A Survey of Iris Recognition System

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***Abstract*—The uniqueness of iris texture makes it one of the reliable physiological biometric traits compare to the other biometric traits. In this paper, we investigate a different level of fusion approach in iris image. Although, a number of iris recognition methods has been proposed in recent years, however most of them focus on the feature extraction and classification method. Less number of method focuses on the information fusion of iris images. Fusion is believed to produce a better discrimination power in the feature space, thus we conduct an analysis to investigate which fusion level is able to produce the best result for iris recognition system. Experimental analysis using CASIA dataset shows feature level fusion produce 99% recognition accuracy. The verification analysis shows the best result is GAR = 95% at the FRR = 0.1%.**

***Index Terms*—Biometric System; Iris Recognition; Information Fusion.**

I. Introduction

Biometric technology has been a top research topic nowadays due to its high reliability and capable of human identification applications. Biometric application is identifying an individual based on his or her physical or behavioural characteristics. Physical characteristics consist of fingerprint, palm print, hand geometry and iris patterns or behavioural characteristics such as typing pattern and hand-written signature present unique information about a person and can be used in authentication applications. This type of identification technique is more efficient rather than password or PIN or anything else. Applications such as passenger control in airports, access control in restricted areas, border control, database access and financial services are some of the examples where the biometric technology has been applied for more reliable identification and verification.

This survey paper will focus on iris biometrics. Biometric methods by iris are of interest because people cannot forget or lose their physical characteristics in the way that they can lose passwords or identity cards. Moreover, irises are barely change compare to other biometric traits unless there are accidents or surgery. Biometric methods based on the spatial pattern of the iris are believed to allow very high accuracy, and there has been an explosion of interest in iris biometrics in recent years.

The minute details of the iris texture are believed to be determined randomly during the fatal development of the eye. In addition, it is believed that irises are not the same between each persons and also vary between left and right eye of the same person. The colour of the iris can change as the amount of pigment in the iris increases during childhood. Nevertheless, for most of a human's lifespan, the appearance of the iris is relatively constant.

Iris is an annular part between the pupil (dark portion) and sclera (white portion) of an eye image. The image of iris is clearly shown in Fig. 1. Iris patterns are formed by combined layers of pigmented epithelial cells, muscles for controlling the pupil, a stromal layer consisting of connective tissue, blood vessels and an anterior border layer. The physiological complexity of this organ results in the random patterns of the iris, which carry the most crucial information for human identification system.

In addition, iris pattern consist of high discrimination pattern lying in different scale and orientations. It is also an internal organ, located behind the cornea and aqueous humor and is well protected from the external environment. This characteristics such as being protected from the environment and having more reliable stability over time, compared to other popular biometrics, have well justified the ongoing research and investments on iris recognition by various researchers and industries around the world. Compared to other biometric systems, iris recognition has been in the limelight for high-security biometric applications. Iris based recognition is the most promising for high security environment among various biometric techniques (face, palmprint) because of its unique, stable, and non-invasive characteristic. It is the process of recognizing an individual by analysing the random pattern of iris and comparing it with that of reference in the database.

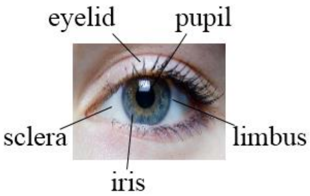

Figure 1: Sample of Iris image

II. Related Work

A typical process of iris recognition system consists of several steps: (i) iris pre-processing method including iris localization and normalization (ii) iris feature extraction technique and (iii) iris classification method as shown in Figure 2.

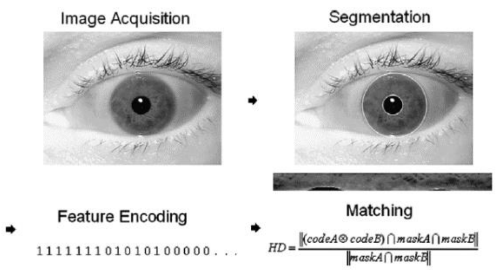

Figure 2: Iris processing stages

Chou et al. [1] proposed that a dual-charge-couple device can capture four-spectral such as red, green, blue, and near-infrared which contain very useful information for simplifying the iris segmentation task. Smartphones also can be used as a device to acquire an iris image in a view of fact that this device also have a tolerable imaging quality. K.B. Raja et al. [2] appoach to intends a new database for visible spectrum iris research with iris image captured using two popular smartphones such as iPhone 5S and Nokia Lumia 1020. R. R. Jillela and A. Ross [3] believed that the quality and the spatial extent of the iris image captured are necessary in image acquisition step in oder to obtain successful result.

A. Iris pre-processing method

Image pre-processing consist of two stages which are segmentation and normalization. The purpose of segmentation in iris involves localizing the iris and pupil boundary. Chou et al. [1] proposed to use circle rectification technique in order to lessen off-axis iris distortion for off-axis angle iris images.

Tsai et al. [4] stated that iris segmentation comprise of a few stages. Firstly, generate the gradient image. In order to produce gradient image, Hough transform is used to estimate circular boundaries, then morphological top-hat filter is applied to detect and compensate light reflection inside pupil. After that, iris image is smoothed by practising Gaussian filter. Second stage is applying fuzzy gray scale curve-tracing (FGCT) to trace a smooth curve in each gradient image.

A.D. Rahulkar et al. [5] stated that iris is localized using Daugman’s integro-differential operator and normalized using Daugman’s rubber sheet model. R. Szewczyk et al. [6] described in details to transform iris images into pseudo-polar coordinate system to obtain rectangular block of normalized iris. A.F. Mat Raffei et al. [7] approached to localize iris boundaries using circular Hough Transform because it was based on a voting system and was very tolerant of noise.

M. Nabti et al. [8] and M. Fairhurst et al. [9] proposed to adopt Daugman’s rubber sheet model to transform iris region into a fixed rectangular block and produce 2D array consist of horizontal dimension of angular resolution and vertical dimension of radial resolution .

R.M. Farouk et al. [10] proposed to use active contour models for iris preprocessing. This models works in three steps. Firstly, locate the outer iris boundary by using circular Hough Transform. Second, locate the inner iris boundary by using the discrete circular active contour (DCAC). Last step for this model is to locate the eyelids, eyelashes, and noise regions.

N. Sudha et al. [11] approached that circular Hough Transform able to detect circular boundaries from the edge map of the iris image and normalization occurred by resizing the segmented iris image to 256 x 256 pixels. While S. Umer et al. [12] explored that in order to localize the iris region, we must first find the edge points. On these edge points, Restricted circular Hough Transform (RCHT) was applied.

H.M. Sim et al. [13] approached to apply ellipse localisation boundary technique which combine the calibration algorithm and direct least square ellipse (DLSEFGC) to segment iris images precisely from non-cooperative (off-angle) environment. As for off-angle images, geometric calibration technique was used to compensate the distortion by restoring pupil shape to a circular as possible.

B. Iris feature extraction method

Feature extraction is refer to the process of encoding the discriminatory information obtained from the segmented or normalized iris, called as feature vector [3].

Chou et al. [1] employed an edge type descriptor, which characterized an iris pattern with multiscale step edge-type maps. Edge-type maps extracted with derivatives of Gaussian (DoG) and Laplacian of Gaussian (LoG). In [4] , Gabor filter was used to detect iris feature points, and generate a feature vector for each feature point. Firstly, Gabor filter extracted the local feature points from the segmented iris image in the cartesian coordinate system and estimate the dominant orientation of each detected feature point. After that, local feature point detector was adopted to generate a rotation-invariant feature vector for each local feature point with respect to its dominant orientation [4].

A.D. Rahulkar et al. [5] approached to extract iris feature in twelve-directions by using multiscale combined directional wavelet filterbank (CDWFB). The partial inner iris region is divided into six-sub regions and only four-sub regions are selected in order to reduce the effect of noise. CDWFB was applied in each of the region and each sub-band represents iris texture characteristics in a particular scale and direction.

While R. Szewczyk et al. [6] proposed a method to analyze noisy iris biometric data. In this paper, reverse biorthogonal 3.1 wavelet gave the best recognition result. Iris feature was encoded using Discrete Wavelet Transform (DWT) and rbio 3.1 wavelet. Then, signature is generated using V4 component as this component is very sensitive to significant elements inside the iris structure, thus increases the algorithm robustness.

A.F. Mat Raffei et al. [7] proposed a method of multiscale sparse representation of local Radon transform for feature extraction. Local Radon transform is utilized in feature extraction because its computation is simple and it has a fast processing time combined sparse representation local Radon transform (sLRT) and multiscale representation local Radon transform (mLRT). This method of feature extraction works in a few steps starting from down sampling the normalized iris image into different length of scales and different orientations of angles until transform into iris feature vector.

As for M. Faihurst et al. [9], employed 1D Gabor wavelet for feature encoding. Each rows of 2D normalized iris pattern corresponds to a circular ring on the iris region. These rows are divided into a number of 1D signals which coil with

1DLog-Gabor wavelets [9].

M. Nabti et al. [8] obtained a new feature extraction technique which combine special Gabor filters and wavelet maximum components. Feature vector produced is presented in two different method which are statistical measure (mean and variance) and moment invariants. Moment invariants is also suitable to mapping the filtered image to vectors so that their similarity distance can be measure.

While V.V.S. Tallapragada et al. [14] used multiclass kernel Fisher analysis (KFA) and its consequent features set for iris recognition. For this proposed technique, support vector machine (SVM) is used to identify a set of linearly separable hyper planes which are linear function of the feature space as well as being used as classifier.

R.M. Farouk et al. [10] proposed to employ Gabor for feature extraction. In this technique, the resized segmented iris region is convoluted with 2D Gabor wavelets. At the end of this process, the magnitude produced will be used for recognition using the multi-dimensional artificial neural network (MDANN).

N. Sudha et al. [11] applied a partial Hausdorff distance (PHD) for feature matching. This proposed method compare the linear pattern of irises locally by computing the PHD between part of irises (parts of 2 binary edge images. Earlier, linear pattern generated from edge detection algorithm. S. Umer et al. [12] used multiscale morphologic operator as a feature extraction technique in iris recognition. This technique consider iris features at different scales and orientations produced bright residues and dark residues. These residues produced after applying morphologic top-hat transform. Feature vector generated will be used to design two-class classifier.

While H.M. Sim et al. [13] approached Haar wavelet decomposition combine with Neural Network to become Neuwave feature extraction. This technique transform the normalized polar image into different wavelet coefficient that forms the bit pattern (iris_temp).

A.F. Abate et al. [15] used watershed based iris detection (BIRD) for smart mobile devices to extract two kinds of features from the reshape region. These region characterize both the iris colour and texture.

Raghavendra and Busch [16] proposed the use of multiscale binarized statistical image feature extraction (M-BSIF) because this method allow merging of several filter responses that in turn extract not only a rich set of information but also allows one to generalize the BSIF for presentation attack detection of iris on both visible and NIR spectrum. This filters are invent using a set of natural image patches, so that it can overcome the demand of manual tuning of filters parameter.

K.B. Raja et al. [2] approached a feature extraction technique which based on deep sparse filtering to acquire robust features for unconstrained iris images. Deep sparse filtering is achieved by forming more than one layer for learning. In addition, number of features are the only parameter needed in learning sparse filtering.

Kong et al. [17] approached 2D Gabor filters applied with zero direct current (DC) to extract phase information of an iris image in a dimensionless polar coordinate system. Hugo Proenca et al. shared the simplest feature selection algorithms which is Fisher-score [18]. A new concept proposed is bit discriminality. This measure shares the roots of Fisher discriminant and has a visual representation.

Whereas A.F. Mat Raffei et al. [19] proposed to use 1D Log Gabor filter to extract unique features of each person. Smereka et.al. [20] used rectified linear unit (reLU) to the output derived from a set of Gabor wavelets.

Proenca et al. [21] suggested to use convolution between a normalized data with a bank of Multi-lobe Differential Filter (MLDF) in order to extract iris codes for strong biometric trait which is iris texture. As or weak biometric traits which are eyelids, eyelashes, and skin, Proenca et al. [21] have used texture feature descriptor to encode information in the region of interest by using local binary pattern (LBP).

In other work, Park et al. [22] employed global and local feature extraction. In general, global feature extraction can be defined as extracting all the pixel values in the detected iris boundaries. While local feature extraction is a process of extracting iris from a set of characteristic regions to become a set of key points. In this paper, local feature extraction was selected because it provides more robust to such variations since it used only a subset of particular regions.

Local feature extraction used two well-known distribution-based descriptors, gradient orientation histogram and local binary pattern (LBP) and Gaussian blurring and standard deviation were used to ensure smooth variations among all local pixel values [22]. After key points are detected, points can be directly used for matching.

H.-A. Park et al. [23] proposed one best Gabor filter that can cope with every kind of iris images by using two Gabor filter (long(short frequency) and short(high frequency) to extract iris codes.

Vatsa et al. [24] performed two feature extraction based on global and local information of iris images. Global feature extraction based on textural feature made used of 1D log polar Gabor transform-based. Textural feature extraction provides the global properties that are invariant to scaling, shift, rotation, illumination and contrast. Besides that, local features represented by topology of the iris images are extracted using Euler number [24-26]. Euler number provides local information of iris patterns and are invariant to rotation, translation, scaling, and polar transformation of the image.

C. Iris classification method

Iris matching is basically comparing test images from the datasets with training images to perform recognition. Chou et al. [1] proposed an edge-type matching technique to carry out iris recognition. It is stated that this method is a concept of classifier ensembles. Tsai et al. [4] approached possibilistic fuzzy matching (PFM) technique for a pair of point set by combining the fuzzy alignment algorithm and the possibilistic fuzzy c-means (FCM). While A.D. Rahulkar et al. employed a fused post-clasifier to reduce false rejection rate due to artifacts [5]. The method works by fusing multiple ROCs acquired from selected four iris regions with post-classifier to obtain high performance.

R. Szewczyk et al. [6] used hamming distance as a classifier. Hamming distance performs two operation. Firstly, the logical expression XOR between to binary vectors of length n is performed. Then, summarized the differences between compared vectors on the particular positions. Lastly, similarity score is acquired by dividing the obtained sum by N.Y.Song et al. [27] improved sparse representation classification (SRC) iris recognition method based on sparse error correction (SEC) model. SEC model which based on iris recognition uses the whole iris images training set as a dictionary to classify a new test sample, which result in immense size dictionary as basic SRC method and results in expensive computation. To validate the recognition results, sparsity concentration index (CSI) was performed.

Similar as [6], A.F. Mat Raffei et al. [7], M. Fairhurst et al. [9], M. Nabti et al. [8], A.F. Abate et al. [15], Kong et al. [17], A.F. Mat Raffei et al [19] and H.M. Sim et al. [13] used Hamming distance to match two iris templates.

V.V.S. Tallapragada et al. [14] proposed hidden Markov model as classifier because that separability among the feature sets of the iris features is quite low and distance-based classifiers like nearest-neighbour classifier fail to compare the features.

R.M. Farouk et al. [10] approached three favored matching technique. The first is WED-matching technique proposed by Zhu et al. [28]. Second is HD-matching method which proposed by Daugman [29] and the last one is SP matching method that approached by Riad et al. [30].

For classification purposes, S.Umer et al. [12] presented a multi-class problems that transformed into two-class problems using dichotomy method. To build the system, they adopted a leave-one-out classification strategy. Then, support vector machine is employed to do the classification.

Raghavendra and Busch [16] used 8 independent linear support vector machine (SVM) classifier. From 8 linear SVM, the first four are applied on periocular and the rest are on iris modality. From the four periocular iris, one each is used in on the three independent M-BSIF features and one is used on the feature level fusion of M-BSIF. The same goes to four iris modality, one each is used on the three independent M-BSIF features and the other one is used on the feature level fusion of M- BSIF.

While K.B. Raja et al. [2] proposed a sparse representation classification (SRC) to improve recognition accuracy. As for Othman and Dorizzi [31], feature extraction and matching are performed on the fuse reconstructed image by OSIRISV4.1.

For iris matching, S. Barra et al. [32] used spatiogram or spatial histogram because it capture the global position of the pixels as an alternative of the relation between their pairs. This type of histogram captured the information related to the range of function and also information relating to the spatial domain.

III. Information Fusion In Iris

Fusion of different biometric traits can be represented into three categories which are feature level fusion, score level fusion and decision level fusion [13]. Feature level fusion method extracts different features from biometric traits and combines them into a single temple. Score level fusion technique determine the match score based on the degree of similarity between two biometric traits and the scores are consolidated to produced a single matching score. H.M. Sim et al. [13] combined the iris and face biometric trait at the weighted score level to fuse the matching scores produced from the face and iris recognition matching processes. This work chose the weights by experimenting with each matcher to find the maximum accuracy recognition rate.

Othman and Dorizzi [31] approached a local-quality based system to form a fuse iris image from a sequence of periocular image of a given person. The normalized images and their corresponding masks and local quality matrices will then interpolated to a double resolution using bi-linear interpolation.

D.S. Guru et al. [33] proposed fusion of face features from PCA and FLD techniques. Measured distances from both method are fused using different operators such as mean, max, minmax and appending and proved a good performance on both verification and recognition results. In this paper, the covariance matrices of PCA and FLD are integrated using product rule to retain the natures of both covariance matrices with an expectation in high performance.

Park et al. [22] had used score level fusion by using multiple instances and multiple algorithms in his work. The method of fusion applied in multiple instances is using simple sum rule without any score normalization. While method of fusion applied in multiple algorithms is using weighted sum rule after using the maximum-maximum normalization.

Strong and weak biometric traits are combined by using usual fusion rule such as product, sum, min, and max [21]. In [21], min and max rules proved performance that close to strong classifier while product rule leaded to the worst results. To reduce classification complexity and enhance performance accuracy, H.-A. Park et al. [23] practiced the SVM classification method based on two calculated Hamming Distance, one from long Gabor filter and the other from short Gabor filter. This fusion is categorized as score level fusion. Vatsa et al. [24] applied fusion between textural and topological features of iris images by using 2v-SVM to reduce the FRR while maintaining low FAR.

Table 1: Summary of iris fusion

Biometric trait/features	Method of fusion	Ref.
Face+iris	Weighted score level fusion	[13]
Normalized iris images	Bilinear interpolation	[31]
Left+left and right+right of iris images	Simple sum rule	[22]
Multiple algorithm (GO, LBP, SIFT	Weighted sum rule	[22]
Iris texture+eyelashes+eyelids+skin	Product, sum, min, max	[21]
Iris code bits	SVM classification	[23]
Iris textural +iris topological	2v-SVM	[24]

IV. Experimental Analysis

To evaluate the effectiveness of the fusion method, we conduct a testing using the widely used CASIA database consisting of 308 subjects. We randomly choose five images from each class for training and the rest is use for testing. Evaluation is performed using identification and verification performance for a different types of fusion approach. Fig. 3

shows the recognition rates with different level of fusion approach for iris images. The performance for feature level and matching score level is very similar, however fusion at decision level produce the lowest recognition rates. Fusion at feature level is performed by concatenating two different features producing high discrimination power of fused feature vector. This feature contain rich information exist in iris images, thus this method produce the highest recognition rates which is 99%. The analysis of verification rates is shown in Figure 4. The result shows the best performance is GAR = 95% at FRR = 0.1% when the fusion is performed using 120 PCA coefficients. In this approach, fusion is performed using concatenation method.

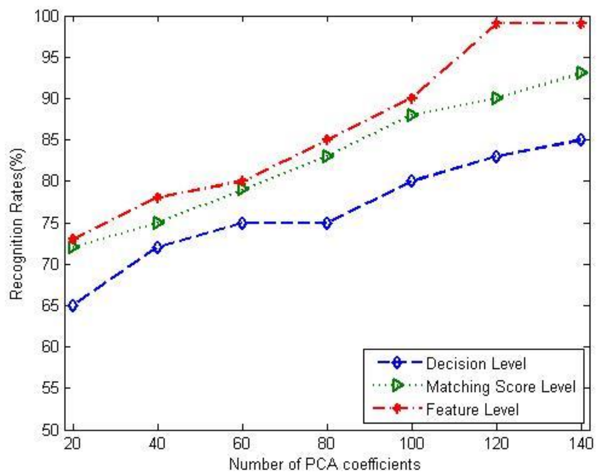

Figure 3: Recognition rate analysis of different number of PCA coefficients.

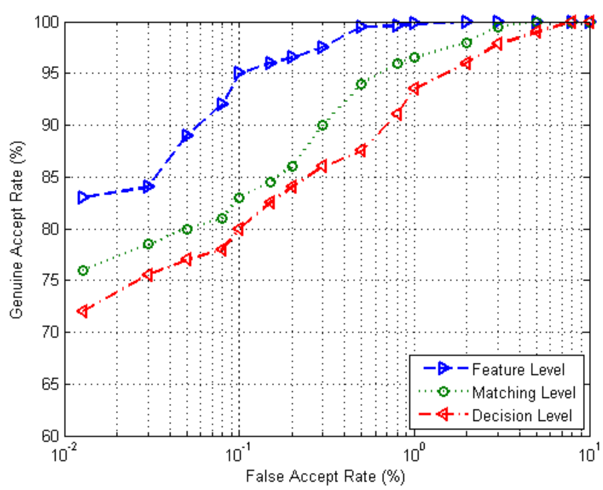

Figure 4: Verification rate analysis of different level of fusion approach.

V. CONCLUSION

In this paper, we have investigate different level of fusion approach for human iris recognition and verification. Three level of fusion method is tested using CASIA database. Feature level fusion outperform the other fusion approach with the best performance is 99% when the fusion is performed using 120 PCA coefficients. By using less number of PCA coefficients, different fusion approach produce nearly similar result due to the less number of information exist in the feature space. The best verification rates using feature level fusion is GAR = 95% at FRR = 0.1% when 120 PCA coefficients are used in the fusion process.

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