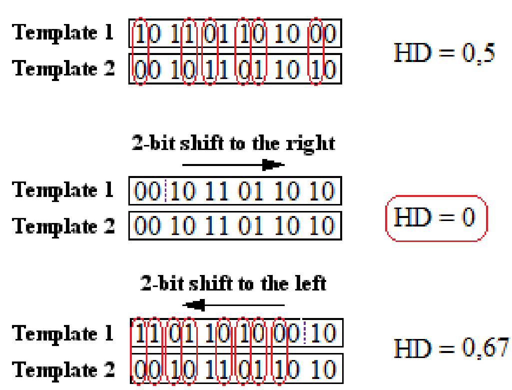
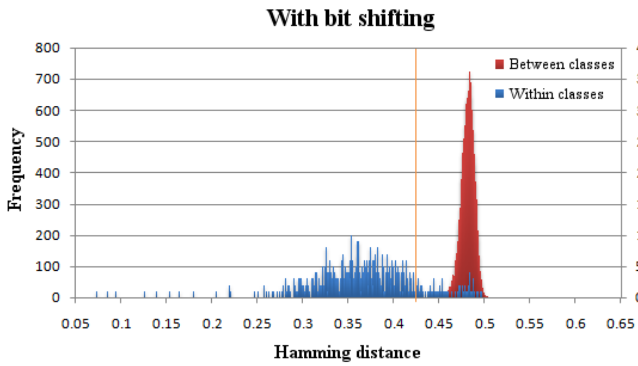


Figure 6. Example of calculating the Hamming distance (HD) with one step shift of iris bit templates.

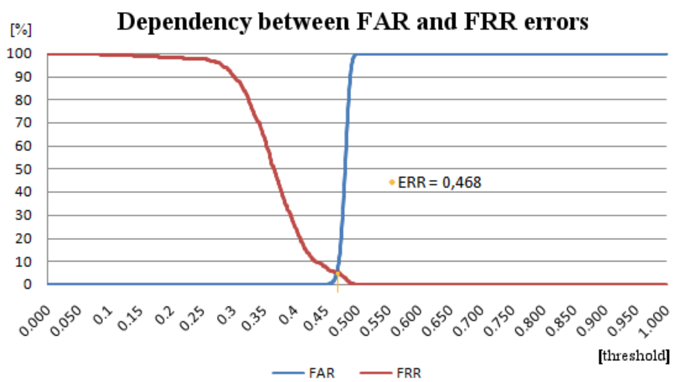
III. RESULTS

The results have been carried out over a CASIA database of 108 persons (classes), and each person contributed 7 different images [11]. The comparison within the class provides the comparison of seven images of a person among themselves. The comparison between classes, however, provides the comparison of one iris image of a person with one of all other persons.

The results (Fig. 7) of the comparison led to the threshold value of the HD = 0.427, which gives the rate of false approval (FAR – False Acceptance Rate) equal to 0%, and, on the other hand, gives 11.584% False Rejection Rate (FRR).



(a)



(b)

Figure 7. Histogram of comparisons within classes and between classes (a) and the graph of dependency between FAR and FRR errors for given HD value (ERR gives the Equal Error Rate) (b).

As we were developing a prototype system with the goal to build a foundation for possible improvements and for a real test system, we were very satisfied with the achieved results. Nevertheless, the comparison with other systems/algorithms is always of our interest, thus, Tab. I gives an insight into the results of the iris recognition systems evaluated at the last ICE (Iris Challenge Evaluation) in 2006. For more details see [13,14].

IV. CONCLUSION

The implemented system for the verification of the person based on iris is founded on phase. The system contains the segmentation, normalization, feature selection and comparison step. A key part of the system is segmentation, to which we devoted special attention in the development, since it is a foundation of all of the following steps. In two cases (out of 756) we encountered an error in the segmentation step, e.g. the segmentation of iris did not succeed, and, consequently, we were unable to apply further steps. We will continue working on improvements, since the results are already encouraging. One of the forthcoming bigger steps in the development of our prototype system is also the integration of the iris image capturing sensor.

TABLE I. ICE 2006 RESULTS FOR FAR=0.1%, WHERE THREE FRR ESTIMATIONS ARE REPORTED BECAUSE OF 30 DIFFERENT PARTITIONS OF THE IRIS DETABASE FOR TEST PURPOSES [14]; OUR IMPLEMENTATION ON CASIA DATABASE FOR FAR=0.1% GAVE FRR=7.7%.

Group	**FRR [%]**		
	Minimum	***Median***	***Maximum***
Sagem-Iridian	0.473	1.22	2.31
Cambridge	1.06	1.93	3.29
Iritech	0.993	2.06	3.84

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