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A Study on Fake Iris Detection under Spoofing Attacks

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Abstract: Human iris recognition is the most promising field of biometrics for reliable user identification. Human iris contains a unique textural pattern which remains stable throughout lifetime. This makes it the most desirable biometric modality. However, iris pattern is obfuscated by various covariates like textured contact lenses and printed iris images that result in iris spoofing where an imposter impersonates the genuine enrolled user. This poses a great challenge in iris recognition when used in large-scale applications. The study presents a detailed study on the effect of iris spoofing via. textured contact lenses and print attacks on iris recognition performance. Various researchers have proposed algorithms for the detection of fake and genuine iris samples in order to reduce iris spoofing attacks. However, there is a need to provide more generalized algorithms for detection of unpredictable spoofing attacks, so that, the system is secure, computationally efficient and accurate.

Key words: Biometrics, contact lens, iris recognition, iris spoofing, print attacks, accorate

INTRODUCTION

Human iris is the most reliable biometric entity which has been used in many large-scale applications like Aadhar project (Anonymouse, 2005) for recognizing millions of citizens in India and in UAE for border control entry (Tan and Kumar, 2013). Iris texture was proposed as a biometric modality for the first time in 1987 by Flom and Safir. After that, Daugman (2004) made first commercial biometric algorithm based on iris recognition which is still widely used in many commercial systems. Although, iris texture pattern is unique and reliable it is affected by various covariates leading to iris spoofing where an imposter impersonates the genuine user's identity. Theses covariates include dilation of pupil due to illumination variations (Hollingsworth *et al*., 2009), multiple iris sensor interoperability (Arora *et al*., 2012a; Connaughton *et al*., 2012) consumption of alcohol (Arora *et al*., 2012b) and the person under medical treatment (Rakshit and Monro, 2007). Another set of covariates include contact lenses like transparent soft contact lenses and colored textured contact lenses. Recently, it was found that the number of contact lens wearers have increased worldwide between 3-5% (Nichols, 2012). These pose a challenge in iris recognition as they obfuscate the natural iris textural pattern. However, iris recognition can be successfully done even through soft transparent contact lenses and eyeglasses (Negin *et al*., 2000). But these have been found to decrease the overall iris recognition accuracy (Thompson *et al*., 2013; Baker *et al*., 2010). Though soft non-textured lenses do not tamper the iris pattern but these have some visible markings on them in addition to the boundary between the support and the corrective region of the lens that changes the iris pattern. Another way to spoof iris texture is by presenting a printed iris image to the system to impersonate a genuine user's identity. This is called iris spoofing through print attack. In this, either the iris pattern is first printed by a high-quality printer and then scanned which is called print+scan or the photo is captured by a scanner which is called print+capture (Ratha *et al*., 2001). Effect of iris spoofing is from I IITD databases (Kohli *et al*., 2013; Yadav *et al*., 2014; Gupta *et al*., 2014; Kohli *et al*., 2016).

Literature review: Despite the advantages of iris as a biometric modality, iris spoofing poses a threat where an imposter impersonates an enrolled user's identity to gain the user's privileges. This poses a great challenge to iris recognitionwhen used in large-scale applications. The detection of fake irisdue to printed iris image or textured contact lens can be broadly categorized as) recognizing iris textural pattern) exploiting biological characteristics for iris liveness detection and) analyzing physical properties of the iris.

MATERIALS AND METHODS

Iris textural pattern recognition techniques

Iris spoofing via. contact lenses: Daugman (2003) presented Fourier spectrum of fake printed iris pattern which consisted of periodic iris pattern which occurs in

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dot matrix printing as opposed to the natural human iris. However, these days dot matrix printing style is rarely used which makes Fourier transform less reliable for fake iris detection. Wei *et al.* (2008) proposed three methods based on iris edge sharpness, texture feature extraction and co-occurrence matrix at grey level in which texture features and co-occurrence matrix outperform other proposed methods.

Fake iris database was created using different types of contact lenses with live images taken randomly from IACAS (2006) and CASIA (2005) databases. It was concluded that the co-occurrence matrix outperforms other proposed methods by giving correct recognition rate of 100% as compared to iris edge and iris-texton which gave 97.8 and 98.3% accuracies, respectively. He *et al.* (2009) proposed fake iris detection algorithm using LBP (Local Binary Pattern) which extracted textural features from sub-regions along with Adaboost algorithm for LBP feature selection. About 600 fake iris images were acquired using 20 different types of contact lenses. A total of 10,000 iris images were used which contained randomly selected samples from CASIA-Iris-V3 UID Ltd. (2012) and ICE v1.0 UNDCVRI. (2012). The proposed method gave better results as compared to other proposed methods. Zhang *et al.* (2010) proposed weighted LBP method for contact lens detection. SIFT (Scale Invariant Feature Transform) was used to rank LBP encoding sequence which was used for feature extraction along with SVM (Support Vector Machine) classifier for classifying genuine and fake iris images. The method was applied on a database of 1400 iris images with 55 different cosmetic contact lenses applied on 72 different subjects with 4 different iris cameras. Some of the samples were taken from CASIA-Iris-V3. It was concluded that the proposed method obtained a correct classification rate of 99.14% when using mixed database as compared to 88.05% when using 4 different iris cameras for training and testing samples. Doyle *et al.* (2013) proposed modified LBP method for iris-spoofing detection of contact lenses where images were taken in blocks with kernel size varying from 1-15 with increments of 1 to construct feature-vector. Notre dame cosmetic contact lens 2012 database was used with 3000 training images and 1200 testing images captured from LG-4000 iris camera. The database consisted of 3 categories of contact lenses: none, soft transparent and textured contact lens from three manufacturers: Johnson and Johnson, ciba vision and cooper vision. The correct classification rate of 98% was achieved for correctly detecting textured lenses. Kohli *et al.* (2013) proposed LBP method with SVM classification for colored lens detection. IIITD Contact Lens database was used.

The database consisted of a total of 6570 images taken from 101 subjects with 3 categories of contact lenses: none, soft transparent and colored contact lens (blue, grey, green and hazel) acquired from cogent dual iris sensor and VistaFA2E iris sensor. At 0.01% FAR (False Acceptance Rate) with VeriEye simulator 72.95% accuracy was obtained for lens detection. By using LBP with SVM classification, lens detection improved to 94.41%. Yadav *et al.* (2013) examined the effect of classification accuracy using contact lenses for iris recognition by using two types of databases: IIIT-D and ND-Contact Lens databases. An approach for contact lens detection with modified LBP was proposed to detect contact lenses, thus, improving iris recognition accuracy. It was concluded that soft lenses have a smaller false non-match ratio as compared to textured lenses. Also, removal of textured lenses resulted in increase in recognition accuracy. Doyle *et al.* (2015) proposed a novel contact lens detection algorithm using Binarized Statistical Image Feature (BSIF) (Kannala and Rahtu, 2012) for Notre Dame Contact Lens Database (NDCLD'15) with no lens, soft and textured lenses from five manufacturers. It was concluded that BSIF gave 100% correct classification rate as compared to LBP which gave 97% accuracy. The comparative analysis of techniques used for fake iris detection using contact lenses is summarized in Table 1.

Table 1: Comparison of proposed techniques for iris spoofing via. textured contact lenses

Researchers and years	Database	Feature extraction	Results
Wei *et al.* (2008)	Database 1: 160 fake iris (4 types of contact lenses) 160 live iris (samples from CASIA and BATH)	Measurement of iris edge sharpness (IES) Iris-Texton Feature extraction) method (ITF)	**Database 1:** IES: CCR: 97.8%, FAR: 1.87%, FRR: 2.5%, ITF: CCR: 98.3% FAR:1.25% FRR:1.87%, CM: CCR:100% FAR:0% FRR: 0%
	Database 2: 480 fake iris (16 types of contact lenses) 480 live iris (samples from CASIA and BATH)	Co-occurrence Matrix (CM)	**Database 2:** IES: CCR: 97.8% FAR: 1.87% FRR: 2.5%, ITF: CCR: 95.8%, FAR: 4.17% FRR:5.83%, CM: CCR:94.1%, FAR:8.13%, FRR:3.75%
He *et al.* (2009)	About 600 fake iris with 20 different contact lenses 10,000 total live iris with samples from CASIA-Iris-V3 and ICE v1.0	LBP with adaboost learning	FAR (%): 0.67 FRR (%): 2.64

Table 1: Continue

Researchers and years	Database	Feature extraction	Results
Zhang *et al.* (2010)	About 1400 iris images with 55 different cosmetic contact lenses applied on 72 different subjects with 4 different iris cameras: Iris Guard IG-H100, OKI IRIS PASSh, Iris King IKEMB-100 and CASIA-Cam V3	Weighted LBP with SVM classification	**Mixed database:** CCR:99.14% FAR: 0.44% FRR:1.13% **Cross-sensor:** CCR: 88.05% FAR: 10.56% FRR: 15.63%
Chen *et al.* (2012)	About 1000 live images with 600 printed fake iris images using HP Laser jet 5000 printer, 200 contact lens images and 200 artificial eye images	Wavelet packet transform	EER: 0.12%
Doyle *et al.* (2013)	Notre dame cosmetic contact lens 2012 database with 3000 training images and 1200 testing images captured from LG-4000 iris camera with categories: none, soft transparent and textured contact lens from three manufacturers: Johnson and Johnson, ciba vision and cooper vision	Weighted LBP	CCR: 98% for detecting textured contact lenses
Kohli *et al.* (2013)	IIITD Contact Lens database is used which contains a total of 6570 images taken from 101 subjects with 3 categories: no lens, transparent soft lens and colored lens (blue, grey, green and hazel) acquired from cogent dual iris sensor and vistaFA2E iris sensor	LBP with SVM classification	At 0.01%FAR, VeriEye simulator: 72.95% accuracy LBP with SVM classification, lens detection accuracy improves to 94.41%
Yadav *et al.* (2014)	IIIT-D contact lens Iris database, Notre dame contact lens detection	Modified LBP	**IIITD**-No Lens: 62.14% soft lens: 61.63% Textured Lens: 94.74% **ND contact lens**: No lens: 72.6% Soft lens: 50% Textured lens: 97%
Hu *et al.* (2015)	Clarkson (516 live iris and 840 fake textured contact lens in night and normal lights with moving subjects	LBP histogram, LBP correlogram, intensity histogram, intensity correlogram Local Phase Quantization (LPQ) histogram and varying focus) and Notre Dame	Error rates: Clarkson: 2.43% Notre Dame: 0.41%
Gragnaniello *et al.* (2015a, b)	IIITD and notre dame	LBP, SIFT, SID (Rotation and Scale Invariant Descriptor), BSIF, Local Contrast-Phase Descriptor (LCPD), Multi-resolution LBP	Error rates with SID ND I: 0.1% ND II: 0.0%: Cogent: 6.2% Vista: 3.5%
Doyle *et al.* (2015)	Notre Dame Contact Lens	BSIF Database (NDCLD'15)	Classification rate: BSIF: 100% LBP:97%

CCR: Correct Classification Rate, FFR: False Rejection Rate, FAR: False Acceptance Rate, EER: Equal Error Rate

RESULTS AND DISCUSSION

Iris spoofing via. print attacks: Albacete *et al.* (2008) analyzed the performance of 1D Log-Gabor wavelets for fake printed iris shown in Fig. 1 images suffering from direct attacks, where synthetic biometric samples were provided to the system for spoofing purpose. Hamming distance was used for matching iris templates. About 1600 live iris images were acquired including 800 fake printed iris images from LG Iris Access EOU3000. It was concluded that at 0.1% FAR, the success rate of direct attack was 33.57%. He *et al.* (2009) proposed a novel algorithm based on wavelet packet decomposition for feature extraction of fake printed and real iris images. SVM was used for classification of fake and real iris samples. About 1000 live iris images were collected with 220 blurred and 140 clear printed samples. The live images were used from SJTU iris database Version 2.0.

The images of SJTU (Iris database of Shanghai Jiao Tong University, Version 2.0) were printed using HP LaserJet 1020 printer. The proposed method achieved 98.18% of correct classification rate with blurred printed images while for clear printed images 98.57% was achieved as compared to other proposed methods. Galbally *et al.* (2012) proposed iris liveness detection technique due to fake printed iris images using motion, focus and occlusion features along with sequential floating feature selection algorithm. The database consisted of 1600 live iris image samples from 50 subjects of BioSec baseline database (Fierrz *et al.*, 2007) with 800 fake images acquired from LG Iris Access EOU3000 sensor. It was concluded that the average classification error varied from 24-0% by varying feature sub-sets. Galbally *et al.* (2014) proposed 25 image quality features to distinguish between fake and real iris images using BioSec baseline database with 800 fake iris samples and

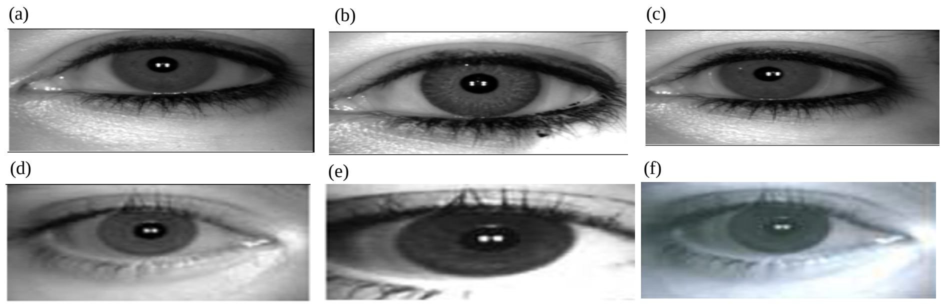

Fig. 1: Iris spoofing via. contact lenses and print attacks: a) Without lens; b) With textured lens; c) With soft transparent lens; d) Original image; e) Print+scane and Print+capture (Kohli *et al*., 2013; Yadav *et al*., 2014; Gupta *et al*., 2014; Kohli *et al*., 2016)

800 live samples. The proposed technique obtained 4.2% of FFR (False Fake Rate), 0.25% of FGR (False Genuine Rate) and 2.2% of HTER (Half Total Error Rate). Gupta ***et al.*** (2014)studied iris spoofing using print attacks by using IIITD iris spoofing database using LBP, HOG (Histogram of Oriented Gradients) and GIST with SVM classification. It was concluded that LBP detected print attacks as compared to HOG and GIST. Gragnaniello ***et al.*** (2015) proposed LBP descriptor with SVM classification for liveness detection in case of iris print attacks. MobBIO Multimodal (Sequeira *et al*., 2014) and MICHE databases (Marsico *et al*., 2014) were used which consisted of fake printed images captured from mobile devices. The proposed method gave promising results with FFR of 0.25% on MobBIO and 0% on MICHE databases. Hu ***et al.*** (2016) implemented regional features by using spatial pyramid and relational measure which extracted features based on neighborhood pixels for iris liveness detection. The feature descriptors used were LBP histogram, LBP correlogram, intensity histogram, intensity correlogram, Local Phase Quantization (LPQ) histogram. These were applied on spoofing databases: Clarkson, Warsaw, Notre Dame and MobBIOfake (Sequeira *et al*., 2014). Results showed a minimum error rate of 0.41% for MobBIOfake database. Gragnaniello ***et al.*** (2015) analyzed local feature descriptors for spoofing types: printed fake iris and contact lenses. The databases used are notre dame, IIITD spoofing, Warsaw and ATVS. SID (Rotation and Scale Invariant Descriptor) descriptor obtained minimum error rate for all the databases. The comparative analysis of various techniques used by researchers for iris spoofing via. print attacks has been summarized in Table 2.

Biological techniques: Rigas and Komogortsev (2015) analyzed eye movement signals for both live and printed fake iris images. The eye movements were tracked using EyeLink at 1000 Hz and implemented with a CMITechBMT-20 system on a database of 400 printed images from 200 subjects. The printouts were taken using HP Laserjet 4350dtn. The average classification accuracy obtained was 96.5% with EER (Equal Error Rate) of 3.4%. Park (2006) found that the contractions of hippus (dilation and contraction of pupillary movements between the sphincter and dilator muscles) of the human eye result in modification of pupil to iris ratio with which detection of fake contact lens iris images is possible with the real live images. Puhan ***et al.*** (2011) extended the research of Park (2006) by implementing a technique in which the textured lenses would not occlude the iris and take into account hippus movements, thus detecting textured lenses which were not possible by Park (2006). Bodade and Talbar (2009) proposed varying illumination in which the real iris has a reduced pupil to iris ratio as opposed to fake iris which has a fixed ratio. Huang ***et al.*** (2013) created NIR (Near-Infrared) acquisition system for iris images with varying visible light for measuring pupil to iris ratio along with SVM classification. Chen ***et al.*** (2012) proposed iris liveness detection by capturing iris images at near-infrared (860 nm) and blue (480 nm) wavelengths. The feature vector consisted of measurement of a Relative Number of Conjunctival Vessels (RNCV) and Entropy Ratio of Iris Textures (ERIT) at both wavelengths along with SVM classification. The proposed method obtained minimum EER of 0.12% as compared to other proposed methods. Czajka (2015) studied pupil dynamics by exposing iris to varying illumination. It was concluded that iris responded quickly to dark-to-light as compared to light-to-dark illumination variation.

Physical techniques: Lee *et al*. (2006) performed fake iris detection by using Purkinje images where position and distance parameters were based on the human eye. The database was collected from 30 subjects with contact lenses, without contact lenses and with glasses giving a total of 300 images. The method gave 0.33% of both FAR

Table 2: Comparison of proposed techniques for iris spoofing via print attacks.

Authors and years	Database	Feature extraction	Results
Ruiz-Albacete *et al.* (2008)	About 800 fake and 800 live iris images from 50 subjects from LG Iris Access EOU3000 sensor	1D Log-Gabor wavelets with hamming distance matching	FAR (%): SR (%) 0.1: 33.57 1: 48.02 2: 53.03 5: 61.19
He *et al.* (2009)	1000 live iris images (220 blurred and 140 clear printed images). Samples of live images from SJTU iris database version 2.0 which were printed using HP LaserJet 1020 printer	Wavelet Packet Transform with SVM classification	CCR:Printed blurred images: 98.18% printed clear images: 98.57%
Galbally *et al.* (2012)	BioSec baseline database (800 fake and 800 live iris images from 50 subjects from LG Iris Access EOU3000 sensor)	Motion, focus, occlusion and contrast features along with Sequential Floating feature selection algorithm	Average classification error for varying feature sub-sets: 24-0%
Galbally *et al.* (2014)	BioSec baseline database	Error sensitivity measures, structural similarity measures, information theoretic measures, distortion specific measures, training based measures and natural scene statistics measures	4.2% of FFR, 0.25% of FGR and 2.2% of HTER
Gupta *et al.* (2014)	IIITD iris spoofing database (6570 images of 101 subjects acquired from Cogent CIS 202 dual iris sensor and VistaFA2E single iris sensor with 3 categories: no lens, soft and colored textured lens HP Color LaserJet 2025 printer is used for taking printouts	LBP, HOG and GIST	Print+ScanAccuracy:LBP: 100% HOG: 97.22% GIST:65.19% LBP+HOG:92.32%Print+Capture Accuracy:LBP: 95.26% HOG:81.04% GIST:58.66% LBP+HOG: 72.38%
Rigas *et al.* (2015)	400 fake printed images using HP Laserjet 4350dtn printer from 200 subjects	Local unit centroid, local unit power, local unit variance and local unit SNR	Classification accuracy: 96.5% EER: 3.4%
Gragnaniello *et al.* (2015)	MobBIO Multimodal database (800 fake printed images and 800 live images captured from Asus Transformer Pad TF 300T), MICHE database (338 live images collected from Samsung Galaxy S4 out of which 40 fake printed iris images)	LBP	MobBIO: HTER: 4.75FFR: 0.25FGR: 9.25MICHE:HTER, FFR,FGR: 0
Hu *et al.* (2015)	Warsaw (852 live iris images and 815 fake printouts collected in NIR illumination) and MobBIOfake database	LBP histogram, LBP correlogram, intensity histogram, intensity correlogram, Local Phase Quantization (LPQ) histogram	Error Rates:Warsaw: 1.05% MobBIOfake: 2.40%
Gragnaniello *et al.* (2015)	Warsaw and ATVS	LBP, SIFT, SID, BSIF (Binarized Statistical Image Features), Local Contrast-Phase Descriptor (LCPD), Multi-resolution LBP	Error Rates:SID: 0% for both Warsaw and ATVS

FFR: False Fake Rate, FGR: False Genuine Rate, HTER: Half Total Error Rate, SR: Success Rate

and FRR parameters. However, limited database was used. Hughes and Bowyer (2013) used a setup of iris sensor in which a human iris was visualized as a flat surface as opposed to a textured lens which was seen as a curved surface as it was placed on the surface of the convex cornea.

CONCLUSION

Human iris is regarded as the most stable biometric modality owing to its unique textural pattern and stability throughout the lifetime. It has been used in many large-scale applications for identifying millions of citizens. The increasing demand of biometric technology based on human iris has led to research work in the field of iris spoofing which poses a challenge in iris recognition domain. Iris spoofing via. contact lens and print attacks obfuscates the natural iris pattern. Researchers have made efforts to detect fake and genuine iris samples. However, the proposed liveness detection algorithms research on familiar spoof materials. Therefore, generalized liveness algorithms need to be implemented for unseen and unpredictable spoofing attacks. The steps included in iris recognition like data acquisition, feature extraction, feature selection and performance analysis must be revisited in the case of spoofing attacks which is referred to security by design. The vulnerability of features against spoofing attacks must be taken into account, so that, additional features can be added to make the system more secure and computationally efficient for unseen and unpredictable spoof attacks.

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