

A Review of the Iris Recognition Methods Used for the Individual Authentication

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ABSTRACT

The automatic iris recognition has become one of the most important techniques for authenticating the identity of individuals. The analysis of human iris is a reliable tool for the individual authentication due to the iris structure. Iris patterns constitute one of the uniqueness, permanence, and performance biometric traits. Moreover, the iris is considered as not easily tampered biometric traits. Therefore, this paper considers investigating the common automated methods of iris recognition. It surveys the development of utilizing iris images as an authentication means through the explanation of the historical improvement of the processes of the iris analysis. The contribution of this paper is to provide readers with huge information collected and discussed from more than 40 papers of iris recognition studies which have been published in a period of more than 20 years.

Keywords: Biometric traits; iris normalization; feature extraction; iris recognition and classification.

1 Introduction

Automatic biometric systems indicate to the measurable physiological or behavioral characteristics used to verify the identity of individuals. Several biometric traits are used to authenticate the identity of individual such as face, iris, fingerprint, handwriting, signature, voice, gait, and DNA [1]. Biometrics should meet the specified recognition accuracy, speed, and resource requirements. In other words, biometric systems are important for many applications that are related to security such as passenger control in airports, access permission in restricted areas, border control, database access, and financial services [2]. The biometric features are unfeasible to be lost, forgot, or stolen easily in contrast with other methods such as passwords or bin codes. Furthermore, biometrics of every human being are unique, accurate and stable information [3], [4]. The analysis of iris provides rich and distinctive information which can be used to identify individuals. As shown in figure 1, the iris of human eyes is a thin, colored ring around the pupil. It is bordered between an inner and outer circles. The inner circle locates between the iris and pupil boundary, the outer circle locates between the sclera and iris boundary [4]. There are five parts inside the iris: crypts, radial area and furrows, radial, ciliary area, and collarette. These parts together ensure achieving the biological function of iris which controls the amount of light entering through the pupil [5]. The exploitation of the automatic recognition of iris has been rapidly increased and become one of the most reliable and accurate techniques for biometric authentication. The fundamental and theoretical idea of the recognition the analysis of the human iris was proposed in 1939 [6]. Whilst the implementation of that idea was carried out in 1990 [7].

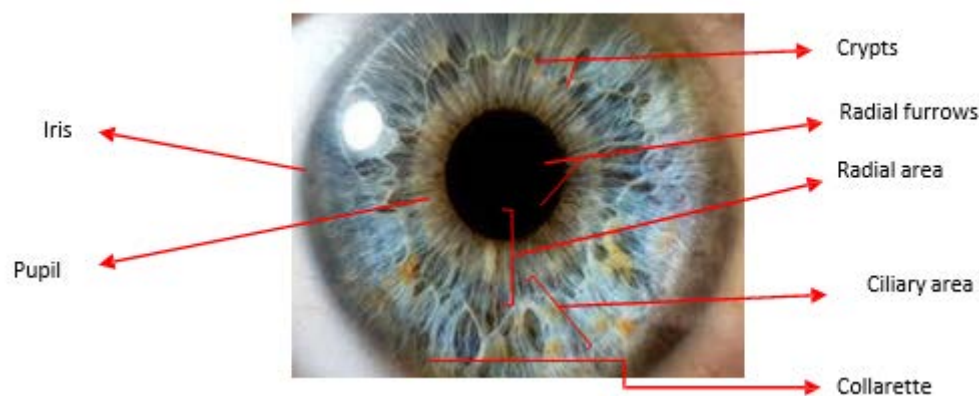


Figure 1. Iris structure

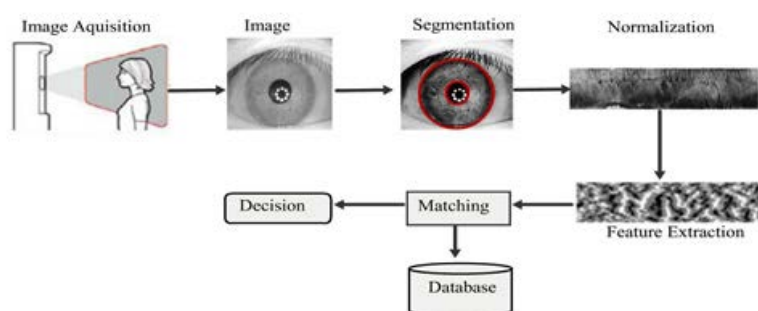


Figure 2. Diagram of the recognition of iris system

According to the previous studies collected in this paper, it would be noticed that, for over two decades, the recognition of iris images has broadly been a reliable biometric authentication technique.

Considerable studies state that an automatic recognition of iris is achieved by following five steps [8]. The first and foremost is the acquisition of iris images. It is done by standard iris camera operated invisible infrared light band. Due to the large number of available iris datasets, researchers often rely on published images such as CASIA iris, UBIRIS, MMU, and UPOL [8], [9].

The image pre-processing is the second step. It is simply adopted for the enhancement of the region of interests. It includes enhancement, segmentation, and normalization [10]. Followed by the feature extraction as a third stage to collect the effective descriptors that present the iris pattern. Finally, the classification models are implemented to measure similarities and dissimilarities between two or more iris images. Figure 2 depicts the steps of iris recognition algorithm. The discussion presented in this paper is to explain the sequential phases in several studies of the iris identifications: image pre-processing, feature segmentation, normalization, feature extraction, and finally the classification. The discussion also involves the common datasets examined in those studies.

2 The Development of Iris Recognition

As mentioned earlier and shown in figure 2, the framework of the process of iris recognition requires image requisition, image pre-processing, Feature Extraction, and the classification.

2.1 Image Acquisition

Capturing valid iris images for the recognition process requires acquiring photos with good resolution and clarity. Furthermore, any noise must be removed, because noises such as illumination causes poor decisions [6]. To avoid noises, infrared cameras are recommended to be used for this issues [2]. There are several available datasets of digital images of human iris. These datasets have been analyzed and examined in huge number of studies. Table I shows the common datasets and the number of images and the classes on every database.

2.2 Pre-processing Phase

The image pre-processing phase aims improve the image features by removing unwanted distortions and enhancement of informative features of images. This task is to ensure exactly detecting the region of iris. Majority of iris recognition studies include four stages: enhancement, localization/segmentation, and normalization [1].

The pre-processing is the initial and important stage for yielding accurate recognition rates. Applying similar techniques was quite familiar among various studies. Generally, those techniques started with converting the images from color to grayscale images [8]. Followed by converting to the black and white images using threshold values [4]. Those two stages were dominant in a huge number of the available studies. The following phases of the segmentation are not unified, because the image conditions in the different datasets are not always similar due to the image resolution and clarity [3].

Some studies considered the detection of the inner and outer borders of the iris[16]. Other studies tried to locate the eye pupil first and then went out to detect the iris [12]. In contrast, a large number of previous studies utilized morphological processes to detect the region of the whole iris correctly [7], [17]. In some case, the detection is for partial parts of the iris circle especially when the eyelid covers the top or the bottom of the iris. For example, one of the available studies concentrated on segmenting left and right quadrants of the iris images [7].

Moreover, the normalization is considered as an image processing stage of iris recognition. It is as next phase after the segmentation. The aim of the normalization is to enhance the segmented region from the whole iris image [18]. Homogeneous rubber-sheet, which found by Daugman model, is one of most common methods used to normalized iris images [10]. It is used to remap each point within the iris region to a pair of polar co-ordinates [19].

Table 1. The common datasets of iris images used in iris recognition studies

Reference	Name	Description	Image number	Class number
[6]	CASIA V1.0	Chinese Academy of Sciences Institute of Automation (CASIA) version 1.0	756	108
[11]	CASIA-Iris V3 Interval	Chinese Academy of Sciences Institute of Automation (CASIA) version 3 Interval http://biometrics.idealtest.org/dbDetailForUser.do?id=3	249	99
[12]	CASIA-IrisV4-Interval	Chinese Academy of Sciences Institute of Automation (CASIA) version 4 Interval	2639	249
[13]	CASIA-V3 Lamp	Chinese Academy of Sciences Institute of Automation (CASIA) version 3 Lamp	1000	50
[13]	MMU1	Multimedia University Database: MMU1 and MMU2 Iris Databases. [Cited 2012; Available from: http://pesona.mmu.edu.my/ccte0].	450	90
[14]	UPOL	Phoenix database, http://www.inf.upol.cz/iris/	384	64
		IIT Delhi database,		

[14]	IITD	http://www4.comp.polyu.edu.hk/~csajaykr/IITD/Database_Iris.htm http://web.iitd.ac.in/biometrics/Databaseliris.htm	2240	224
[15]	UBIRIS	Department of Computer Science, University of Beira Interior http://iris.di.ubi.pt/	1877	241

2.3 The Development of Iris Recognition Throughout the Time

The discussion of the development of iris recognition in this section considers the feature extraction and the classification models. One of the earliest attempts of iris recognition was presented in 2004 to rely on rubber sheet model have been applied to segment and detect the radius and center coordinates of the pupil. Afterward the normalization of iris regions is to convert to pseudo-polar coordinates instead of Cartesian coordinates [20]. For feature extraction, it employs Canny edge. Based on KNN classifier the classification of the extracted feature achieved 92.63% as recognition rate [20]. A novel method was introduced in 2007 to establish iris identification based on one-dimension discrete cosine transform (1D-DCT) to extract the feature followed by classifying the vectors of features using hamming distance classifier to minimize the error rate up to 2.59×10^{-4} [21]. In 2008 [22], Haar wavelet decomposition approach was applied to extract the iris features. Hamming distance was also utilized to measure the rate of the similarity among iris features. That method obtained 98.45% as a high accuracy level.

Another study investigated three methods of feature extraction: Gabor Wavelet (GW), Local Binary Pattern (LBP), and Histogram of Oriented Gradient (HOG) techniques [23]. Those techniques were applied to extract the feature vectors of the whole dimensions of the normalized iris as well as the half dimensions to find out the most informative feature group. Two classification models were examined with the extracted features: Hamming distance and Euclidean distance. All results obtained using both classifiers with all features were high, but the best correct recognition rate presented was by Hamming distance with the features of half iris using HOG [23].

The comparison of three different techniques of feature extraction was also carried out by [1]. Gabor wavelet, Log Gabor wavelet (LGW), and principal component analysis (PCA) as feature extraction methods were used to extracted the features after localizing the region of the interest and normalizing iris. The results yielded from the features of Gabor wavelet using both Euclidean distance and Hamming distance classification models were higher than those of PCA.

Three studies published in 2013 [4], [11], [24] exploited support vector machine (SVM) to distinguish between human iris samples. Although they used SVM as a classification model, the process of the feature extraction was done in various ways. Comparing the performance of SVM with Hamming distance was carried out on feature vectors extracted by 1D Log Gabor wavelet [4]. The result by SVM was 82.38, but that accuracy rapidly increased when the features of HAAR wavelet were included to reach 99.88% of the correct recognition rate [4]. SVM as classification model was also applied in [11] to classify the iris pattern based on the features of gray level co-occurrence matrix (GLCM) and gray-level run length matrix (GLRLM). In that study SVM was used to classify those features separately and then the combination of both feature groups. It obtained results of 57.14, 75%, and 88.89% of the recognition rates from GLRLM, GLCM, and both features respectively. Furthermore, SVM gained a high level of the correct recognition of 97.22% when analyzing feature vectors of 20 attributes extracted by Discrete Wavelet Transform (DWT) [24].

Proposing a novel technique based on LBP called average local binary pattern (ALBP) to extract the features of the human iris was presented in [12]. KNN and SVM were applied to examine the proposed features. SVM obtained the best recognition rate of 99.91%.

A study of analyzing features according to the texture code matrix of the iris was published in 2014 [7]. SVM was applied to classify those features and reached 98% of the correct recognition level. In addition, the use of SVM was also discussed to discriminate the iris images based on the feature extracted by three sequential strategies. The first is to sort orientation probability distribution function (OPDF). Second, to sort magnitude probability distribution function (MPDF). Third, to reduce number of key points and dimension of feature element based on combined above two methods. SVM gained 99.93% of the accuracy rate [13].

Low level of the accuracy rate was presented by [16] which also published in 2014. They extract the features using Neighborhood-based Binary Pattern (NBP) technique. That technique finds the connection between the pixels of iris images then calculates the mean followed by the variations. A binary matrix is yielded which analyzed using hamming distance for classification. It presented 76.25% of the overall accuracy rate.

Poor results were presented using Hamming distance classifier to analyze the features of iris patterns extracted by phase encoding of Zernike moments (ZMs) [25]. They obtained 32.7%, 42.6%, and 54.3% of the equal error rate (EER) when they examined their method to classify iris images in three different datasets [25]. Another study [26], which published in 2014, provide promised results when it analyzed the iris features extracted applying a strategy of three stages to present the informative descriptors. That strategy includes Discrete Sine Transform (DST), Hilbert transform and Fast wavelet Hadamard Transform (FWHT). The classification of those features using random forest classifier reached 93.4% as accuracy rate.

One of the papers published in 2015 considered Euclidean distance classifier to compute the distance between the test image and the trained images [14]. The classifier analyzed features extracted using triangular discrete cosine transform (T-DCT). The best performance of classification of three different datasets was 94.04% [14]. Additionally, the combination of discrete wavelet transform (DWT) and Discrete Cosine Transform (DCT) have been applied for extracting the features [27]. Followed by

applying binary particle swarm optimization (BPSO) algorithm as feature selection technique to obtain the most important iris features. The selected features were classified using Euclidean distance classifier. The best result of that experiment was 90.5% as an accuracy rate [27].

Moreover, the available studies in 2016 are quite significant. One of those studies applied VGG-net as feature extraction technique. VGG-net is a type of the deep convolutional neural networks. The feature vectors extracted by VGG-16 was then classified using SVM multiclass algorithm [28]. It showed a classification performance of 99.4%. Furthermore, SVM multiclass algorithm gained 94.23% accuracy level when it was applied to distinguish the features of iris pattern which extracted using Gray Level Co-occurrence (GLCM) technique [8]. Moreover, SVM with kernel functions of Polynomial and Radial Basis (RBF) and artificial neural networks ANNs were used as classification models [29]. The feature extraction technique used was 1D Log Gabor wavelet (1D-LGW). Both classifiers applied and gained high performances. SVM with RBF presented the highest accuracy rate of 100% [29]. ANN was intensively utilized with several groups of features [30]–[33]. One of those groups was extracted using a combination of discrete wavelet transform (DCT) and principal component analysis (PCA). For the classification, two combinations based on feed-forward neural networks (FFNN) were found. The first is with Particle Swarm Optimization (PSO); known as FFNNPSO. The role of PSO is to generate best

weights. The second is with gravitational search algorithm (GSA); known as FFNGSA. GSA is to provide optimum weights and biases that produced minimum error and higher recognition rate. The implementation of FFNNPSO and FFNGSA on the features extracted using DCT and PCA gave 90% and 100% as best results, respectively [32]. Although the implementation of ANN yielded great results with huge numbers of datasets, the noisy images often cause confusing the classification [34]. Therefore, researchers have tried increasing the ANN performance to ensure gaining high results even it analyses noisy images. One of those attempts creates several step to manage image noise. Such as the identification removal of the pixels of camera reflection [33].

During the last two years the performance level of iris recognition studies of has clearly improved. One of those studies analyzed iris for gender identifications [6]. It used some of the common methods for feature extraction: Wavelet Transform, Gabor filter, GLCM, and Tamura. For the classification, ANN and SVM were used. They gave 83.65% and 90.25% of the accuracy rates, respectively. The utilization of Bernstein polynomia and Fourier transform (BPFT) was proposed as hybrid method of feature extraction [9]. Those features were classified using SVM and K-means clustering SVM (KSVM). Diverse results were yielded according to the extracted features analyzed with both applied classifiers: features extracted by Fourier transform with SVM (F+SVM) and KSVM (F+KSVM), features extracted by Bernstein polynomia with SVM (B+SVM) and KSVM (B+KSVM), and finally the classification of the features of the hybrid technique using both classifiers as (H+SVM) and (H+KSVM). All results obtained showed high accuracy rates, but the best accuracy was yielded by the classification of the hybrid features using SVM. Another study considered Off-the-Shelf CNN which is one of the methods of deep learning techniques [35]. The extracted features represent the informative characteristics of the iris images. For the classification, SVM was exploited to gain 98.8% of correct recognition.

Furthermore, a study presumes that the high level of accuracy is based on many factors. One of those factor is the precisely localization of iris in the phase of feature segmentation. Therefore, they apply the algorithm of Coarse precision positioning. For the feature extraction, Gabor filter was used. The feature vectors were classified using an improved version of the Hamming distance to achieve 96.5% as an accuracy level [36].

The following tables 2 to 6 summarize those studies which reached 90% or more as accuracy rates. Tables are divided based on the classification models.

Table 2. The results of the accuracy rates yielding by using SVM algorithm considering various iris datasets and based on different pre-processing steps and feature extractions

Study	Pre-processing	Feature Extraction	Dataset Name	Number of images datasets			Accuracy
				All	Training	Testing	
[7]	circular Hough transform+ Rubber sheet model	Texture code matrix (TCM)	CASIA interval version3	1386	leave-one-out Cross validation		99.90%
			UPOL	384			100%
			MMU1	450			99.77%
			IITD	2240			99.16%
[12]	Homogeneous rubber sheet model	LBP and ALBP	CASIA interval version4	1090	10 folds Cross validation		99%
			CASIA thousand	10000			
			UBIRIS v1	1205			
[13]	coarse -to- fine segmentation	OPDF and MPDF	CASIA V3 Interval	700	10 folds Cross validation		98.47%
			CASIA-V3 Lamp	1000			98.91%
			MMUV1	450			98.36%

Table 3. The results of the accuracy rates yielding by using ANN algorithm considering various iris datasets and based on different pre-processing steps and feature extractions

Study	Pre-processing	Feature Extraction	Dataset Name	Number of images datasets			Accuracy
				All	Training	Testing	
[19]	Hough transform+ Homogeneous rubber sheet model	3D-GLCM	CASIA v1	378	288	90	94.22%
			CASIA-Iris-Syn v4	420	315	105	91%
[29]	Hough transform+ Rubber sheet model	Log Gabor	CASIA v4	1080	Not mentioned		92.5%
[30]	Adaptive Histogram Equalization	DCT	MMU2	500	100	400	98.57%
[32]	Hough transform+ rubber sheet model	DCT+PCA	CASIA v3	344	Not mentioned		90%
[33]	noise detection and removal of a camera reflection + Hough transform	LBP+ GLCM	CASIA	500	200	300	94.5%
			MMU	500	200	300	96.5%

Table 4. The results of the accuracy rates yielding by using KNN with Hamming distance considering various iris datasets and based on different pre-processing steps and feature extractions.

Study	Pre-processing	Feature Extraction	Dataset Name	Number of images datasets			Accuracy
				All	Training	Testing	
[4]	Hough transform	Haar wavelet+ Log Gabor	Chek	60	40	20	99.88%
			CASIA	700	300	400	99.91%
[21]	Hough Transform	DCT	CASIA	2156	1232	924	100%
			Bath	2955	Not mentioned		100%
[22]	histogram equalization	Haar wavelet	CASIA intervalv3	344	Not mentioned		98.45%
[36]	the Canny edge extraction and Hough transform	Gabor filter	Not mentioned	160	80	80	96.5%
[37]	Hough transform and Daughman algorithm	Wavelet Transform	CASIA-iris-thousand	20	10	10	97.8%
[38]	Integro-differential approach and the Hough Transform	Log Gabor	CASIA Iris	1080	Not mentioned		93.6%

Table 5. The results of the accuracy rates yielding by using Forest random considering various iris datasets and based on different pre-processing steps and feature extractions.

Study	Pre-processing	Feature Extraction	Dataset Name	Number of images datasets			Accuracy
				All	Training	Testing	
[24]	Histogram. Equalization	DWT+ PCA	CASIA V1	756	108	648	98%
[37]	Hough transform+ rubber-sheet model	Log Gabor	CASIA v1	756	540	216	90.55%
					432	324	93.9%
					324	432	95.07%
[43]	Hough transform + rubber sheet model	Local Binary Patterns Histogram (LBPH)	Warsaw-BioBase	200	Not mentioned		95%

Table 6 The results of the accuracy rates yielding by using KNN with Euclidean distance considering various iris datasets and based on different

Study	Pre-processing	Feature Extraction	Dataset Name	Number of images datasets			Accuracy
				All	Training	Testing	
[1]	Hough transform + rubber sheet model+ histogram equalization	Gabor wavelet	CASIA	300	Random proportions		99%
		Log Gabor wavelet					92%
		PCA					90%
[10]	Hough transform+ rubber-sheet model	PCA+ DWT	CASIA iris v4	40	Not mentioned		92.6%
[20]	Hough transform+ rubber-sheet model	box-counting	CASIA interval v4	60	5 fold Cross validation		92.63%
[23]	Integro-differential operator+ rubber sheet model	GW+LBP+HOG	MMU	130	104	26	99%
[27]	Radon Transform + Top hat filtering	DWT+DCT+ BPSO	IITD	2240	224	2016	97.81%
			Phoenix	384	64	320	94.53%
[39]	Hough transform + rubber sheet model	Fourier descriptors (FD) +PCA	CASIA intervalv4	350	50	300	94%
							92%
[40]	Hough transform + rubber sheet model	empirical mode decomposition (EMD)	CASIA V1	756	108	648	100%
[41]	Not mentioned	GF+ genetic algorithm	JLUBR-IRIS	90	27	63	97.3%
			CASIA V3				92.8%
[42]	Not mentioned	PCA+ scattering transform	IIT Delhi	210	105	105	99.2%

3 Statistical Validation of the Iris Recognition Studies

The experimental evaluation on the performance of a proposed method is a crucial and necessary task to carry out in every recognition study. There are several methods to evaluate the outcomes of the predication stage. The follows explain common methods applied in the collected studies in this paper.

3.1 Common Classification Models

Despite the various types of classifiers, this survey, which involves more than 40 of literature reviews of iris recognition, has figured out that four classifiers were dominant: SVM, ANN, KNN, and Random forest. This allows creation of new experiments with considering other classifiers. It might support to increase the performance or decrease the computational time.

3.2 Division of Datasets

Dividing datasets into training and testing sets is a crucial task in the prediction, because the correct way of the division plays an important role to avoid prediction bias [3]. The available previous studies considered the division of the datasets applying one of the cross validation techniques [7], [26], [44] or adopting a random proportion [30], [35] such 60:40, 70:30, or 80:20 for training and testing sets, respectively.

3.3 Statistical significance

Considerable number of the discussed studies applied the predictive accuracy rate for result validation [20], [43]–[45]. Others relied on the equal error rate (EER), False Acceptance Rate (FAR) and False Rejection Rate (FRR) [9], [41].

4 Discussions

The explanation of the collected studies has found out that most of the traditional positioning methods use Hough transform and Integro-Differential Operator (Daugman circular detection). In addition, they are popular techniques for iris segmentation. To this regards, the Hough transform technique is better than Integro-Differential Operator technique because it shows less error rate in iris segmented [42]. On the other hand, the disadvantages of the Hough transform are that it needs a large memory and special hardware for its computation. Moreover, the use of integro-differential operator technique is preferred in case of real time applications. In contrast, Integro-Differential Operator has failed when image has had noises. On the other hand, the estimation results yielded from the features extracted by ZMs have shown very low rates comparing with other studies which analyzed same image datasets using same classifiers but different feature extraction techniques.

Indeed, picking the database and the classifier method greatly affect the accuracy rate of the system. Notwithstanding the researchers in [9] and [36] carried out the implementation using the same database on their works, moreover, both researchers used Log Gabor for extracting the features, but the results in mentioned studies were different. This difference was because of applying different classifiers. The first work applied SVM but, the other applied Euclidean distance.

5 Conclusion and Future Work

This paper has collected more than 40 previous studies of the field of automatic iris recognition. It has discussed the approaches used in those studies, in terms of the explanation of the applied image pre-processing, feature extraction, classification, and the statistical significances in those studies. Furthermore, this paper has illustrated a wide knowledge to present the effective methods for iris recognition. In contrast, it has pointed out the weak methods which led to poor outcomes. Moreover, it has addressed the common datasets of iris images analyzed for an automatic recognition. Consequently, this paper guides its readers to find various methods for iris identification. So, readers, who are interested in finding different processes of iris recognition which might provide high results, can easily develop new approaches for classification of iris images. Finally, this work will be followed by developing different algorithms of iris feature segmentation, extraction, and classification to find out how new results might be various from the results of the previous studies.

REFERENCES

- [1] P. S. Patil, S. R. Kolhe, R. V. Patil, and P. M. Patil, "The Comparison of Iris Recognition using Principal Component Analysis, Log Gabor and Gabor Wavelets," *Int. J. Comput. Appl.*, vol. 43, no. 1, pp. 29–33, 2012.
- [2] A. K. Jain, A. Ross, and S. Prabhakar, "An Introduction to Biometric Recognition," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 14, no. 1, pp. 4–20, 2004.
- [3] J. N. Pato and L. I. Millett, *Biometric Recognition: Challenges and Opportunities*, vol. 3, no. 2. THE NATIONAL ACADEMIES PRESS, 2010.
- [4] H. Rai and A. Yadav, "Iris recognition using combined support vector machine and Hamming distance approach," *Expert Syst. Appl.*, vol. 41, no. 2, pp. 588–593, 2014.
- [5] L. Masek, "Recognition of human iris patterns for biometric identification," 2003.

- [6] A. Paul and D. Loganathan, "A Novel Classifier for Gender Classification from Iris Code used for Recognition," *IJCSN Int. J. Comput. Sci. Netw.*, vol. 6, no. 35, pp. 325–331, 2017.
- [7] S. Umer, B. C. Dhara, and B. Chanda, "Texture code matrix-based multi-instance iris recognition," *Pattern Anal. Appl.*, vol. 19, no. 1, pp. 283–295, 2016.
- [8] R. Luhadiya and P. D. A. K. Prof., "Iris detection for Person Identification using Multiclass SVM," in *International Conference on Advances in Electronics, Communication and Computer Technology (ICAECCT)*, 2016, pp. 387–392.
- [9] M. Ramya, V. Krishnaveni, and K. S. Sridharan, "Certain investigation on iris image recognition using hybrid approach of Fourier transform and Bernstein polynomials," *Pattern Recognit. Lett.*, vol. 94, pp. 154–162, 2017.
- [10] H. Kabir Rana, M. S. Azam, and M. R. Akhtar, "Iris Recognition System Using PCA Based on DWT," *SM J. Biometrics Biostat.*, vol. 2, no. 3, pp. 1–5, 2017.
- [11] R. Luhadiya and A. Khedkar, "Iris Recognition using Fusion of Gray Level Co-occurrence Matrix and Gray Level Run Length Matrix," *Imp. J. Interdiscip. Res.*, no. 1, pp. 1182–1189, 2017.
- [12] C. Li, W. Zhou, and S. Yuan, "Iris recognition based on a novel variation of local binary pattern," *Vis. Comput.*, vol. 31, no. 10, pp. 1419–1429, 2015.
- [13] Y. Chen, Y. Liu, X. Zhu, F. He, H. Wang, and N. Deng, "Efficient iris recognition based on optimal subfeature selection and weighted subregion fusion," *Sci. World J.*, vol. 2014, no. 2, 2014.
- [14] M. I. R, P. B. P, M. K, and S. Ramachandran, "Enhanced Iris Recognition using Discrete Cosine Transform and Radon Transform," in *INTERNATIONAL CONFERENCE ON ELECTRONICS AND COMMUNICATION SYSTEM (ICECS 2015)*, 2015, no. ICECS, pp. 2–7.
- [15] H. Proença and L. A. Alexandre, "UBIRIS: A noisy iris image database," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 3617 LNCS, pp. 970–977, 2005.
- [16] I. Hamouchene and S. Aouat, "A New Texture Analysis Approach for Iris Recognition," *AASRI Procedia*, vol. 9, pp. 2–7, 2014.
- [17] C. N. Devi, "Automatic Segmentation and Recognition of Iris Images: with Special Reference to Twins," in *International Conference on Signal Processing, Communications and Networking (ICSCN -2017)*, 2017, vol. 25, no. 2, pp. 178–17886.
- [18] Z. Shi, S. Setlur, and V. Govindaraju, "Digital image enhancement using normalization techniques and their application to palmleaf manuscripts," *State University of New York at Buffal*, 2005.
- [19] R. Y. Dillak and M. G. Bintiri, "A novel approach for iris recognition," *Proc. - 2016 IEEE Reg. 10 Symp. TENSYP 2016*, pp. 231–236, 2016.
- [20] C. Khotimah and D. Juniati, "Iris Recognition Using Feature Extraction of Box Counting Fractal Dimension," *J. Phys. Conf. Ser.*, vol. 947, no. 1, 2018.
- [21] D. M. Monro, S. Rakshit, and D. Zhang, "DCT-based iris recognition," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 29, no. 4, pp. 586–595, 2007.

- [22] T. W. Ng, T. L. Tay, and S. W. Khor, "Iris recognition using rapid Haar wavelet decomposition," in 2010 2nd International Conference on Signal Processing Systems (ICSPS), 2010, vol. 1, pp. 820–823.
- [23] G. Savithiri and A. A. Murugan, "Performance Analysis on Half Iris Feature Extraction using GW, LBP and HOG," *Int. J. Comput. Appl.* (0975 – 8887), vol. 22, no. 2, pp. 27–32, 2011.
- [24] M. M and D. K. B. Raja, "A novel approach for iris recognition using DWT & PCA," *Int. J. Adv. Netw. Appl.*, vol. 5, no. 1, pp. 1830–1836, 2013.
- [25] C.-W. Tan and A. Kumar, "Accurate Iris Recognition at a Distance Using Moments Phase Features," *IEEE Trans. Image Process.*, vol. 23, no. 9, pp. 3962–3974, 2014.
- [26] S. Akbar, A. Ahmad, and M. Hayat, "Iris Detection by Discrete Sine Transform Based Feature Vector Using Random Forest," *J. Appl. Environ. Biol. Sci*, vol. 4, no. August 2014, pp. 19–23, 2014.
- [27] S. S. Dhage, S. S. Hegde, K. Manikantan, and S. Ramachandran, "Dwt-based feature extraction and Radon transform based contrast enhancement for improved iris recognition," in International Conference on Advances Computing Technologies and Applications (ICACTA-2015), 2015, vol. 45, pp. 256–265.
- [28] W. Setiawan and F. Damayanti, "Layers Modification of Convolutional Neural Network for Pneumonia Detection," *J. Phys. Conf. Ser.*, vol. 1477, no. 5, 2020.
- [29] S. S. Salve and S. P. Narote, "Iris recognition using SVM and ANN," *Proc. 2016 IEEE Int. Conf. Wirel. Commun. Signal Process. Networking, WiSPNET 2016*, pp. 474–478, 2016.
- [30] A. I. Mozumder and S. A. Begum, "An efficient approach towards iris recognition with modular neural network match score fusion," *2016 IEEE Int. Conf. Comput. Intell. Comput. Res. ICCIC 2016*, 2017.
- [31] M. Sharkas, "A neural network based approach for iris recognition based on both eyes," *Proc. 2016 SAI Comput. Conf. SAI 2016*, pp. 253–258, 2016.
- [32] M. R. M. Rizk, H. H. A. Farag, and L. A. A. Said, "Neural Network Classification for Iris Recognition Using Both Particle Swarm Optimization and Gravitational Search Algorithm," *Proc. - 2016 World Symp. Comput. Appl. Res. WSCAR 2016*, no. 1, pp. 12–17, 2016.
- [33] K. Hajari, U. Gawande, and Y. Golhar, "Neural Network Approach to Iris Recognition in Noisy Environment," *Phys. Procedia*, vol. 78, no. December 2015, pp. 675–682, 2016.
- [34] M. Arsalan et al., "Deep learning-based iris segmentation for iris recognition in visible light environment," *Symmetry (Basel)*, vol. 9, no. 11, 2017.
- [35] K. Nguyen, C. Fookes, A. Ross, and S. Sridharan, "Iris Recognition with Off-the-Shelf CNN Features: A Deep Learning Perspective," *IEEE Access*, vol. 6, pp. 18848–18855, 2017.
- [36] Z. Li, "An Iris Algorithm Based on Coarse and Fine Location," in *2017 IEEE 2nd International Conference on Big Data Analysis*, 2017, pp. 744–747.
- [37] T.-Y. Chai, B.-M. Goi, Y. H. Tay, and W.-J. Nyee, "A Trainable Method for Iris Recognition Using Random Feature Points," in *2017 Conference on Technologies and Applications of Artificial Intelligence (TAAI)*, 2017, pp. 142–147.

- [38] K. Okokpujie, E. Noma-Osaghae, S. John, and A. Ajulibe, "An Improved Iris Segmentation Technique Using Circular Hough Transform," in *IT Convergence and Security 2017, 2018*, pp. 203–211.
- [39] M. Hamd and S. Ahmed, "A Biometric System for Iris Recognition Based on Fourier Descriptors and Principle Component Analysis," *Iraqi J. Electr. Electron. Eng.*, vol. 13, no. 2, pp. 180–187, 2017.
- [40] S. S. Harakannanavar, K. S. Prabhushetty, C. Hugar, A. Sheravi, M. Badiger, and P. Patil, "IREMD: An Efficient Algorithm for Iris Recognition," *Int. J. Adv. Netw. Appl.*, vol. 3587, pp. 3580–3587, 2018.
- [41] F. He, Y. Liu, X. Zhu, W. Deng, X. Zhang, and G. Huo, "The affection of gabor parameters to iris recognition and their optimization," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 8232 LNCS, pp. 330–337, 2013.
- [42] S. Minaee, A. Abdolrashidi, and Y. Wang, "IRIS RECOGNITION USING SCATTERING TRANSFORM AND TEXTURAL FEATURES Shervin Minaee , AmirAli Abdolrashidi and Yao Wang ECE Department , NYU Polytechnic School of Engineering , USA," in *2015 IEEE Signal Processing and Signal Processing Education Workshop (SP/SPE)*, 2015, pp. 37–42.
- [43] R. Gnana Praveen, M. Ravi Viswanath, and M. Sriraam Kumaar, "Iris recognition using visible images based on the fusion of Daugman's approach and Hough transform," *ACM Int. Conf. Proceeding Ser.*, pp. 50–57, 2018.
- [44] P. Samant and R. Agarwal, "Comparative analysis of classification based algorithms for diabetes diagnosis using iris images," *J. Med. Eng. Technol.*, vol. 42, no. 1, pp. 35–42, 2018.
- [45] M. Shaik, "Improved normalization approach for iris image classification using SVM," *Springer Nat. Singapore Pte Ltd, Commun. Comput. Lect. Notes Electr. Eng.*, vol. 443, pp. 139–145, 2018.