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A Review of Literature on Iris Recognition Techniques

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Abstract— The identification of the iris of the eye is one of the systems with good reliability. In view of the development of information technology and computer technologies, many intelligent techniques have been used to identify people through the iris of the eye. To increase confidentiality and security, the iris print can be used to identify trusted and authorized people. Artificial intelligence algorithms such as artificial neural networks, genetic algorithms, swarm algorithms, and deep learning algorithms have been used. These algorithms have achieved varying degrees of accuracy in determining the iris of the eye and identifying people through it. And intelligent hybrid technologies have achieved high accuracy rates.

Index Terms— Biometric, Iris Recognition Technique, Feature Extraction, Segmentation, Texture Matching.

1 Introduction

Biometrics is an automated way to identify a person based on physiological and behavioural traits. A biometric identification system analyses unique physiological features or behavioural characteristics for identification or verification. Physiological features include characteristics that are genetically included, such as the iris, fingerprint, face, retina, vein, voice, and hand geometry, while behavioural traits include handwriting, gait, signature, and keystroke typing. Among these features, the iris is unique. Because the iris has distinct phase information spanning about 249 degrees of freedom [1]. Iris recognition has been considered the most accurate and reliable biometric system. The iris borders the pupil at its inner border and the sclera at its outer border. The iris is the colored internal organ that is circular in shape and controls the size of the pupil as it works to regulate the amount of light that can penetrate the eye [2]. Iris patterns have a high degree of randomness and uniqueness, even among identical twins, and they remain consistently stable throughout life. Iris recognition is a method of identifying people based on unique patterns within the annular region surrounding the pupil. The uniqueness of the iris patterns stems from the richness of fabric details arising from the crypts, radial grooves, threads, pigment frills, spots, stripes, and arcuate ligaments. This results in a complex, irregular, randomly distributed shape that makes the human iris one of the most reliable biometric properties. In nature, iris patterns are unique. Even if they are identical twins or from left to right eye in the same person, no two irises are alike. Fig. 1 shows the anterior aspect of the iris.

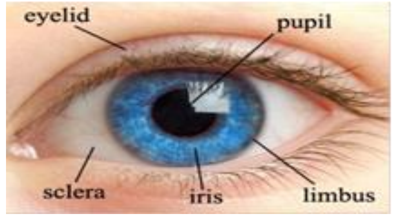

Fig. 1. The anterior aspect of the iris [2]

The Iris recognition system is useful and applicable in the field of information security and personnel authentication, such as access control in security areas, passenger verification at airports and stations, computer access in defence organisations and research companies, database access control in distributed systems [3].

2 Iris Recognition

The idea of using iris patterns for identification was proposed by an ophthalmologist named Frank Burch in 1936 [4]. In the 1980s, the idea appeared in films, but it remained science fiction and conjecture. In 1987, two other ophthalmologists, Aran Sapphire and Leonard Flom, patented the idea, and in 1989 they asked John Daugman (then teaching at Harvard) to create truly workable algorithms for iris recognition. Daugman's algorithms can be found initially in the original paper "High-Confidence Optical Identification of People through Statistical Independence." They combined the fields of classical pattern recognition with modern computer vision, mathematical statistics, and human-machine interface studies. It is a multidisciplinary field. The patents are owned by Iridian Technologies and are the basis for all current iris recognition systems and products. This identification system is used in the UAE to monitor border crossings and, as of 2004, was able to generate 420,000 parcels from 180 countries in the world [5].

3 The Mechanism of Iris Recognition

Iris recognition, or iris scanning, is the process of using visible and near-infrared light to capture a high-contrast image of a person's iris. It is a form of biometric technology in the same category as face and fingerprint recognition [6]. The process of iris recognition can be summarised in the following steps [7]:

First: Initially, the location of the pupil is revealed, followed by the detection of the iris and eyelids.

Second: Unnecessary parts (noise) are excluded, such as eyelids and eyelashes, to cut only the part of the iris, which is then broken into blocks and converted into distinct values to identify the image. Third: The matching is then done in the same way with the feature data that was already extracted.

4 Artificial Intelligence Techniques Used For Iris Recognition

There are many artificial intelligence techniques that have been able to identify people through the iris of the eye with varying degrees of accuracy, and these artificial intelligence techniques are:

4.1 Artificial Neural Networks

An artificial neural network is a model designed to simulate the human brain. An artificial neural network contains a number of very simple arithmetic interconnected processors called neurons, which are similar to biological neurons in the brain. Neurons are connected by weight links, passing signals from one neuron to another. Each neuron receives a number of input signals through the weight links. Fig. 2 represents the artificial neural network model [8].

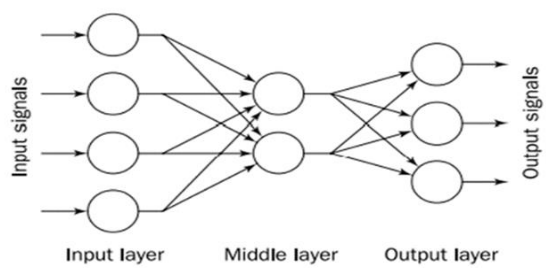

Fig. 2. A typical model of an artificial neural network [8].

The neural networks that are based on the concept of computation similar to the brain are viewed in several ways, such as "parallel distributed processing, artificial nervous system, and neural computation" to ensure the computation in a parallel manner, which provides fast processing, unlike the traditional computer, which works in a sequential way, which takes a long time for the computations. The basic concept of neural networks is to design a simple mathematical framework for brain system-like business and proceed to learn it and recognize the ability of the machine to solve various complex problems [9][10].

4.2 Deep Learning

Machine learning is defined as a subset of artificial intelligence that has revolutionised many fields in the past few decades. DL is largely based on artificial neural networks (ANNs), a computational model inspired by the workings of the human brain. Like the human brain, it is made up of many computer cells or "neurons" that each perform a simple operation and interact with each other to make a decision [11]. Artificial intelligence allows a computer to think intelligently without minimal human intervention. Various machine learning algorithms are capable of modelling high levels of input data, but deep machine learning provides a more adaptive method using deep neural networks that learn properties from the input data and then make the computer capable of making decisions [12].

4.3 Deep Neural Networks

The ability of artificial neural networks to simulate the memorization and information processing activities of human neurons enables computer systems and data processing systems to perform classification and approximation operations in a human-like manner, which has led to great progress in computing operations and network technologies represented by advanced neural networks that have taken development in size and complexity. [12]. Over the past 10 years, deep neural networks have made supervised learning tasks like handwriting recognition, machine translation, language modeling, and image classification much better. They have also made supervised iris recognition much better [13].

Deep neural networks combine a number of layers using simple elements that run in parallel, inspired by biological neural networks. An artificial neural network consists of an input layer, a number of hidden layers, and an output layer. Deep learning is achieved using neural network architectures. The term "deep" refers to the number of layers used in the network. The more layers in the network, the greater the depth of the network. Figure (3) represents a deep neural network consisting of a group of layers connected by cells, and each hidden layer uses the output of the previous layer as its input [14].

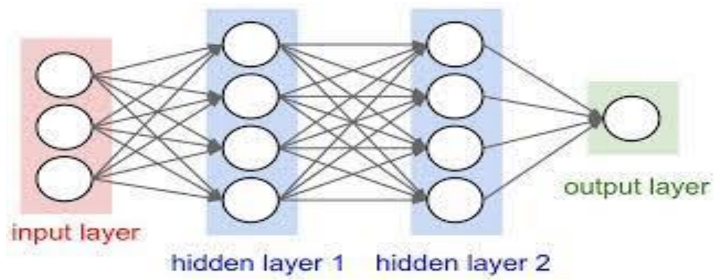

Fig. 3. A deep neural network [14].

4.4 Genetic Algorithms

A genetic algorithm is defined as a search process inspired by the theory of natural evolution. This algorithm reflects the process of natural selection whereby the fittest individuals are selected to breed in order to produce offspring from the next generation. Genetic algorithms are commonly used to create high-quality solutions to search and improvement problems by relying on biologically inspired factors such as mutation, crossover, and selection. Some ways that GA can be used are to improve the performance of decision trees, optimise hyper parameters, etc. [15].

4.5 Fuzzy Logic

Fuzzy logic is an approach to computing that relies on "degrees of truth" rather than the usual "true or false" (1 or 0) logical (or binary) logic that a modern computer relies on. Fuzzy logic allows the manipulation of many possible truth values through the same variable. Fuzzy logic attempts to solve problems using an open and imprecise spectrum of data and inferences that make it possible to obtain a set of accurate conclusions. Fuzzy logic is meant to solve problems by taking all the information into account and making the best decision possible given the information.

The idea of fuzzy logic was first introduced by Lotfi Zadeh of the University of California at Berkeley in the 1960s. Zadeh was working on a problem of computer understanding of natural language. Natural language-like most other activities in life and in reality in the universe-cannot be easily translated into the absolute terms of zero and one. Whether everything can ultimately be described in binary terms is a philosophical question worth pursuing, but in practice, there is so much data we might want to supply to a computer in a state in between and so, more often than not, are the results of computing. It may be useful to see fuzzy logic as the way thinking really works, and binary, or logical, reasoning is simply a special case of it [16].

4.6 Swarm Intelligence (SI)

Swarm intelligence or bio-inspired computation in general refers to a subset of artificial intelligence (AI). It has been identified as an emerging field, which was coined for the first time by Gerardo Beni and Jing Wang in 1989 in the context of developing cellular robotic systems [17]. Swarm intelligence refers to a type of problem-solving ability that appears in the interactions of simple information processing units. The concept of swarm indicates plurality, randomness, and chaos, and the concept of intelligence indicates that the problem-solving method is to some extent successful. They can be insects, birds, or humans; they can be matrix elements, robots, or stand-alone workstations [18].

Particle swarm optimization is a heuristic global optimization method originally proposed by Kennedy and E-Bernhart in 1995, in which the idea of an algorithm is based on simulating swarm intelligence (Swarm Intelligent). By simulating the behaviour of searching for food in a flock of birds, by means of a group of elements called a flock, spread randomly in a specific area to be then searching for food within this area, and during the process of birds searching for food from one place to another, each element of this flock represents a solution Suggesting an optimization problem for access to food (solution), birds naturally exchange information with each other while roaming and searching for food from one place to another, which ultimately leads to the flow of all birds to the place where food can be found [19]. Moving birds from one place to another equals a developing flock solution, good information equals the most optimistic solution, and food resources equals the most optimistic solution during the entire training course. The most optimistic solution can be worked out in the particle swarm optimization algorithm with everyone's cooperation. A particle of no quality and size serves each individual, and the simple behavioural pattern of each particle is organised to show the complexity of the entire particle swarm. This algorithm can be used to solve complex optimist's problems. Due to its many benefits, such as being simple and easy to use, the algorithm is widely used in fields like function optimization, model classification, machine study, neural network training, signal tracking, system fuzzy control, automatic adaptive control, etc. [20].

5 Literature Review

- In 2008, Xu et al, developed a newly proposed method for iris feature extraction using the Intersecting Cortical Model Network (ICM), which is a simplified model of the Pulse Coupled Neural Network (PCNN) model. After the preprocessing is done, the optimised iris image is put into an (ICM) network, and the third output is used as iris codes. The ICM network has excellent image segmentation performance, so the encryption process is fast enough. Then iris features such as grooves, ridges, crypts, and jagged necks are divided almost perfectly. An iris recognition platform is produced and the hamming distance between codes for two irises is calculated to measure the difference between them. In order to evaluate the proposed method, the algorithm was tested on the CASIA iris image database v1.0, and the results showed that the ICM network has great potential for iris feature extraction, and recognition accuracy of 97.74% was obtained, while the ratio of FAR and FRR metrics was 0.76% and 1.5%, respectively [21].
- In 2012, Abhiram et al, presented an approach to improve iris recognition by extracting the unique built-in circular sector and triangular DFT-DCT feature, along with inserting a disk-shaped structural element into the preprocessing stage. A feature selection algorithm based on binary particle swarm optimization (BPSO) was used to obtain the optimal subset of features from the feature space. When the proposed technique was used on the IIT Delhi Iris Database, the results showed that feature extraction in the form of an "Astroid" worked very well. This led to a significant increase in the recognition rate, which reached 97.12% accuracy with a much smaller number of iris features for recognition [22].
- In 2013, Elgamal and Al-Biqami, applied a new method for iris image compression and feature extraction based on Discrete Wavelet Transformation (DWT). The dimensions of the features obtained were further reduced using Principal Component Analysis (PCA), which significantly reduces the size of the iris database images. In the matching phase, the supervised classifier is used, the k-nearest neighbor(k-NN). The proposed technique was tested on a standardized iris database, the IIT Delhi Iris Database, with a classification accuracy of 99.5%. This shows that, compared to other recent work, the proposed method is strong and effective [23].
- In 2013, researchers Khedkar and Ladhake, extracted iris features from the CASIA-IrisV1 database using the 2D Walsh Hadamard Transform (WHT) method. Then compare the results of the three networks: Multi-Layer Perceptron (MLP), Radial Basis Function (RBF), and Support Vector Machine (SVM) by varying a set of parameters including momentum, step size in the hidden and output layers, learning rules, and the number of neurons in the hidden layer for the purpose of determining the most appropriate neural network for iris classification. The results of the experiments showed the progress of the hidden MLP single-layer network over the other structures with an accuracy of 95%. This trait was also found on iris

patterns changed by a Gaussian noise filter, which made the cost of recognition go down by a small amount (90.5%) [24].

- In 2014, Bharath et al, proposed two new techniques, namely, the radon transform threshold (RTT) and gradient-based isolation (GI). RTT is used to extract the salient features from the preprocessed image. Whereas GI is a preprocessing technique that uses the edge detection property of the gradient operator to isolate patterns, thus obtaining a prominent iris texture. The feature selection algorithm based on binary particle swarm optimization (BPSO) is used to search the feature vector space for the optimal feature set. Experiments on two standard iris databases, IIT Delhi Iris Database and CASIA Iris Interval, show that the proposed techniques work well, with a recognition accuracy of 95.93% and 84.17%, respectively [25].
- In 2015, Dhage et al, presented a new method for recognising iris patterns through a combination of preprocessing using radon transform and top hat filter to improve the fine detail of iris edges and using discrete wavelet transform (DWT) and discrete cosine transform (DCT) to extract features. Feature selection using binary particle swarm optimization. The individual stages are checked and each stage is attempted to be improved. The Radon transform is used to detect lines in the texture of the iris, and top-hat filtering is used to improve the image. A combination of DWT and DCT is used to extract prominent iris features. The BPSO-based feature selection algorithm is used to search the feature vector space for the optimal feature set. Experimental results on the IITD standard database showed an accuracy of 97.81% [26].
- In 2015, Saminathan et al, presented a new method based on applying a multi-class support vector machine (SVM) machine learning classification algorithm for both iris authentication and recognition. Three types of kernels (linear, polynomial, and quadratic) are combined with three methods (sequential minimal optimization, quadratic polynomial, and minimal square) and compared with the other three classification methods: Hamming distance, local binary mode, and FFNN. The character extraction and representation yield the class vectors of 2,400 elements, representing the density values. Experiments done with the CASIA-IrisV3-Interval database show that the Least Square Method of Quadratic Kernel SVM works best. This method has the best identification rate of 98.5% and a best false acceptance rate (FAR) of 0% [3].
- In 2015, Minaee et al, presented a method that includes two sets of features for use in iris recognition: scattering transform-based features and textural features. PCA is also applied to extracted features to reduce the dimensions of the feature vector while preserving most of the information for its initial value. A Minimum Distance Classifier (MDC) is used to perform template matching for each new test sample. The proposed model was tested on the IIT Delhi Iris Database and showed high results, with the best accuracy rate of 99.2% [27].
- In 2016, researcher Tharwat did a study on the Principal Component Analysis (PCA) technique and compared two methods for calculating PCA, which are the covariance matrix and the single value analysis (SVD) method. PCA has been applied in real applications, including biometrics, image compression, and the visualisation of high-dimensional data sets. The PCA technique was used as a feature extraction method to identify individuals using a Nearest Neighbor (NN) classifier. The aim of the study was to investigate the effect of the number of principal components on classification accuracy and CPU time. The results showed a 95% classification accuracy for an ORL dataset, and this accuracy is fixed when the number of main components is increased from 20 to 100. As for the ear dataset and Yale face dataset, the accuracy was fixed at 94% and 85%, respectively, when the number of principal components was more than 15 and 20 [28].

- In 2016, Minaee et al, proposed a method to verify the application of deep features extracted from VGG-Net followed by the Multiclass-Support Vector Machine (SVM) classification algorithm for iris recognition. The proposed model was tested on two well-known iris databases, IIT Delhi Iris Database and CASIA-Iris-Thousand, and the results showed an accuracy rate of 99.4% and 90%, respectively [29].
- In 2018, researchers Alaslani and Elrefaei, presented a study on the design of the iris recognition system. The iris is segmented using the circular Hough transform and normalised with a rubber sheet model. Then feed the segmented and matched image as input to CNN (Alex-Net). The features extracted from a pre-trained convolutional neural network (Alex-Net model) are then evaluated, followed by a multi-class support vector machine (SVM) algorithm to perform the classification. The performance of the proposed system is checked when extracting features from a segmented iris image and from a normal iris image. The proposed iris recognition system was tested on four public datasets (IITD iris, CASIAIris-V1, CASIA-Iris-thousand, and CASIA-Iris-V3 Interval). The system achieved excellent results with a very high accuracy rate of 100%, 98.3%, 98%, and 89% for the mentioned data sets, respectively. The results showed that the accuracy of recognition is higher when features are taken from a segmented image than when they are taken from a natural image [30].
- In 2019, researchers Oyeniran et al, built a multi-algorithm method for iris identification based on a multiclassifier approach. They applied Hough Circular Transform techniques for the purpose of localization and segmentation in order to isolate the iris from the entire eye image and to detect noise. The normalisation process was carried out using the Daugman model. In this study, the characteristics were extracted using the Continuous Wavelet Transform (CWT) continuous wavelet transform. In the classification stage, the Hamming Distance, Nearest Neighbor, and Euclidean Distance classifiers were adopted. This system was trained using 500 iris images from the CASIA database, while 100 unregistered iris images were used to verify the system. The results showed a classification accuracy of 70%, and the ratio of the FAR and FRR scale was 0.00% and 0.03%, respectively [31].
- In 2019, researcher Tobji et al, presented a proposed "FMnet" algorithm for iris recognition using Fully Convolutional Networks (FCN) and Multi-Scale Convolutional Neural Networks (MCNN). This method works by segmenting and identifying the iris of the eye based on a group of convolutional neural networks (CNN) and on several networks operating at different degrees of accuracy. The segmentation process is performed using a network (FCN), while the feature extraction process is done using a network (MCNN), and the classification process is through a network (CNN). This proposed method overcomes the problems of classical methods that use feature extraction only, by performing feature extraction and classification together. The proposed algorithm shows how well convolutional networks work in iris recognition and gets better results in classification rates on different databases: CASIA-Iris-Thousand with an accuracy of 95.63 percent, UBIRIS.v2 with an accuracy of 99.41 percent, and LG2200 with an accuracy of 93.17 percent [32].
- In 2019, the researcher Ghaffari et al, presented a proposed method for identifying the iris of the eye based on the PCA technique called the Intensity Separation Curvelet Based PCA (ISCPCA). The proposed method uses edge detection by Canny Edge detection and Hough transformation to extract the iris from the input eye image. The histogram of the iris image is then equalised to increase its contrast, and then FDCT is subjected to splitting it into its sub-bands. The standard principal component analysis (PCA) is applied to the resulting frame to calculate its eigenvectors. The Euclidean distance between the resulting eigenvectors and the eigenvectors of the images in the data set is then computed to find the best match. Experimental results on the images of the CASIA-Iris-Interval dataset show that the proposed ISC-PCA technology is

significantly superior to the latest PCA-based approaches. In addition, the results of learning-based technologies are competitive but at a much lower computational cost. The performance of learning-based iris recognition techniques is known to depend on their feature extraction methods. So, using ISC-PCA with learning-based classification algorithms can make them work much better, as 95.93% accuracy was found [33].

- In 2020, Oyeniyi et al, used the continuous wavelet transform method to optimise the iris feature extraction. This method significantly reduces computation time and improves accuracy compared to the Gabor filter, Fourier transform, and other wavelet transformations. The continuous wavelet transform (CWT) performance of feature extraction shows that it is more stable and consistent even with a very high level of noise in the data than that of the vesicle-discrete transform (DWT). In this work, a Support Vector Machine (SVM) classifier was used to classify iris images, and the results showed validation metrics with 0.8% FAR, 1.4% FRR, and 97.8% performance recognition accuracy, which used the CASIA database [34].
- In the year 2020, researchers Azam and Rana, used a method aimed at identifying individuals who need a high level of security by recognising the iris of the eye. However, improving recognition accuracy mostly depends on feature extraction and classification techniques. Therefore, this study emphasises feature extraction and classification effectively through Convolutional Neural Network (CNN), Convolutional Neural Network, and Support Vector Machine (SVM) respectively to increase recognition efficiency. The proposed technique and experimental evaluation of network performance were applied to iris images from the CASIA database. The experimental results showed that the proposed technique performed well, with an accuracy rate of 96.3% [35].

6 PRACTICAL RESULTS OF LITERATURE REVIEW

Table 1. Summary of Practical Results and Algorithms Used In the Literature Review

#	*Authors, Year*	*Feature Extraction*	*ML Approach/ Algorithm*	*Dataset*	*Recognition Accuracy*
1.	Xu et al, 2008	Intersecting Cortical Model (ICM) network	Hamming Distance (HD)	CASIA-Iris-V1	97.74%
2.	Abhiram et al, 2012	circular sector and triangular DCT	Binary Particle Swarm Optimization (BPSO)	IIT Delhi Iris Database	97.12%
3.	Elgamal & Al-Biqami, 2013	Discrete Wavelet Transformation (DWT) + (PCA)	K-nearest neighbor (K-NN)	IIT Delhi Iris Database	99.5%
4.	Khedkar & Ladhake, 2013	2D Walsh Hadamard Transform (WHT)	Multi-Layer Perceptron (MLP)	CASIA-Iris-V1	95%
5.	Bharath et al, 2014	Radon transform (RT)and gradient-based isolation(GI)	Binary Particle Swarm Optimization (BPSO)	IIT Delhi Iris Database	95.93%
				CASIA-Iris-Interval	84.17%
6.	Dhage et al, 2015	Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT)	Binary Particle Swarm Optimization (BPSO)	IIT Delhi Iris Database	97.81%
7.	Saminathan et al, 2015	iris template features	Least Square Method Of Quadratic Kernel Support Vector Machine (SVM)	CASIA-IrisV3-Interval	98.5%

8.	Minaee et al, 2015	Texture+ Scattering Features + (PCA)	Minimum Distance Classifier (MDC)	IIT Delhi Iris Database	99.2%
9.	Tharwat, 2016	Principal Component Analysis (PCA)	Nearest Neighbor (NN)	(ORL) dataset Ear dataset Yale face dataset	95% 94% 85%
10.	Minaee et al, 2016	pre-trained VGG-Net	Multiclass-Support Vector Machine (SVM)	IIT Delhi Iris Database CASIA-Iris-Thousand	99.4% 90%
11.	Alaslani & Elrefaei, 2018	pre-trained Alex-Net	Multiclass-Support Vector Machine (SVM)	IIT Delhi Iris Database CASIA-Iris-V1 CASIA-Iris-Thousand CASIA-Iris-Interval	100% 98.3% 98% 89%
12.	Oyeniran et al, 2019	Hough Circular Transform+Continuous Wavelet Transform (CWT)	Hamming Distance (HD) + Nearest Neighbor + Euclidean Distance	CASIA database	70%
13.	Tobji et al, 2019	Multi-Scale Convolutional Neural Network (MCNN)	Convolutional neural network (CNN)	CASIA-Iris-Thousand UBIRIS.v2 LG2200	95.63 % 99.41% 93.17%
14.	Ghaffari et al, 2019	Intensity Separation Curvelet Based PCA (ISC-PCA)	Euclidean Distance	CASIA-Iris-Interval	95.93%
15.	Oyeniyi et al, 2020	Continuous Wavelet Transform (CWT)	Support Vector Machine (SVM)	CASIA database	97.8%
16.	Adam & Rana, 2020	Convolutional neural network (CNN)	Support Vector Machine (SVM)	CASIA database	96.3%

From the above table, it is clear that there are many techniques used in extracting the characteristics of the iris. In addition to the intelligent algorithms used in the classification and matching process, which were applied to groups from a variety of standard iris data sets.

There are several factors that affect the classification accuracy rate, given that accuracy is the main criterion for differentiating between classifications and matching algorithms to identify the iris of the eye. Among these factors is the quality of the images of the iris data set, as the noise represented by eyelashes and the reflection of light on the iris has an effect on the classification accuracy results. The preprocessing of iris images, which includes iris and pupil detection, iris segmentation, and iris normalization, plays an important role in the accuracy of classification. As well as using the appropriate method for extracting traits and a classification algorithm.

Based on the accuracy standard, we can say that the methods (pre-trained Alex-Net) and (Multiclass-Support Vector Machine (SVM)) presented by the researchers [30] are the best methods that get a 100% accuracy rate.

7 Conclusion

Iris recognition is one of the most effective methods for the purpose of authentication because it is very distinctive, stable with age, and well protected. Iris formation occurs during pregnancy, resulting in patterns and colours that are random and unique to each person. This paper provides a technical overview of the literature review and a chronological presentation of iris recognition techniques by different researchers. Based on the foregoing, it was concluded that most of the work performed on iris recognition is somewhat similar but mainly focused on four main areas, which are iris segmentation and normalization, which includes noise removal, feature extraction, and classification and matching of iris templates. Most of the work done for iris recognition is fairly similar and has had varying degrees of classification accuracy. However, there is a significant improvement in techniques to enhance recognition accuracy.

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