The First ICB* Competition on Iris Recognition

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Abstract

Iris recognition becomes an important technology in our society. Visual patterns of human iris provide rich texture information for personal identification. However, it is greatly challenging to match intra-class iris images with large variations in unconstrained environments because of noises, illumination variation, heterogeneity and so on. To track current state-of-the-art algorithms in iris recognition, we organized the first ICB Competition on Iris Recognition in 2013 (or ICIR2013 shortly). In this competition, 8 participants from 6 countries submitted 13 algorithms totally. All the algorithms were trained on a public database (e.g. CASIA-Iris-Thousand [3]) and evaluated on an unpublished database. The testing results in terms of False Non-match Rate (FNMR) when False Match Rate (FMR) equals to* 0.0001 *are taken to rank the submitted algorithms.*

1. Introduction

With the pronounced needs for reliable personal identification, iris recognition [16][21] has become an important enabling technology in our society. The first successful iris recognition algorithm was proposed by Daugman [16]. He applied odd and even Gabor filters for iris feature extraction and encoding. This classical method has been widely known and utilized in commercial applications. In addition, some other researchers have dedicated themselves to iris recognition. Wildes *et al*. [26] proposed to represent iris features by four-level Laplacian pyramid. Boles and Boashash [15] applied wavelet zero-crossings features over concentric circles on iris area. Sun and Tan [24] used ordinal measures to qualitatively represent iris patterns. Although iris patterns are naturally ideal for identification, the development of high-performance iris recognition algorithms and transferring them from research labs to practical applications are still challenging. Automatic iris recognition has to face unpredictable variations of intra-class iris images in real-world applications.

To evaluate the performance of existing iris recognition algorithms, some governments and institutes have organized several influential iris recognition competitions, such as ICE [4], IREX [5], NICE.I [8], NICE.II [9] and so on. These large-scale competitions independently evaluate iris recognition algorithms in different conditions. Similarly, the first ICB Competition on Iris Recognition (or ICIR2013 shortly) is organized to track the state-of-the-art of iris recognition. ICIR2013 which is open to both academia and industry focuses on promoting and advancing iris recognition technology. It employs two iris image databases, i.e., CASIA-Iris-Thousand [3] and IR-TestV1, for training and testing purposes respectively. The iris images used in ICIR2013 are acquired under near infrared illumination in short distances, which means that the testing results can stand the performance of testing algorithms in short-distance iris recognition in real applications. Both of these two databases have a great number of subjects, i.e. 1,000 subjects and 2,000 iris classes. Thus, ICIR2013 has the advantages in reporting the performance of iris recognition algorithms in big-data environments.

In total, 8 institutions and companies participated in ICIR2013 and provided 13 valid submissions. To assure a fair competition and comparable results, all participants had to strictly follow an unbiased evaluation protocol. The

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CASIA-Iris-Thousand [3] or other iris image databases can be used for training. As for testing stage, all possible intra-class comparisons are implemented to evaluate the False Non-match Rate (FNMR) providing a total of 20,000 intra-class match results. One sample is selected from each iris class to evaluate the False Match Rate (FMR) so there are totally 1,999,000 inter-class match results. If an intra- or inter-class comparison cannot be successfully implemented due to failure to enrollment or match, a random variable ranging from 0 to 1 will be assigned as the matching score. It is fair for all participants with the same rule. And we think the worst case for a biometric system is a random decision rather than a definitely wrong decision. Each participant can maximally submit 3 algorithms. ICIR2013 only accepts qualified iris recognition algorithms which meet the following requirements due to limited competition resources: the Equal Error Rate (EER) must be less than 5% on the training database; the average processing time for feature encoding must be less than 3 seconds and the average matching time must be less than 0.1 second on a normal personal computer. A public platform, the Biometrics Ideal Test (BIT) [2], is used to organize the competition.

The remainder of this paper is organized as follows. Section 2 introduces the databases applied in ICIR2013. Section 3 presents the employed performance metrics. Section 4 describes the participants and their algorithms. Experimental results are illustrated in Section 5. Section 6 concludes this paper.

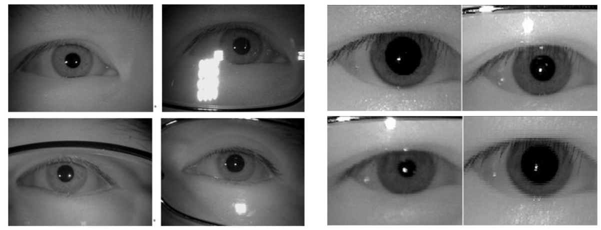
2. The CASIA databases

2.1. The training database

The training database (CASIA-Iris-Thousand [3]) contains 20,000 iris images of 1,000 subjects (i.e., 20 images/subject and 10 images/eye). CASIA-Iris-Thousand was collected using IKEMB-100 camera (Figure 1(a)) produced by IrisKing [7]. All iris images of CASIA-Iris-Thousand are 8 bit gray-level BMP files and the image resolution is 640×480. There are some examples showing in Figure 2(a). The main sources of intra-class variations in CASIA-Iris-Thousand are eyeglasses and specular reflections. Since CASIA-Iris-Thousand is the first publicly available iris dataset with one thousand subjects, it is well-suited for studying the uniqueness of iris features and developing novel iris classification and indexing methods. More

(a) (b)

Figure 1. The iris cameras used for collection of (a) CASIA-Iris-Thousand and (b) IR-TestV1.



(a) (b)

Figure 2. Examples of iris images from (a) the ICIR2013 training database (CASIA-Iris-Thousand) and (b) the ICIR2013 testing database (IR-TestV1).

technical details about this database can be found in the official website [3] where this database is publicly available.

2.2. The testing database

The testing database named IR-TestV1 contains 10,000 iris images of 2,000 eyes from 1,000 subjects. The database has a female-male ratio of nearly 1:1 and an age range from 0 to 70 years old. Figure 3 shows the gender and age distributions of subjects in IR-TestV1.

The iris images of IR-TestV1 were captured using IG-H100 camera (Figure 1(b)) produced by IrisGuard [6] in one session. Each subject contributed 10 iris images of both left and right eyes, i.e., 5 images per class. The main sources of intra-class variations in IR-TestV1 are motion blur, non-linear deformation, eyeglasses and specular reflections. All iris images of IR-TestV1 are 8 bit gray-level BMP files and the image resolution is 640×480. There are some testing iris image examples showing in Figure 2(b).

3. Performance measures

Popular performance metrics [16] of biometric recognition including False Non-match Rate (FNMR), False Match Rate (FMR), Equal Error Rate (EER) and Receiver Operating Characteristic (ROC) are taken to report the competition results.

The definitions of FMR and FNMR are dependent on the chosen decision criterion θ. Given the similarity distributions P_{Au} and P_{Im} for authentic and imposter respectively,

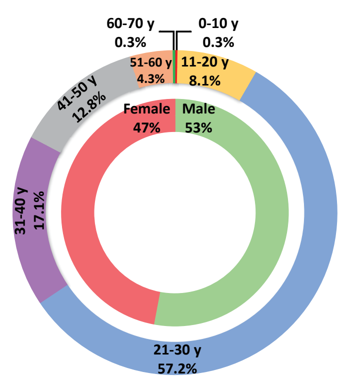


Figure 3. Gender and age distribution of subjects in IR-TestV1.

the FMR and FNMR can be calculated as

$$FMR(\theta) = \int_{\theta}^{1} P_{Im}(x)dx,$$
$$FNMR(\theta) = \int_{0}^{\theta} P_{Au}(x)dx. \quad (1)$$

The values of FMR and FNMR change with the value of θ. In our competition results, the metric FNMR4 means the value of FNMR when FMR equals to 0.0001 and FNMR4 is used to rank the performance of submitted algorithms, which is similar to the evaluation method in face recognition competitions. Meanwhile, the probability of successful attacking on a 4-digit bank password is 1/10000. So many biometric systems set the threshold of identity verification when FAR is one in 10000. Therefore we choose to use the FNMR4 as the criteria of iris algorithm ranking.

In addition, a ROC curve plots FMR against FNMR, and EER refers to the point in the ROC curve when FMR is equal to FNMR. Mathematically, based on a specific threshold $\hat{\theta} = \underset{\theta}{argmin}|FMR(\theta) - FNMR(\theta)|$, EER is defined as

$$EER = \frac{FMR(\hat{\theta}) + FNMR(\hat{\theta})}{2}. \quad (2)$$

4. Participants

4.1. Information

There are totally 8 participants from 6 countries. They come from companies, universities and institutes.

Table 1. Information of the participants.

Participant	Affiliation	Nationality
CDAC	Centre for Development of Advanced Computing	India
UFRJ	University Federal of Rio de Janeiro	Brazil
NSL	Nihon System Laboratory, Ltd	Japan
TSP	Telecom-SudParis	France
IF	Institut Fresnel (CNRS UMR 7249)	France
DUT	Dalian University of Technology	China
ZYET	Zhuhai YiSheng Electronics Technology Co, Ltd	China
HH	University of Halmstad	Sweden

4.2. Summaries of selected algorithms

CDAC. The main challenge in an iris recognition system is segmenting the exact iris boundaries from iris images consisting of noises such as specular reflections, eyelashes and eyelids. This algorithm basically aims at removing such noises and detecting the exact pupil and iris boundaries from captured iris images.

The algorithm consists of the following modules: pupil segmentation, iris segmentation, iris normalization, feature extraction and matching. Firstly, the pupil is detected in the image using thresholding and morphological operations. For segmenting the iris boundary, a rough circular iris boundary is first estimated and then region based active contour is applied to extract the exact zigzag iris boundaries. The iris center is then adjusted according to the newly detected iris boundaries. The upper and lower eyelids are estimated using parabolic fitting. The eyelashes are detected through a method based on histogram thresolding.

The segmented iris images are then converted into polar form of fixed dimensions. The eyelids, eyelashes, pupil and specular reflection regions are masked in the polar iris images. 1D log Gabor filter is used to extract the features in binary format. The Hamming distance is used for matching.

NSL. The NSL, a Japanese software company developed an original algorithm for iris pattern extraction and matching. This algorithm specifically focuses on iris of Asians where feature variations are minimal (compared with Caucasian iris patterns) and comes up with a methodology that vastly improves the accuracy of iris pattern matching of Asians. NSL puts great efforts in detecting and removing eyelash noises on Asian iris patterns and offers a practical algorithm to biometrics. Specifically, there are two noise removal challenges in the iris image processing procedure:1) Detect "small involuntary eye movement", perform its correction and reduce the noise of area near the pupil and iris.2) Recognize the eyelids and eyelashes, also detect reflection of tear gland further, and then exclude those noises from iris features.The reflection noises have not been addressed sufficiently for this ICB competition and the topic will be addressed in the future. Moreover, the next challenge for us is "anomalous images" and "less texture iris" matching. In most of the anomalous images it is hard to detect iris areas. If the pupil is not a perfect or near perfect circle, the detection error tends to be higher. Less texture irides give very close scores between genuine and imposters. We will introduce some logics to estimate iris texture value together with the quality based information, to have multiple stages in both extraction and matching to improve the accuracy.

TSP. The Institut Mines Telecom/Télécom Sudparis system is based on the open source iris recognition system "OSIRIS-V4.1", proposed by the BioSecure association [1]. It is composed of four processing modules: segmentation, normalization, encoding and matching. To segment the iris, the contours are considered as an optimal path retrieved by the Viterbi algorithm [25] for joining in an optimal way, the points of high gradients. Such gradients are computed on images processed by the anisotropic smoothing filter in order to reduce the noise while keeping strong edges. The Viterbi algorithm is then exploited at two resolutions: at a high resolution precise contours are recovered, while at a low resolution the optimal path corresponds to coarse contours. Contrary to the previous version of the system published in [25], in OSIRIS-V4.1, there is no assumption of circularity of the normalized iris and pupil contours. In fact, the coarse contours are directly used in the Daugman's rubber-sheet [17] to obtain the iris and pupil borders. The encoding and matching modules are based respectively on 2D-Gabor phase demodulation and Hamming distance classification inspired by Daugmans works.

IF. As shown in Figure 4, the main idea developed in QICF (Quality-based Iris-Code Fusion) is the construction of a higher-quality iris template during the enrollment and labelling step to improve iris recognition accuracy [23]. This template is obtained by fusing iris-codes from multiple images selected with respect to a quality score [18], as depicted in Figure 4. The fused iris-code is then simply binarized to get a classical iris-code representation on which identification is performed. An iris-code is computed from a 240×20 polar representation of the iris texture and Masek's log-Gabor wavelet [22] (λ=0.5, λ=18) is applied. During the recognition step, the fusion of best-quality iris-codes has not been exploited.

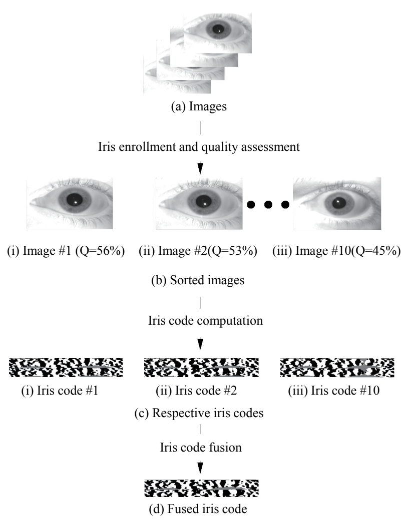


Figure 4. Sketch of the enrolment and labelling step in the algorithm IF.

DUT. In the preprocessing stage a new method for iris localization is proposed. An eye detector based on AdaBoost algorithm is firstly used to coarsely locate the eye region. After that the image is binarized according to the histogram. The binary image is then projected in both x- and y-axis to obtain the pupil position. Finally, the edge map is computed by the canny edge detector and then the pupil boundary is estimated in accordance with the localization of iris outer boundary. For iris recognition procedure, we employed the method [19] published in Pattern Recognition Letters, in which the weighted co-occurrence phase histogram(WCPH) is used to characterize the local iris texture and the similarity between image pairs is measured by Bhattacharyya distance. The method considers the effects of noise by computing the percentage of uncorrupted pixel numbers in the mask image.

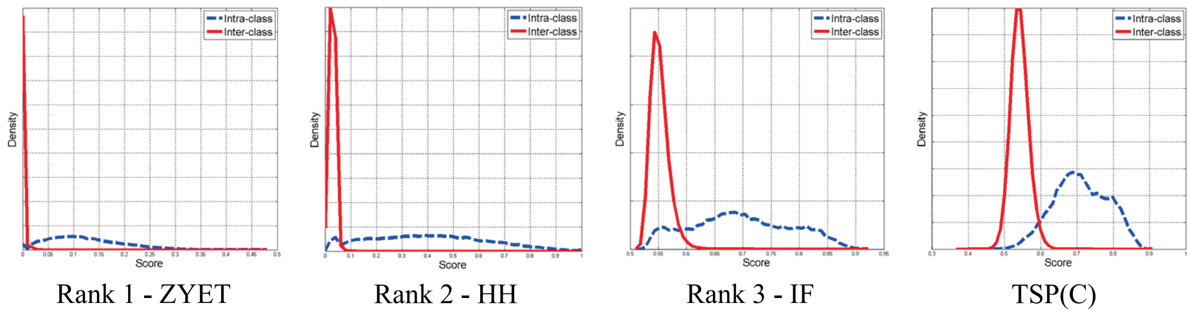
ZYET. The ZYET method is based on an iris image segmentation algorithm that uses circular Hough transform based on Canny edge detection and ellipse fitting technique using active contour technique. Firstly, all candidate edges are detected in an iris image by Canny edge detector, and then edge orientation is used to eliminate the wrong edges. Secondly, the inner boundary of the iris is detected by the gray property of the pupil and circular Hough transform, and edges that cannot be part of the outer boundary of the iris are removed. Finally, remainder edge segments are merged together and an optimum ellipse is fitted for the merged segments. The outer boundary of each angle proportion is approximated to the ellipse boundary based on active contour technique. In order to normalized images, the ellipse boundary of each angle is adjusted to be approximated to the outer boundary of the iris. Then the segmented iris image is unwrapped into to a rectangular region using simple trigonometry.

HH. The Halmstad University system fuses two different algorithms, one based on the Gabor spectral decomposition proposed in [11], and another based on the SIFT (Scale-Invariant Feature Transform) operator [20]. In the first algorithm, input images are analyzed with an square retinoscopic sampling grid of constant dimensions, which is positioned in the pupil center. Development experiments have shown that sufficient accuracy can be obtained only with the lowest Gabor frequency channel. Thus, for the speed purpose, only this channel is extracted. The pupil center is estimated by the iris segmentation algorithm based on the Generalized Structure Tensor (GST) proposed in [10]. Note that only the pupil center is needed, therefore the GST algorithm runs only up to the detection of the pupil boundary (not needing to detect the sclera boundary, which in general is more sensitive to errors, also allowing computational time savings). For the matcher is based on the SIFT operator, a free implementation of the SIFT algorithm[1] is used, with the adaptations for iris images described in [14]. SIFT keypoints are extracted only in the region given by the square retinotopic sampling grid defined above. Scores of the two systems are fused to obtain a single score using linear logistic regression fusion as described in [13]. Training of the fusion expert is done using intra- and inter-class matching scores from the training database (CASIA-Iris-Thousand). This trained fusion approach is used because it has shown better performance than simple fusion rules (like the mean or the sum rule) in previous work [13, 12]. Scores are finally normalized to the 0-1 range by min-max normalization.

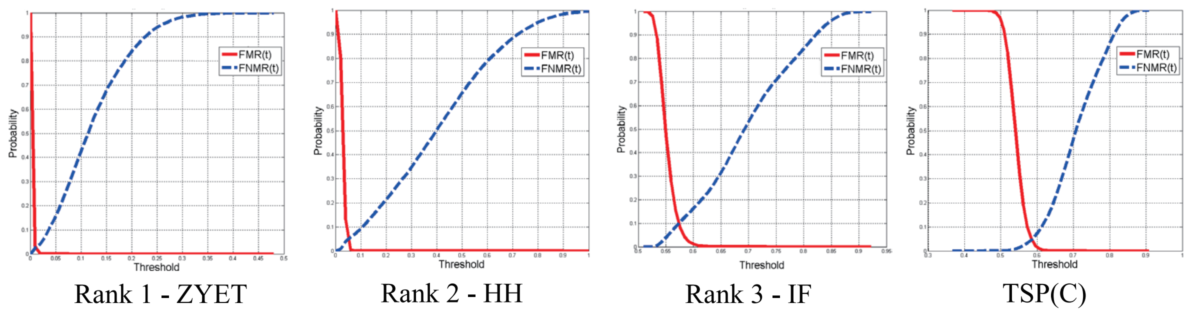
5. Results

To keep up with the development and applications of iris recognition, we select two different databases collected by different cameras for training and testing respectively, which is the greatest challenge in this competition. After testing, we select the metric FNMR4 (the value of FNMR

[1] http://vision.ucla.edu/∼vedaldi/code/sift/assets/sift/index.html



(a)



(b)

Figure 5. (a) The score distributions of the top three algorithms and TSP(C). (b) The FMR and FNMR graphs of the top three algorithms and TSP(C).

when FMR equals to 0.0001) in order to rank the algorithms submitted by 8 participants as presented in Section 3.

According to the values of FNMR4, three algorithms, i.e., ZYET, HH, IF, are ranked in the first three places. However we noticed that in the original TSP results, a smaller matching score indicates higher similarity of two images, which did not follow our requirements stated in the demo code. Therefore, their results evaluated in the competition (FNMR when FMR=0.0001) cannot stand for the real performance. In the present paper, the corrected results marked as TSP(C) are reported to show the real performance of the submitted algorithm. The testing results of the top three algorithms and TSP(C) are shown in Table 2. At the same time, we can calculate the values of FMR and FNMR depending on the score distribution and the threshold θ on range (0, 1) to draw the FMR and FNMR graph for each algorithm based on Equation (1). Figure 5(a) demonstrates the score distributions. And Figure 5(b) are the FMR and FNMR graphs of the four algorithms respectively. Similarly, Figure 6 shows the ROC curves of the top three algorithms and TSP(C).

The submitted algorithms mainly include three parts: iris

Table 2. The testing results of the top three algorithms and TSP(C).

Rank	Participant	Nationality	FNMR4	EER
1	ZYET	China	7.09%	2.75%
2	HH	Sweden	9.24%	3.19%
3	IF	France	42.16%	9.33%
	TSP(C)	France	31.41%	3.02%

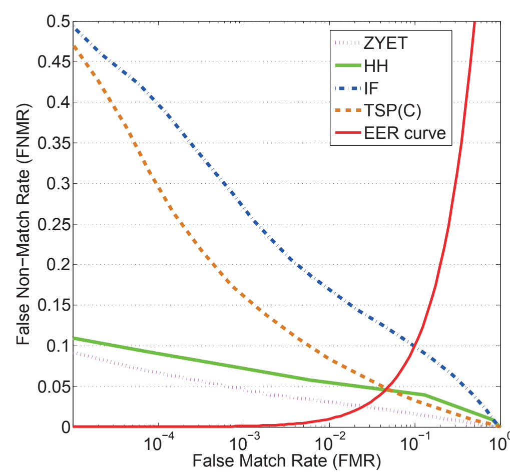


Figure 6. The ROC curves of the top three algorithms and TSP(C).

image segmentation, normalization and feature extraction. In segmentation part, iris areas are segmented based on some edge detection methods, for example, Canny edge detector, gradient based edge extraction and so on. After segmentation and normalization, two of the submitted algorithms apply fusion schemes in feature extraction. The IF algorithm applies code-level fusion after iris feature extraction and encoding to fuse iris codes of iris images with different qualities. This fusion scheme can enhance iris recognition accuracy efficiently and effectively. Different from the IF algorithm, the HH algorithm fuses two sets of different local features in score level to combine the complementary advantages of two kinds of features. Both of these two fusion methods are efficient and common schemes to improve recognition accuracy in iris recognition. Feature extraction methods in other algorithms are mainly based on Gabor wavelet, e.g., 1D Gabor, 2D Gabor, log-Gabor. Gabor wavelet, the most widely used method in iris recognition, can refine the high frequency of images and focus on texture details. Thus Gabor based feature extraction methods are considered to be appropriate to represent iris features and useful for iris image discrimination.

6. Conclusions

This paper has presented the evaluation results of the first ICB Competition on Iris Recognition in 2013, which aims at tracking current state-of-the-art algorithms in iris recognition. In total, 8 participants from 6 countries submitted their algorithms and most of the results are encouraging. Usually, the submitted algorithms consist of iris detection and normalization, feature extraction and matching. We have found that variant edge detection methods were applied to segment iris areas efficiently and effectively. Meanwhile, Gabor based methods are widely used in iris feature extraction due to the unique advantages of Gabor wavelet. In the future, Gabor based methods will still be popular in iris feature representation.

The usability of the iris recognition algorithms in unpredictable environments is still challenging. Thus, some other important aspects in real applications, such as speed and template size, will be utilized to systematically evaluate algorithms in the future competitions. In addition, biometrics, including face, fingerprint, multimodal fusion and so on, are also subjected to our concerns in the future.

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[5] IREX. http://www.nist.gov/itl/iad/ig/irex.cfm.

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