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IRIS RECOGNITION SYSTEMS: TECHNICAL OVERVIEW

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ABSTRACT

Iris recognition has been actively researched in recent years. This paper provides an up-to-date review of major iris recognition researches. Strengths of iris recognition systems over other biometrics systems in security applications were first identified. After this, an overview of iris recognition and its applications was presented. Literature review of most recent iris recognition techniques is also presented. Description and limitations of the public iris databases which are used to test the performance of these iris recognition algorithms was also given.

KEYWORDS: Architecture, Database, Matching, Recognition, Templates, Threshold

INTRODUCTION

Biometric identification is an emerging technology which gains more attention in recent years. It employs physiological or behavioral characteristics to identify an individual [1]. A biometric characteristic is a biological phenomenon's physical or behavioral characteristics that can be used in order to recognize. Physiological characteristics are characteristics that are genetically implied such as iris, fingerprint, face, etc. Behavioral or psychological characteristics are characteristics that are acquired or learned during life such as handwritten, signature, a person's gait, her typing dynamics or voice characteristics [2]. Among these characteristics, iris has distinct phase information which spans about 249 degrees of freedom [3, 4]. This advantage allows the iris recognition to be the most accurate and reliable biometric identification characteristics [5]. Because of these distinctive characteristics, many automatic security systems based on iris recognition have been deployed worldwide for border control access, and so on [6, 7, 8].

History of Iris Recognition

The idea of using iris patterns for personal identification was originally proposed by an ophthalmologist named Frank Burch in 1936 [9]. In the 1980's the idea had appeared in films, but it still remained science fiction and conjecture. In 1987 two other ophthalmologists, Aran Safir and Leonard Flom, patented this idea, and in 1989 they asked John Daugman (then teaching at Harvard University) to create actual applicable algorithms for iris recognition. The Daugman algorithms could be found initially in the original paper "High confidence visual recognition of persons by a statistical independence." They combined the field of classical pattern recognition with modern computer vision, mathematical statistics and studies of the human-machine interface. It is an interdisciplinary field. The patents are owned by Iridian Technologies and are the basis for all current iris recognition systems and products [9]. This identification system is been used in United Arab Emirate (UAE) for border-crossing control and as at 2004, it had been able to generate 420,000 expellees from 180 nations in the world [10].

Generic Architecture of Iris Recognition System (IRS)

A complete iris recognition system is composed of four parts: *image acquisition; iris pre-processing (i.e. localization, normalization and enhancement), feature extraction and matching* [11, 12, 13]. A typical iris recognition system as two arms as shown in figure 1. These are: the registration arm and the verification arm when the template of the iris image to be verified is compared with iris templates stored in the iris database. Image acquisition captures the iris images. Infrared illumination is used in most iris acquisition. Iris localization step localizes the iris region in the image. Iris boundaries are modeled as two circles which are not necessarily concentric. The inner circle is the papillary boundary or the iris inner boundary. The outer circle is the limbic boundary or iris outer boundary. The noise processing is often included in the segmentation stage of the recognition system. Possible sources of noise are eyelid occlusions, eyelash occlusions and specular reflections [14, 15]. Most localization algorithms employed gradient based methods in order to find edges between the pupil and iris and the iris sclera. The feature extraction stage encodes the iris image features into a bit vector code such as reflected in equation 1. A convenient threshold level is chosen as the ceiling value for feature encoding.

$$I_{x,y} = \begin{cases} 1, & If\ value\ \geq threshold\ value \\ 0, & if\ otherwise \end{cases} \quad (1)$$

In most algorithms, filters are utilized to obtain information about the iris texture. Then the outputs of the filters are encoded into a bit vector code. The corresponding matching stage calculates the distance between iris codes and decides whether it is a match or recognizes the submitted iris from the subjects in the data set based on decision threshold level as shown in equation 2.

$$Decision_{template} = \begin{cases} Accept, & If\ value\ \geq Decision\ threshold\ level\ value \\ Reject, & if\ otherwise \end{cases} \quad (2)$$

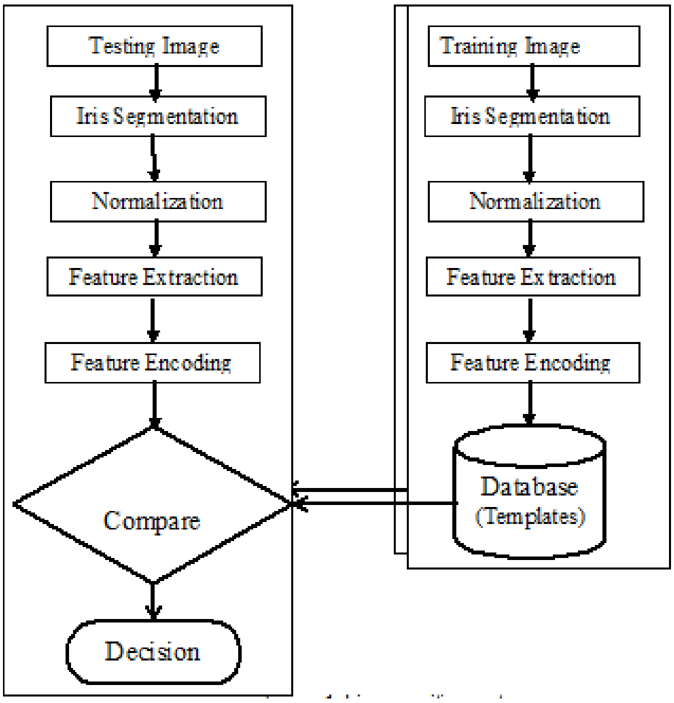

Figure 1: Iris Recognition System

Architecture

This section gives an overview of the major feature extraction frameworks, features, techniques employed in iris recognition techniques. There are different framework types that had been used in iris recognition system. Single in-line single Feature Extraction Method (SISFEM) [16]. Single in-line Multiple-steps Feature Extraction Method (SIMFEM) [17, 18]. Complex (multiple line architecture) can either be two, three or more lines. Complex architecture can be any of these forms: Complex Architecture, Multiple Feature Extraction Architecture (CAMFEM), Complex Architecture, Single Feature Extraction Method (CASFEM) [8].

Pre-Processing Stage

The pre-processing stage consists of localization and segmentation of the iris from the acquired eye image. Pre-processing stage consist of Localization of the inner and outer boundaries of the iris and Segmentation of the iris.

Localization

Localization of the boundaries of the iris is very important so as to remove the pupil, sclera, and other occlusion such as upper and lower eye lids of the subject [19, 20]. Some methods used by researchers among others are: threshold method [21]; Hough's algorithm [22].

Others employed different models for localizing the iris images from the captured human faces. Guangzhu *et al.* employed seven levels model to remove occlusion before isolating the inner and outer circles that defines the iris region [23].

Segmentation

Segmentation isolates the iris region from the whole eye. This stage is very central to correct processing of the recognition system. Some of the methods used includes: Integro-differential operator [24, 25, 26, 27, 28]; enhanced integro-differential method [29]; moving agent [28]; the Houghs transform [30-36]; circular Houghs transform [37]; iterative algorithm [38 - 40]; Chan-Vese active contour method [41]; Fourier spectral density [42].

Daugman proposed an Integro-differential operator for locating the inner and outer boundaries of iris, as well as the upper and lower eyelids. The operator computes the partial derivative of the average intensity of circle points, with respect to increasing radius, *r*. After convolving the operator with Gaussian kernel, the maximum difference between inner and outer circle will define the center and radius of the iris boundaries. For upper and lower eyelids detection, the path of contour integration is modified from circular to parabolic curve [3, 10]. Wildes used edge detection and Hough transform to localize the iris. Edge detector is applied to a grey scale iris image to generate the edge map. Gaussian filter is applied to smooth the image to select the proper scale of edge analysis. The voting procedure is realized using Hough transform in order to search for the desired contour from the edge map. The center coordinate co-ordinate and radius of the circle with maximum number of edge points is defined as the contour of interest. For eyelids detection, the contour is defined using parabolic curve parameter instead of the circle parameter [35].

Black hole search method was proposed by Teo and Ewe to compute the center and area of a pupil [43]. Since the pupil is the darkest region in the image, this approach applies threshold segmentation method to find the dark areas in the iris image. The dark areas are called "black holes". The center of mass of these black holes is computed from the global image. The area of the pupil is the total number of those black holes within the region. The radius of the pupil can be calculated from the formula of a circle. Richard *et al.* developed an iris segmentation approach which was able compensate all four types of noises in order to achieve higher accuracy rate [1]. It consists of four parts: firstly, the pupil is localized using thresholding and Circular Hough Transform methods. Secondly, two search regions including the outer iris boundaries are defined to locate the outer iris. Next, two search regions are selected based on pupil position to detect the upper and lower eyelids and finally, thresholding is implemented to remove eyelashes, reflection and pupil noises.

The method's performance on CASIA iris database was found to perform as high as 98.62% accuracy. Cui *et al.*, decomposed the iris image using Haar wavelet before pupil localization [44]. Modified Hough's algorithm was used to obtain the center and radius of pupil. Iris outer boundary was localized using an integral differential operator. Texture segmentation was adopted to detect upper and lower eyelids. The energy of high spectrum at each region is computed to segment the eyelashes. The region with high frequency is considered as the eyelashes area. The upper eyelashes are fit with parabolic arc. The parabolic arc shows the position of the upper eyelid. For lower eyelid detection, the histogram of the original image is used. The lower eyelid area is segmented to compute the edge point of the lower eyelid and the lower eyelid is fit with edge points.

Kong and Wang proposed Gabor filter and variance of intensity approaches for eyelash detection [45]. The eyelashes were categorized into separable eyelashes and multiple eyelashes. Separable eyelashes are detected using 1D Gabor filters. A low output value was obtained from the convolution of the separable eyelashes with the Gabor filter. For multiple eyelashes, the variance of intensity in a window is smaller is smaller than a threshold, the center of the window was considered as the eyelashes.

Normalization

Normalization is used generally to reduce the segmented iris images to a regularized size for proper extraction of features. There many methods of normalization employed by researchers. These methods include: the Rubber sheet model developed by Daugman [4], trapezium normalization method solicited by Mahboubeh and Abdolreza [46]. Few IRS were developed without normalization of segmented iris image [47]. Because of the complexity involved in other normalization methods, most of the systems developed so far use Daugman's rubber sheet normalization method [12, 48].

Post Processing Stage

Feature Extraction

Feature extraction stage is the stage where the normalized iris image is segmented and encoded for template formation [12, 49]. Different features were point of concern to different researcher, all aiming at achieving a more robust and efficient iris recognition systems. These features ranges from tuxtural features [17]; phase features [50]; zero-crossing [51]. Jaishanker *et al.*, proposed a unified framework based on random projections and sparse representation that was able to handle the challenges inherent in iris recognition systems [52]. The framework was able to handle the problem of unconstrained acquisition, robust and accurate matching and privacy enhancement without compromising security. The framework was able to handle segmentation error and use of a wide range of artifacts during image acquisition. The proposed quality measure was also able to handle alignment variations and recognition from iris videos. Its privacy and security was enhanced by a way of cancelable iris templates. Jaishanker *et al* (2009) extended the original method

(Sparse Representation) through Bayesian fusion framework where different sectors of the iris images are recognized using Sparse Representation and the results of different sectors are combined based on their quality [52]. Aishwarya *et al.* employed Fuzzy Neural concepts for iris recognition system [11].

Classifier and Threshold

Sun *et al.*, developed an elastic iris blob matching algorithm to overcome the limitations of local feature based classifiers (LFC) [53]. In addition, in order to recognize various iris images efficiently, a novel cascading scheme was proposed to combine the LFC and an iris blob matcher. When the LFC is uncertain of its decision,, poor quality iris images are usually involved in intra-class comparison. Then the iris blob matcher is resorted to determine the input iris' identity because it is capable of recognizing noisy images. Accuracy of the cascaded classifier increased greatly, but the execution cost increased by 1% and 3% on Daugman's and Noh's algorithm respectively. The compliance level of the iris template being tested is compared with each members of the iris database. This compliance level compared with decision threshold which will be used either to accept or reject membership of the tested iris template.

CONCLUSIONS AND RECOMMENDATIONS

Though many researchers had worked on iris recognition systems using available public databases, it is required that black iris databases should be made available. Many of the already developed systems could not conveniently work for black iris, modification of existing system is necessary for them to recognize black iris correctly. Development of these will enhance cross boarder criminal detection in black continents.

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APPENDICES

Table 1: Analytical X-Ray of Iris Recognition Systems

		Pre-Processing			Post-Processing				
Author(S) & Year	**System (Image Capture)**	**System (Image Pre-Processing)**	**System (Iris Localization)**	**System (Iris Normalization)**	**System (Iris Feature Extraction)**	**System (Matching Technique)**	**Database**	**Accuracy**	**Suspected Limitation**
Shenna *et al.*, 2005			Dyadic Wavelet Transform (DWT)	Rubber sheet model		An elastic Iris blob matching algorithm with cascaded classifier	CASIA	Performs better than single classifier	
Dagman, 2007		Snake algorithm. Statistical inference for excluding eyelids & lashes	Fourier-Based Trigonometry and Off-Axis Gaze.						Irregularity of inner and outer circle of the iris
Hugo and Alexander, 2007			Integro-differential operator	Rubber sheet	2-D Gabor filter	Hamming distance	UBIRIS, CASIA and ICE	30% reduction in FFR in noisy	
Hunny *et al.*, 2008		Circular Hough Transformation			Hybridization of Haar wavelet and LOG-Gabor wavelet	Excussive OR (XOR)	BATH and IITK	97.66% which is 4.02% better than Haar and 2.02% better than Gabor Wavelet method	
Jaishanker *et al.*, 2009			Linear Hough's transform		Gabor features extraction.	Sparse representation and Bayesian fusion of features.			Two methods for solving security problem was introduced. They are: random projection and random permutations.
Aishwarya *et al.*, 2011	Monochrome CCD cameras (800 x 640) were used for the capture.		Rectangular Hough's transform, threshold was used to remove eyelids and lashes	Rubber sheet normalization method.	Harr wavelet method with Embedded Zero tree wavelet method	Class weighted fuzzy neural classifier was used for the matching		99.25%	The use of proper capturing device can improve the recognition of the system
Falohun *et al*, 2013	Frontech web camera with 5.0 Megapixels	Morphological operations	Hough's transform and Integro-differential operator	Rubber sheet model	Enhanced Inverse Analytical Fourier-Mellin transform		CASIA and Captured iris images		

BATH: Bath University Database; IITK: Indian Institute of Technology Kampur; CASIA :Chinese Academy of Science Institute of Automation; UBIRIS: University of Beira IRIS