Al-Qadisiyah Journal of Pure Science

Manuscript 1243

A Survey on Iris Recognition systems

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REVIEW

A Survey on Iris Recognition Systems

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Abstract

This paper is the literature on the iris recognition systems. Iris recognition has grown significantly in recent years because iris information is unique across individuals and unlikely to repeat the iris so it is less susceptible to forgery, and it is also safer from a health standpoint. Which can be used for the individual's recognition purposes. There is a wide and active research community devoted to identification based on iris to improve performance and increase speed and accuracy, these ongoing efforts have resulted in cutting-edge techniques and algorithms. These technologies allow the intricate iris patterns to be converted into compact and discriminative templates, allowing for efficient storage and comparison for identification purposes, and contributing to the widespread adoption of iris recognition across multiple domains. In this study, we presented a survey to highlight some of these techniques and empirical findings from previous studies, as well as suggest directions for future works.

Keywords: Iris feature extraction, Biometric identification, Iris recognition, Iris detection, Biometric recognition system

1. Introduction

Technology plays a main role in the life of every individual they facilitate life dramatically, on the other hand; fraud, security threats and theft of personal data developed in parallel, so it is very important to save data and secure them completely, this conflict has led to the development of biometrics systems. Biometric systems use the biometric traits of humans as data to discriminate a person. These data cannot be lost or stolen, thus utilized as an effective solution for identification and verification processes. Demand for improved biometric systems has recently increased to enhance reliability and privacy in daily life [1,2].

Iris recognition a one of the biometric features that involves the use of iris patterns as input data. The iris is a colored part of the eye that organizes the entry of light into it. The patterns on the human iris are known for its complex and unique. These patterns are established during fetal development and are generally unchanged by aging throughout a person's lifespan. According to statistics, the crypt, furrow, and trabeculae patterns on the iris are among the most distinguishing features in humans and, thus can be used for reliable and precise personal recognition [3,4].

The rest of this paper includes 7 sections structured as follows: section 2 explains the basic stages of iris recognition systems, section 3 surveys the most common previous research, section 4 gives a brief explanation of some of the techniques for iris feature extraction, section 5 explains the domain of the problems, the results and discussion are given in section 6 and finally, the conclusions and future work are in sections 7 and 8, respectively.

2. Iris recognition system

The Iris recognition is one of accurate and reliable biometric identification systems. It can be used for different applications such as immigration control, national identification, criminal investigation, banking, health care, and education. The iris

Received 1 December 2023; accepted 11 April 2024.
Available online 20 August 2025

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https://doi.org/10.29350/2411-3514.1243

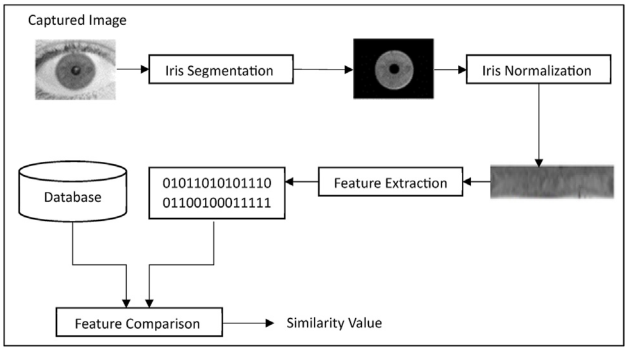

Fig. 1. Basic steps of iris recognition systems [5].

recognition system consists of five stages including image acquisition, iris segmentation, normalization, feature extraction and feature matching [5], as shown in Fig. 1.

a. **Image Acquisition**: the first step is the acquisition of a high-resolution image of the iris by using suitable imaging hardware systems like cameras, sensors etc. To get fine details of the iris patterns.
b. **Iris Segmentation**: the iris's inner and outer borders are located in this step, which can be detected as circular or elliptical shapes. The result is a rectangular block of iris region.
c. **Normalization**: this procedure creates iris areas with the same fixed dimensions so that similar features appear in two images of the same iris taken under different lighting circumstances.
d. **Features Extraction**: this step works to extract interest and important features that represent the iris pattern. The main role of the recognition systems is dependent on this step due to the resulting use as an input in a recognition process [6].
e. **Features Matching**: finally, the feature vector extracted from the previous step will be matched with the feature vectors extracted during the training the system and stored in the database in order to recognize the personal identity [7].

3. Literature surveys

There are many articles about human iris recognition because it is the most reliable biometric feature for the identification of an individual's identity. For the iris recognition system to work well, the researchers must address a number of issues, including photos taken in an uncontrolled setting, noisy photographs, blurred images etc. [8]. The following sub-sections surveyed the most common previous iris recognition systems.

Abdulamir and Sarah (2015) [9] in this work the researchers improved a method for iris normalization by using canny edge detection to detect pupil and iris edges then applying circle Hough Transform (HT) to convert the center and radius of iris and pupil area in the image of the dataset from Cartesian coordinates (x, y) into polar coordinates (r, θ). This method is tested on CASIA v4.0 and CASIA v1.0 databases and the accuracy are 99.8% and 100%, respectively.

B.V. Bharath et al. (2015) [10] presented an iris recognition system based on Radon Transform (RT) Thresholding. For this system, the RT method is used for feature extraction and the Cradient-based Isolation method is used to isolate the iris patterns from the image, which uses the edge detection property of the Gradient operator, thereby obtaining the salient iris textures. The Binary Particle Swarm Optimization (BPSO) is used to select the optimal subset of features.

Hadeel and Ahmed (2015) [11] presented a system based on wavelets transform (WT). This system uses two types of wavelets transform filters to extract the iris features (Haar filter and Daubechies db4 filter), and perform the comparison between training and testing iris images using the artificial feed-forward back propagation neural network (FFBNN) method.

Shervin et al. (2015) [12] extracted two types of features, the scattering transform for global features and textural information (Haralick features) for local features of iris images. Haralick's textural features are derived from the co-occurrence matrix of the image. The principal component analysis (PCA) is used for dimensionality reduction in this work.

Safaa and Aqeel (2016) [13] used the Ridge Energy Detection RED algorithm to detect features from rectangle iris templates and constructed two types of templates one for the full iris image and the other for the image that is near the pupil. The iris template features constructed from this method contain the horizontal and vertical filters. The hamming distance is used for comparing two images in this work.

Ekbal et al. (2016) [1] proposed a system based on Semi-Discrete Decomposition (SDD) algorithm. The median filter and the histogram are used to determine an automated global threshold and the pupil center. In this work, the SDD algorithm is used to extract iris features from images and the neural network was utilized for the iris feature vector classification.

Shervin et al. (2016) [14] presented a system based on deep learning. The VGG-Net (Visual Geometry Group) was utilized for feature extraction on two datasets of iris, and the principal component analysis (PCA) for the dimensionality reduction then the classification of these images was performed by using support vector machine (SVM).

M. N. Abdullah et al. (2017) [15] introduced a hybrid recognition system based on face, iris, and fingerprint patterns. For the cropped iris image, the Singular Value Decomposition (SVD) method was used to achieve the features extraction, where first converting from the Cartesian coordinates (x, y) to polar coordinates (p, θ) where ρ takes [0,1] and θ takes the value of [0,2π], the fixed block size resulting from this process will be factorized and resulting Eigenvector can be saved as a feature vector for recognition. The researcher uses an artificial neural network (ANN) to perform the classification for this model.

Veeru et al. (2018) [16] proposed a secure multi-biometric system using the face and iris. This system is based on deep neural network (DNN) and error-correction coding. Dedicated Convolutional Neural Networks (CNNs) are used to extract domain-specific features in order to convert the face and iris patterns into a common feature space. These features are then fused with the help of a joint representation layer (fully connected layer or bilinear layer).

Maram and Lamiaa (2018) [17] presented a system for iris recognition based on deep learning. The Alex-Net Model of Convolutional Neural Networks is used for feature extraction on four datasets of iris images, with the use of a multi-class SVM for the classification process.

Sue and Ahmed (2019) [18] suggested an iris recognition system based on deep learning, where the pre-trained ConvNet model (AlexNet and DenseNet201) are used to extract the features of the image without iris segmentation step and train the support vector machine (SVM) classifier with these features for further image classification. The augmentation, Bayesian optimization are employed to enhance the performance of the system.

Maryim and Ebtesam (2020) [19] proposed a recognition system called IRISNet based on Convolutional Neural Network (CNN) for feature extraction and Softmax layer to perform classification. In this work, the backpropagation and Adam optimization methods are used for updating the weights and learning rate, respectively.

Asaad and Roaa (2021) [20] introduced an iris recognition system using a hybrid technique. Scale-invariant Feature Transform (SIFT) to extract the local feature from the iris image along with the Local Binary Patterns (LBP) technique for the description of the texture of key points created by SIFT algorithm where a coefficient array of features was obtained and converted to LBP, and the results were stored in the feature vector. In this work, the circle HT was utilized for iris localization to find coordinates of the center and radius of the pupil and iris and then used these coordinates to cut the iris region of the entire eye.

Shaimaa et al. (2022) [2] introduced two methods for identifying a person based on iris biometric features. The first method uses a deep learning model called Uni-Net which is assembled of 2 sub-networks, a feature sub-network for iris feature extraction and a masking network for extracted features around the iris region, and then identifies the person by Navie-Bays classifier. The second method is a 2D-CNN model in which the iris image is classified after using an augmentation technique to enlarge the size of the dataset and applying histogram equalization (HE) and contrast limited adaptive (CLAHE) schemas to enhance the iris image.

Ahmed et al. (2022) [21] introduced a robust system for iris recognition by using the multi-range circle Hough transform (MRRCHT) with the multi-scale gray-level co-occurrence matrix (MSGLCM) methods to extract the texture area of the pupil correctly. Then use the Hough transform to extract the outer iris region. For feature extraction, the log-Gabor filter is used. This system was tested on two datasets.

Zainab et al. (2023) [22] presented a recognition system based on iris feature, the researcher uses Polar Spline RANSAC and Total Variation Model techniques for iris segmentation and then uses Gabor filter for extracting features from images.

4. Iris feature extraction techniques

There are various methods for extracting iris features; some of these methods are briefly explained in the following subsections:

4.1. Radon transform (RT)

Radon transform is a mathematical technique that is used for feature extraction, tomography, computer vision and image processing. RT is based on capturing an image's directional features by integrating the image intensity along all potential lines to highlight linear features in an image, such as edges, ridges, or curves. RT is based on the parameterization of straight lines and the evaluation of integrals of an image along these lines [23].

4.2. Semi-Discrete Decomposition (SDD)

Semi-Discrete Decomposition is a technique used for dimensionality reduction and feature extraction.

In which, the k-dimension of matrix A (m × n) is decomposed into a lower-rank approximation of three components, as shown in the following equation:

$$A = \sum_{i=1}^{k} d_i x_i y_i^T \tag{1}$$

Where d is a diagonal of the matrix A, xi and yi are an (m, n)-dimensional column and row vectors, respectively [24].

4.3. Local Binary Patterns (LBP)

Local Binary Patterns is a fast and simple feature extraction technique. Which compares the pixel value of the point (x, y) located at in the center of (3 * 3) mask, with the values of 8 neighbors around it, if the center pixel's value is greater than the neighbor's value, type “1" else type “0". This resulted in a binary value with 8 digit and converted to a decimal number to compute the LBP histogram feature [7].

4.4. Gray level co-occurrence matrix (GLCM)

Gray Level Co-occurrence Matrix is one of the techniques that is widely used for texture feature extraction. The GLCM refers to how often different combinations of gray level values appear in an image. Co-occurrence matrices are constructed in different (d, θ) where d is the distances between point and neighbor cells, and θ represents orientations. High distance refers to an increase in the scale of the texture being sampled. Co-occurrence matrices are constructed in four spatial orientations (0, 45, 90, 135) [25].

4.5. Gabor filter

Gabor filter is a linear and orientation-sensitive filter that is used for texture analysis, segmentation and extracting edge information in an image, 2D gabor filter is given by the formula [26,27]:

$$G(x, y; \theta, f) = \exp\left\{-(1/2)\left[\left(x'^2 / \partial x'^2\right) + \left(y'^2 / \partial y'^2\right)\right]\right\} \cos(2\pi f x') \tag{2}$$

$$x' = x \cos\theta + y \sin\theta \tag{3}$$

$$y' = y \cos\theta - x \sin\theta \tag{4}$$

where ∂x and ∂y gives the dimensions of the filter, θ is the direction of the angle and f is the frequency of the filter.

4.6. Log Gabor filter

Log Gabor filter is a technique that can be used rather than complex Gabor filter in feature extraction, edge and corner detection. In which the logarithmic scale of the Gaussian transfer function is utilized by log-Gabor filters in order to better represent the natural images which means it's more accurate to represent the features [7].

4.7. Scale Invariant Feature Transform (SIFT)

Scale Invariant Feature Transform is a technique used for local feature description of an image. The core goal of this method is to find extreme points in various scale spaces and filter them to produce stable key-points, in order to detect local features in an image around these points, thus local descriptors are generated from these local features for matching two images [28].

4.8. Wavelet transforms (WT)

Analysis of wavelet transforms is one of the several methods utilized for feature extraction of the image, in which the signal is passed through low and high-pass filters to produce approximate and detail coefficients, respectively. Wavelet includes four types of coefficients: approximate, horizontal, vertical, and diagonal detail can be used as a feature for iris recognition system [29].

4.9. Principal component analysis (PCA)

Principal Component Analysis is one of the statistical methods used for feature extraction and dimensionality reduction the principal components can be defined as a direction that maximizes the variance of the projects data and projecting each data point onto only the principal components to obtain lower-dimensional data while preserving as much of the data's variation as possible [25].

4.10. Ridge Energy Detection (RED)

Ridge Energy Detection is one of the recognition algorithms that is used to detect the features based on the orientation of the ridges that occur on the iris image. Primarily deals with identifying ridges within a signal or data set. A ridge can be thought of as a sequence of points that follow a pattern of high energy or amplitude compared to the surrounding points, where the square of the value of the infrared intensity within the pixel refers to the energy of the pixel [30].

Table 1. Recognition rate comparison.

Ref.	Year	Technique	Classifier	Dataset	Recognition Rate (%)
[10]	2014	Radon transform and gradient-based isolation	Euclidean distance	IIT Delhi and CASIA-Iris-Interval	95.93 and 84.17
[11]	2015	WT (Haar filter and)	FFBNN	CASIA v1.0 and real database	84.2 and 90
[11]	2015	WT (Daubechies filter)	FFBNN	CASIA v1.0 and real database	92.8 and 98.7
[12]	2015	scattering transform and textural	Minimum distance	IIT Delhi	99.2
[13]	2016	RED (full iris, near to the pupil)	hamming distance	CASIA v1.0	98.14 and 100
[1]	2016	SDD	NN	CASIA	100
[14]	2016	VGG-Net	SVM	IIT Delhi and CASIA-Iris	98 and 99.4
[15]	2017	SVD	ANN	CASIA v1.0	95
[16]	2018	DNN (face and iris)	Not available	Casia-Webface, CASIA-Iris-Thousand and ND-Iris-0405	99.7
[17]	2018	Alex-Net	SVM	IITD iris, CASIA-Iris-V1, CASIA-Iris-thousand, and CASIA Iris- Interval	100, 98.3, 98 and 89
[18]	2019	AlexNet and DenseNet201	SVM	CASIA.V1	97.22 and 98.81
[19]	2020	CNN	Softmax	IITD V1	96.43
[20]	2021	SIFT and LBP	city blocks	CASIA v4.0	98.67 for left eye and 96.66 right eye
[2]	2022	Uni-Net	Navie-Bays	CASIA v4.0, ITT-Delhi, and MMU	98.55, 99.25, and 99.81
[2]	2022	2D-CNN	CNN	MMU	96.313
[21]	2022	Log-Gabor filter	Hamming Distance	CASIA v4.0 and MMU V2	87.6761 and 94.4724
[22]	2023	Gabor filters	Hamming Distance	UBIRIS.V2	99.66

4.11. AI and deep learning

AI and deep learning models' capacity to automatically extract essential features from raw data has cemented their status as indispensable tools in modern iris identification systems. Deep learning-based methods use various Convolutional Neural Network architectures at all stages of the recognition pipeline: from preprocessing (such as off-axis gaze correction), segmentation and encoding to matching [31].

5. Problem domain

After presenting the previous researches, there is a list of problems, which can be summarized as follows:

a. **Iris Segmentation**: the problem of iris segmentation affects overall system performance, due to incorrect segmentation of the iris, leads to incorrect feature extraction and thus lower accuracy of recognition.
b. **Feature Extraction**: is another problem of the system, how to extract a set of traits that are strong enough to express a person's iris.
c. **Accuracy**: is how well an individual can be identified or verified by the system.
d. **Performance**: the overall performance of the iris recognition system depends on accuracy and speed of the recognition process.

6. Results and discussion

Before discussing the results see Table 1 that summarizes the recognition rate and classifier of each technique, as well as dataset used for evaluation:

Table 2. Time comparison.

Ref.	Year	Method	Classifier	Dataset	Time (s)
[10]	2014	Radon transform and gradient-based isolation	Euclidean distance	IIT Delhi and CASIA-Iris-Interval	0.10 and 0.44
[11]	2015	WT (Haar filter and)	FFBNN	CASIA v1.0 and real database	38 and 89
[11]	2015	WT (Daubechies filter)	FFBNN	CASIA v1.0 and real database	15 and 17
[12]	2015	scattering transform and textural	Minimum distance	IIT Delhi	0.11
[13]	2016	RED (full iris, near to the pupil)	hamming distance	CASIA v1.0	0.366052 and 0.166766
[1]	2016	SDD	NN	CASIA	1.4
[17]	2018	Alex-Net	SVM	IITD iris, CASIA-Iris-V1, CASIA-Iris-thousand, and CASIA Iris- Interval	0.06, 0.08, 0.06 and 0.09
[19]	2020	CNN	Softmax	IITD V1	Less than 1
[20]	2021	SIFT and LBP	city blocks	CASIA v4.0	1.433534
[21]	2022	MSGLCM and MRRCHT	Hamming Distance	CASIA v4.0 and MMU V2	1.87 and 0.61

As seen in Table 1, each research attempts to solve part of the problems explained in the previous section, the researches [9,21] deals with improving the iris segmentation problem. Some of the researchers resorted to using more than one strategy (such as SIFT and LBP in Ref. [20]) in order to enhance the feature extracted by integrate the advantage of each technique but this idea increase the computation costs, which led to a long time for training and recognition of the biometric system. The Table 2 shows the comparison time to perform recognition for each work.

In the other hand, some researchers use a multimodel that integrates the iris with other biometrics, such as fingerprint or face in order to enhance the accuracy of the recognition (such as in Ref. [16]). The AI and deep learning can be employed in the biometric system because of its impact on the various stages of iris recognition and help in highly achieving performance and more secure systems by learning robust and discriminative features from the iris image (such as in Refs. [17,19]).

The ratios of recognition and time still vary according to the characteristics of datasets, the number of images used to train the system, as well as the pre-processing techniques and the techniques used to extract iris traits.

7. Conclusion

There is a wide variety of mechanisms available for performing the recognition. In this paper, we presented a literature survey for some of these methods based on the iris of the human eye. Iris recognition is a stabile biometric technology known for less change throughout a person's lifetime and isn't identical for two irises. Compared with other biometric technologies, iris is considered more reliable, secure and less susceptible to external factors for recognition systems, and all biometric technologies have their importance depending on the different applications in which they are used.

8. Future work

For future work, use more than one technique to extract iris features and training a neural network to choose one of them that appropriate to the input image or it can be using the data mining with this system architecture.

Funding

Self-funding.

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