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A Review on Iris Biometrics as Evolving Technology

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Abstract: Various person authentication issues need to be handled in today's era of information technology. The increasing requirement of enhanced and reliable security systems has led to an unprecedented attention in biometric based person authentication system. As biometrics has advanced, the iris has beenconsidered a preferred trait because unique pattern texture, lifetime stability, and regular shape contribute to good segmentation and recognition performance.Iris based recognition systems are very accurate and precise biometric technique to secure an individual's identity. Iris has developed as one of the most promising traits for large-scale user authentication and a highly suitable candidate for any multimodal biometric system. This paper presents a review on the performance analysis of various methods used in the field of iris recognition.

Keywords: *Iris recognition, Biometrics, Segmentation, Normalization, Performance evaluation.*

1. INTRODUCTION

Biometric is the Greek word in which *bios* (life) and *metron*(measure), and hence biological measurement is termed as *biometric*. Biometrics is the science and technology of measuring and analyzing biological characteristic of human body, extracting a feature set from the acquired human trait, and comparing the extracted features against to the template stored in the database. It differs from traditional user authentication system which is based on something that one has (*e.g.*, smart card, badge, key) and/or something that one knows (*e.g.*, password, Personal Identification Number or PIN). However, these traditional methods have a numerous shortcomings from the point view of security. Forexample, smart card can be duplicated, misplaced, stolen or lost, long password can be difficult toremember and short password can be predicted easily by the imposter. However, security can be easily breached in applications based on traditional user authentication systems when a password is revealed to an unauthorized user or a badge is stolen by an impostor. The development of biometrics systems has addressed the problems that plague traditional identification and verification methods.

Biometrics is defined as the science of automatic identifying an individual based on his/her physical or behavioral characteristics.It is accepted as a legitimate method for determining an individual's identity. Physiological biometrics are related to the shape of the body and are generally more stable, on the contrary behavioral biometrics are related to the behavior of the person and are comparably less stable. Various biometric

systems based on physiological traits such as fingerprints, iris, retina, facial images, palm prints, finger veins, hand geometry etc. or behavioral traits such as speech, gait, handwriting, speakeretc. were developed, implemented and used over years. These systems can beimplemented as security protection systems, criminal investigations, terrorist identification, parenthood determination, corpse identification, logical access points, medical records management, biometrics attendance systems, and surveillance applications.

1.1. Iris is a Living Password

Iris recognition is an automated method of biometric identification/verification that uses the flowery patterns of the human iris as a way of identifying or verifying people.The parts of the iris are formed by many collagenous fibers, contraction furrows, pits, serpentine vasculature, rings, coronas, freckles, rifts, crypts, zigzag collarettes and pits[1-3]. These features and their special relationship to each other give abundant information and random texture, which are used to authenticate a person through iris recognition system. Iris is as distinct as fingerprints according to the biomedical literature[4]and the uniqueness of every iris parallels the uniqueness of every fingerprint.This uniqueness property of iris can be quoted in the words of Daugman, 1993as, 'An advantage of the iris shares with fingerprints is the chaotic morphogenesis of its minutiae'[5]. Also its physiological response to light provides the detection of a dead or plastic iris, thus avoiding any kind of counterfeiting. Iris is naturally destroyed after the death of person. Iris is a protected internal organ of the eye. It is the only internal organ which is externally visible. Iris based identification is secure and reliable because, iris pattern doesn't change for the whole life of a person except in case of surgery. The features of iris of human remain stable throughout life[6]. This is one of the main advantages of iris biometric since almost every other biometric template changes significantly over certain time.

The iris image fully develops in the first six months after the birth of a child. Also, the iris pattern does not correlate with genetic determination since its forming depends on the initial environment of the embryo. Personal identification using iris is non-invasive technique[7-8]and it is believed to be the most reliable among all biometric methods. Furthermore, the probability of finding two people with identical iris is almost zero and even left iris and right iris of person are not identical[9]. Many biometrics are having 16 to 20 distinct characteristics whereas iris is having 266 unique spots. The function of iris is to control the amount of light entering through the pupil. The role of iris is to control the size of the pupil, iris color and expansion and contraction of pupil. The probability for the existence of two similar irises is 1 in 10^{72}.

The United Nations High Commissioner for Refugees (UNHCR) used iris recognition for identification of Afghan refugees[10]. Iris is used in high profile applications such as Indian government's Aadhaar / Unique ID project, which has been ranked as world's largest biometric project through Unique Identification authority of India (UIDAI).

1.2. Background of Iris Biometrics

In 1936, ophthalmologist Frank Burch suggested the idea of using iris patterns as a method to recognize an individual. Adler[4] said that the human iris, which has a very complex layered structure unique to an individual, is an extremely valuable source of biometric information. In 1985, Drs. Leonard Flom and AranSafir, ophthalmologists, proposed that no two irides are identical, and were conferred a patent for the concept of iris identification concept in 1987[11]. In 1994, Dr. Daugman was awarded a patent for his development of biometric personal identification system based on iris analysis and is widely recognized as the inventor of practical iris recognition[12]. This was followed by several landmarked contributions of Boles and Boashash, 1998[13], Wildes et al. (1996; 1997)[1, 7], Ma et al. (2002; 2003; 2004)[14-16], Krichen et al. (2004)[17]in the area of iris recognition.The pioneering work in the field of cancelable iris biometric was performed[18-19].

In general, traditional feature extraction approaches and iris recognition system can be divided into five major categories: phase-based approaches[2,5,20], texture analysis based approaches[13], zero crossing approaches[7], intensity variation analysis based approaches[15-16], and other approaches[21-23].

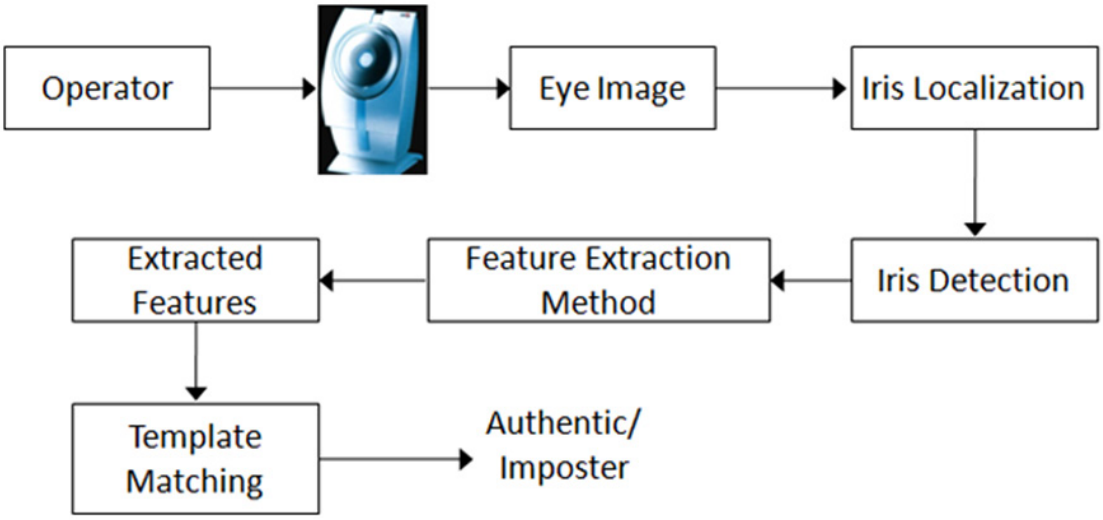

Figure 1: Stages of iris recognition process

2. GENERAL FRAMEWORK OF IRIS RECOGNITION SYSTEM

The Human eye contains sclera, pupil, iris, eyelids, and eyelashes as presented in Figure 2. It is necessary to preprocess the eye image to extract the accurate iris features. The steps of iris recognition system are depicted in Figure 1.

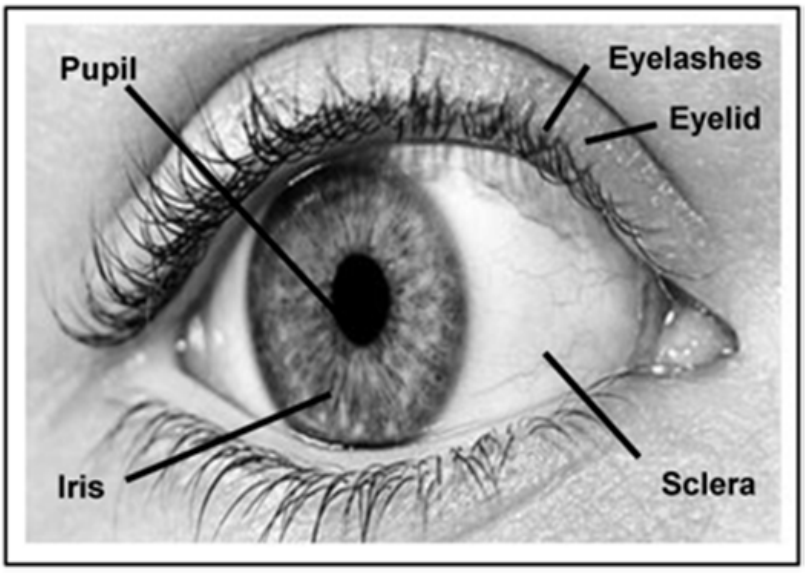

Figure 2: General structure of eye

2.1. Image Acquisition

The image of the iris can be captured using a standard camera using both visible and infrared light. The automatic procedure uses a set of cameras that locate the face and iris automatically thus making the process much more user friendly. The quality of input image helps to store the biometric distinctive feature extraction easier and faster.

2.2. Image Localization

Iris localization detects the inner and outer boundaries of the iris. Lighting reflections, eyelids and eyelashes obstructions are eliminated. This step is important because correct iris region is needed to generate the templates for accurate matching. Some iris localization algorithms are Integro-differential operator, Hough transform, Discrete Circular Active Contour, Bisection method and Black hole search method.

2.3. Image Normalization

Irises from different people may be captured in different size and environment. Size may change because of the variation of the illumination and other factors such elastic deformations in iris texture, which affects the performance of subsequent feature extraction and matching stages. Therefore, the iris region is required to be normalized to compensate for these variations by remapping images from Cartesian coordinates to polar coordinates. Daugman's Rubber Sheet Model is generally used for normalization.

2.4. Feature Extraction

In this stage, various texture analysis methods like Gabor filters, Laplacian of Gaussian filter, Hilbert transform, Wavelet Transform, Discrete Cosine Transformare used to extract the significant features from the normalized iris image.

2.5. Template Creation

Once the features are extracted using any one of the techniques, an iris image is transformed into a unique representation within the feature space. These features are stored which is known as iris code for template creation.

3. IRIS DATABASES

The iris image databases that can be used for biometric purposes are: Chinese Academy of Sciences Institute of Automation (CASIA)[24], Multimedia University (MMU)[25], University of Bath (BATH)[26], University of Olomuc (UPOL)[27], Iris Challenge Evaluation (ICE)[28], West Virginia University (WVU)[29], and University of Beira Interior (UBIRIS)[30].Numerous researchers used CASIA and MMU databases to perform their research.

4. PERFORMANCE ANALYSIS OF IRIS RECOGNITION SYSTEM

The iris is an externally visible, yet protected organ inside eye whose unique epigenetic texture pattern remains stable throughout life until death. These characteristics make it very attractive for use as a biometric for identifying individuals. In recent years, researchers have considered aspects like utilizing real valued features for recognition, developing alternate ways of obtaining the iris codes and concatenating multiple features. A plethora of work has been done in the field of iris recognition. Generally researchers claimed the better performance in terms of accuracy, reliability, speed in capturing images and recognition over the existing systems available at that time. The performance analysis of iris recognition system developed by various researchers on different datasets is shown in Table 1.

Table 1
Performance analysis of iris recognition biometric system

Approach	*Dataset used*	*Feature extraction method used*	*Classification Strategy*	*Key findings*
Sanchez-Avila et al.,(2002)31	• Self- collected iris database 10 subjects	• Dyadic Wavelet Transform	**With Euclidean Distance classifier** • Classification success : 93.6% **With Hamming Distance classifier** • Classification success : 97.9%	• Proposed system using Dyadic Wavelet Transform can achieve high rates of security.
Ma et al.,(2002)14	• Self- collected iris database	• Circular Symmetric Filters	• Correct classification rate: 99.85%	• Proposed algorithm achieves encouraging performance.
Krichen et al.,(2004)17	**Data set – I** • Self- collected iris dataset **Data set –II** • CASIA iris dataset	• Wavelet packets method	**For Data set – I** • FAR: 0% ,FRR: 0.57% **For Data set – II** • FAR: 0.2% ,FRR: 1.38%	• Use of the wavelet packets approach is satisfactory in the context of blurred images and poor iris texture in visible light illumination.
Chu and Chen, (2005)32	• CASIA iris database 108 subjects	• Sobel operator	FAR: 0.0% FRR: 0.69 % Accuracy: 99.14%	• Proposed method with PSO possesses the best recognition performance.
Proenca and Alexandre, (2007)33	• UBIRIS iris database 80 subjects	• Iris Partition and Feature Extraction strategy	• FAR: 0% • FRR: 16.49±0.01% • EER: 2.38±0.0% • Error ROC: 1.73%	• Proposed method is adequate for less constrained image capturing environments, such as in a non-cooperative setting.
Yu et al.,(2007)34	• CASIA iris database (108 irises) • Private iris database (254 irises)	• 2-D Gabor Filter	**For CASIA Database** • Recognition Rate: 97.18% **For Private Database** • Recognition Rate: 99.74%	• Proposed approach does not define and illustrate iris minutia structure.
Birgale and Korkare, (2010)35	• CASIA iris database 108 subjects	• Discrete Wavelet Transform	**With Daubchies wavelet** • FAR: 0.0069, FRR: 1.021 • Average Efficiency: 99.485%	• Proposed method gives an accuracy of 99.474% with a signature of very small length.
Patil et al., (2012)36	• CASIA iris database 30 subjects	• PCA • Log Gabor Wavelet • Gabor Wavelet methods	**With PCA method** • Recognition rate: 90.2% **With Log Gabor Wavelet method** • Recognition rate: 92.4% **With Gabor Wavelet method** • Recognition rate: 99%	• Gabor wavelet method captures more information in much smaller local regions, which makes it better than the Log Gabor wavelet and PCA based methods.

Approach	*Dataset used*	*Feature extraction method used*	*Classification Strategy*	*Key findings*
Mira et al.,(2013)37	• CASIA V3-Interval Iris database • BATH iris database 25 subjects	• Morphological Operators	**For CASIA Dataset** • AUC: 0.99757%, EER: 1.12% • Accuracy: 98.88% **For BATH Dataset** • AUC: 0.99941%, EER: 0.65% • Accuracy: 98.35%	• Experimental results demonstrate the viability of using the proposed morphological approach for iris recognition.
Ali and Tahir,(2014)38	• CASIA – A (Verison 3.1) Iris database 150 subjects	• Gabor Filter	FAR: 0.21% FRR: 0.21% ERR: 99.56%	• Half iris feature extraction coding reduces computational time and memory size.
Chen et al.,(2014)39	• CASIA-V3-Interval iris database 249 subjects • CASIA-V3 Lamp iris database 411 subjects	• SIFT (Scale Invariant Fourier Transform)	For CASIA-V3-Interval Dataset Recognition Rate: 99.82% Equal error rate: 0.78% For CASIA-V3 Lamp Dataset Recognition Rate: 99.93% Equal error rate: 0.82%	• Proposed methods can effectively improve the performance of iris recognition system with respect to CRR and EER.
Saminathan et al.,(2015)40	• CASIA iris database 40 subjects	• Hamming Distance • Local Binary Pattern (LBP) • Feed Forward Neural Network (FFNN) • SVM	With Hamming Distance method Accuracy: 76.8% With LBP method Accuracy: 83.3% With FFNN method Accuracy: 87.0% With SVM method Accuracy: 98.5%	• Proposed work supports for automatic recognition based on iris spectral features.
Minaee et al.,(2015)41	• IIT Delhi iris database 224 subjects	Scattering operator Haralick features	Recognition Rate of proposed scheme using 80 PCA features: 99.2%	Scattering features carry a lot of high-frequency information, which provides discriminating power for iris recognition.

Multimodality is able to solve problems related to unimodal biometrics that affectthe performance of systems such as lack of uniqueness, non-universality,and noisy data.It is based on the concept that the information obtained from different modalities complement each other.The main aim of multimodal biometric is to reduce the error as low as possible and to improve recognition rate. For instance, variations in terms of illumination,pose and expression lead to degradation of performance in face recognition and in iris recognition,non-cooperative situation may degrade iris recognition accuracy. DNA loses accuracy because it does not make out differentiation between monozygotic twins. The main aim of multimodal biometric is to reduce the error as low as possible and to improve recognition rate. The performance analysis of multimodal biometrics having iris as candidate trait is shown in Table 2.

Table 2
Performance analysis of iris trait with other biometrics in multimodal biometric

Approach	*Modalities fused/ Dataset used*	*Fusion level implemented*	*Feature extraction method*	*Classification Strategy*	*Key findings*
Wang and Han,(2009)42	• UBIRSI iris data set • ORL face data set 40 subjects	• Score level fusion using support vector machine	• Log−Gabor phase information based iris verifier • Laplacian face based verifier	**Sum rule** • EER: 0.87 **Product rule** • EER: 0.71 • Fisher EER: 0.53 • Proposed EER: 0.35	SVM−based fusion rule can achieve better fusion effect than the conventional score fusion rules.
Trabelsi et al.,(2011)43	• CASIA V 1.0 iris database • 108 objects palm print CASIA database 312 subjects	• Score level fusion using sum rule	• Fractal analysis method for iris trait • Local binary pattern for palm print	• Area under ROC curve: 0.93 (iris) • Area under ROC curve: 0.9984 (multimodal)	Fusion at score level offered the best compromise between wealth of information and ease of implementation.
Xiuyan et al., (2011)44	• TJU hand vein database • CASIA iris database • CASIA fingerprint database 108 classes	• Score level Min-Max (MM), TanH, Two Quadrics (QQ), Quadric-Line-Quadric (QLQ), DUE	• SURF descriptors (hand-vein) • Discrete Wavelet Transform (iris) • Discrete Wavelet Transform (fingerprint)	• EER: 0.0045% (MM) • EER: .0062% (ZS) • EER: 0.0038 (Tanh) • EER: 0.23% (DUE) • EER: 0.0035% (QQ) • EER: 0.067% (QLQ)	Personal identity verification accuracy could be improved effectively by all proposed fusion algorithm except for DUE.
Gayathri and Ramamoorthy, (2012)45	• PolyU palm print database • Iris IITK database 125 subjects	• Feature level fusion using wavelet fusion	• Gabor Texture	• Recognition accuracy : 99.2% • FRR: 1.6%	Combination of palm print and iris traits outperformed than using them individually.
Nadheen and Poornima, (2013)46	• CASIA Version 1.0 iris database • IIT Delhi ear database 60 subjects	• Feature level fusion using Concatenation method	• PCA for ear and iris	• FAR: 0.05%, • FRR: 0.075% • Accuracy: 93%	Fusion of iris and ear increases the recognition rate rather a single biometric trait.

Approach	*Modalities fused/ Dataset used*	*Fusion level implemented*	*Feature extraction method*	*Classification Strategy*	*Key findings*
Eskandari and Toygar,(2013)47	• ORL -BANCA face databases • CASIA-UBIRIS iris data set 80 subjects	• Transformation based score level fusion • Classifier based score level fusion	• PCA • Subspace LDA • spPCA • mPCA • LBP	**Score level fusion** • Recognition performance (RP): 97.750% **Proposed scheme** • RP: 98.250%	Proposed method achieves improved recognition accuracy compared to unimodal methods and the state-of-the-art systems.
Sudhamaniet al., (2014)48	• SDULMA-HMT multimodal database 106 subjects	• Decision Add	• Local Binary Pattern (LBP) for Iris trait Haar Wavelet for finger vein	• FAR: 0% • GAR: 5%	Fused results using the proposed method shows significant improvement in the performance.
Gawande et al.,(2014)49	• Iris CASIA V2 database • And self-collected fingerprint samples of 100 YCCE college	• Feature level fusion using concatenation Method	• Wavelet Transform (iris) • Minutiae Point's (fingerprint)	• FAR: 2% • FRR: 3% • GAR: 97%	Fusion at feature level enhances the security and 120 bit secure key increases level of authentication.
Bharadi et al.,(2014)50	• Phoenix Iris Database • Self -developed fingerprint database 100 subjects	• Decision level fusion using KNN classifier	• Hybrid wavelets	**Wavelet type I** • PI : 79.2% • Accuracy: 76.1% **Wavelets type II** • PI: 81.5% • Accuracy: 79.8%	Wavelets can be effectively used from rich texture based iris.
Kihal et al.,(2014)51	**Data Set I** • CASIA palm print + Casia-Irisv3-Interval databases **Data Set II** • Poly UPalmprint + CASIA-Irisv3-Interval databases	• Feature level concatenation • Score fusion weighted sum • Decision level fusion using Hamacher t-norm	• Haar Wavelet-packets (iris) • Daubechies2 Wavelet-packets (PolyU palm print) • Daubechies4 Wavelet-packets(CASIA palm)	**Decision level fusion** **Data Set I** • GAR: 100% • FAR : 2.1−3% **Data Set II** • GAR : 100% • FAR 4.10−4%	Fusion of iris and palm-print at different levels gave better results except in case of the feature fusion method, but decision-level fusion with t- norm gave the best performance.
Conti et al.,(2013)52	**Set I** • FVC2002 DB2B + BATH Subjects 10 **Set II** • FVC2002 DB2A+BATH 50 subjects	• Template level	• Log-Gabor-algorithm-based codifier	**Set I** • FAR: 0% • FRR: 5.71% • EER: 2.36% **Set II** • FAR: 0% • FRR: 7.28 ÷ 9.7% • EER: 3.17÷5.76%	ROC curves show the improvements introduced by the adopted fusion strategy.

Approach	*Modalities fused/ Dataset used*	*Fusion level implemented*	*Feature extraction method*	*Classification Strategy*	*Key findings*
Dinakardas et al., (2013)53	• Real-time database (Face, fingerprint and iris) images in a resolution of 200×200 size 350 subjects	• Feature level fusion using sum rule	**Method I** PCA for fingerprint and iris + Fisherface for face **Method II** Fisherface for face + minutiae for fingerprint + LBP for iris	**For Method I** • Confidence Interval (CI): 0.933% • ROC curve: 0.960% **For Method II** • CI: 0.935% • ROC curve: 0.962%	The performance analysis of the second proposed approach outperformed the first one.
Sim et al.,(2014)54	**Data Set-I** • UTMIFM Iris and Face Multimodal dataset **Data Set-II** • UBIRIS v.2 iris database • ORL face dataset	• Score level fusion using weighted Sum approach	• NeuWave Network for iris • Eigenface from PCA for face	**Data Set-I** • FAR: 0.10% • FRR: 0.01% • Accuracy: 99.6% **Data Set-II** • FAR: 0.09% • FRR: 0.01% • Accuracy: 99.4%	Proposed framework offered better solutions to the problems of iris images captured in non-cooperative (off-angle) environment.
Saleh and Alzoubiady, (2014)55	• Database contains Iris and Signature 40 subjects	• Decision level fusion Ant Colony Optimization • And, Or , and Weighted Majority Voting rules	• Contourletis discrete transform (iris) • Linear Discriminant Analysis (signature)	**And rule** • GAR: 96% • FAR: 4% **Or rule** • GAR: 99% • FAR: 1% **Weighed majority voting** • GAR: 98% • FAR: 2%	OR rule was found to be the best for genuine accept rate and recognition rate, while the AND rule was best for false rejected rate.
Aboshosha et al.,(2015)56	• CASIA iris dataset • FVC2004 DB3_A fingerprint dataset • Face94 face dataset 100 subjects	• Score level fusion using Sum, Product, Weighted sum and Min-max normalization	• Log-Gabor filter (iris) • Minutia based algorithm (fingerprint) • Local Binary Pattern (face)	**Sum rule** • Accuracy: 98.81% **Product rule** • Accuracy : 99.31% **Weighted sum rule** • Accuracy: 9.7%	Weighted sum rule outperformed both sum and product rules and presents significantly better results.
Huo et al.,(2015)57	• ORL and CASIA V1.0 face databases • PIE-illum and CASIA V4-Lamp databases	• Feature level fusion using principal components analysis and support vector machine	• Two-dimensional-Gabor filter bank	**Direct fusion** • Minimum total error rate: 0.0167% **PCA fusion** • Minimum total error rate: 0%	Proposed method can not only effectively extract face and iris features but also provide higher recognition accuracy.

Approach	*Modalities fused/ Dataset used*	*Fusion level implemented*	*Feature extraction method*	*Classification Strategy*	*Key findings*
Rajagopal and Palaniswamy, (2015)58	• UPOL iris database • PolyUpalmprint database 123 subjects	• Feature level fusion using PCA	• Hierarchical multiresolution local binary pattern and Gabor wavelets	• Recognition accuracy: 99.96%	Multi-feature (hierarchical multiresolution LBP and Gabor) multimodal feature fusion increases the recognition accuracy.

5. CONCLUSIONS

Iris trait has attracted a lot of interest for the last few decades in the field of biometric technology because of its stable and distinctive texture patterns for personal identification. Effect of noise on the performance of iris recognition biometrics must be considered. In addition non-ideal images (off angle, occluded, blurred, reflection and noisy images) seriously limit the application of the iris recognition system in practical scenarios, where the acquired image could be of low quality due to motion, partial co-operation or the distance of the user from the scanner.So a comprehensive solution for compensating all types of noises should be employed to achieve higher accuracy rate. Iris recognition algorithms should be evaluated against larger database with diversified populations. Even though a lot of work has been pioneered in the field of iris recognition, researchers are still trying to improve and enhance the security, reliability, and accuracy by developing new algorithms/ techniques every year.

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