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ANTI-SPOOFING FOR IRIS RECOGNITION WITH CONTACT LENS DETECTION

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Abstract

Iris is arguably the best biometric modality available for human recognition. The human identification system using iris has been used in large scale and high profile applications including border security control. Recently, iris recognition has faced some challenges that compromise with the robustness of the system. The presentation attack using cosmetic contact lenses is one such challenge. The concept of using a contact lens to the outer layer of the cornea as a refractive device was first suggested in the earlier years of the 19th century. By now, contact lenses are being used increasingly worldwide. Contact lenses are improving as an eye-aid technology at a fascinating speed. Textured contact lenses have emerged as an option for attackers to spoof the iris recognition system. Since iris recognition as a method to achieve authentication needs to be secure and robust; "anti-spoofing" is a must-have module in an automated iris recognition system. This work explores some state-of-the-art methods available in the literature for anti-spoofing for iris recognition to deal with contact lenses as a covariate.

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1. Motivation and Main Results

In the current scenario, the biggest threat to humanity is terrorist organizations posing a huge challenge for security worldwide. Hence, automated person identification and verification are the fundamental requirements for secure and restricted access around the world. The realization of this requirement can be achieved using biometrics at a large scale where iris recognition can be proved handy. In recent times, the presentation attack in the form of printed HD iris images, cosmetic contact lenses have appeared as a big challenge in front of researchers [25]. The effect of contact lenses, their usage and anti-spoofing techniques to avoid the artifacts and to detect the forged attempt at the initial level is the subject matter of the current study. The history of contact lenses, the speed of development in the contacts and the improvements they hold for the future are interesting. Vision correction is a long-lasting requirement universally. Contact lenses are used as an aid to correct refractive errors and maintain ocular health. Nowadays, Contacts are being used by more and more people around the world either to bring back their vision into focus or as a beauty aid. Contact lenses are small prescription lenses to be worn as an eye-aid in contact with the eye floating in the tear film layer on the visible surface of the cornea. In the context of biometric recognition, the iris is a textured part of the eye and this textural information is used as a primary way to achieve human identification; contact lenses especially the textured ones can be applied to human eyes as an iris replacement in order to perform presentation attack. The process of wearing textured contact lenses over natural iris is known as iris texture obfuscation. These contact lenses are available in different specifications, types, and materials to be used for different purposes ranging from nearsightedness to astigmatism. As transparent contact lenses can degrade accuracy, automatic detection of contact lenses becomes essential in order to improve the robustness of iris-based biometric systems. Different types of contact lenses are soft contact lenses, hard contact lenses, daily contact lenses, colored contact lenses, bifocal contact lenses, and silicone hydrogel, etc. They further can be broadly classified as cosmetic and non-cosmetic contact lenses.

The cosmetic contact lenses (CCL) are used for beautification of eyes; whereas non-cosmetic contact lenses (NCCL) are used to correct the vision problems just like eyeglasses and spectacles do. Transparent (non-cosmetic) contact lenses can be considered to consist of two key categories based on the used material: rigid gas permeable (RGP) contact lenses and soft contact lenses.

Another classification of contact lenses exists and includes Daily Disposable, Two-weekly Disposable, Monthly Disposable, Silicone Hydrogel, Colored and Tinted, Continuous Wear, Toric or Astigmatic, Bifocal, Varifocal, and Multifocal contact lenses. Figure 1 shows examples of colored cosmetic contact lenses.

(i) Green (ii) Blue (iii) Brown

Figure 1. Examples of Colored (Cosmetic) Contact Lenses.

The use of textured contact lenses is increasing at a rapid rate worldwide. Textured contact lens is a type of cosmetic contact lens that presents an option for someone to masquerade as someone else. Due to the visibility of the pigment used in cosmetic contact lenses in NIR wavelength, contact lenses are hard to be detected by currently available iris sensors. Thus, impersonation using a textured/cosmetic contact lens presents a fresh challenge among researchers. Figure 2 shows the image of a person with and without contact lens; taken from the ND-Iris-Contact-Lens-2010 dataset. Table 1 describes the iris presentation attack datasets having textured contact lenses.

Figure 2. Images of the same eye (a) without and (b) with contact lens.

Table 1. Iris datasets with textured contact lenses.

Dataset	No. of images	Sensor used
IIIT-Delhi Contact Lens Iris [18]	6570	HP Color LaserJet 2025 (for print photos) and CIS 202 (for others)
LivDet-Iris-2013-Warsaw [14]	1667	IrisGuard AD100, HP LaserJet 1320, Lexmark c534dn
LivDet-Iris-2015-Clarkson [29]	3726	LG IrisAccess, EOU2200
ND-Iris-Contact-Lens-2010 [30]	21700	LG 2200
ND-Iris-Contact-Lens-2013 [31]	5100	LG 4000, IrisGuard AD100
ND-Contact-Lens-2015 [5]	7300	LG 4000, IrisGuard AD100
ND-LivDet-Iris-2017 [21]	4800	LG 4000, IrisGuard AD100
MUIPAD [28]	10296	IriShield MK2120U
WVU UnMIPA [10]	18706	CMITECH EMX-30, IriShield BK 2121U, and IriShield MK 2120U

Anti-Spoofing is defined as a countermeasure against spoofing attacks launched against the iris recognition system that can be done using one of the options like high definition print photos, synthetic iris, presentation attack or contact lenses. Several anti-spoofing approaches have been used by the iris recognition research groups in the recent past. The most popular one is to design a set of filters or a fused filter and to use a classifier to differentiate between a real iris and a textured contact lens. Robust detection of textured contact lenses has been studied by [5, 7, 10, 24, 25]. S. Kumar et al. [32] have studied key existing and emerging covariates of iris recognition where they mentioned contact lens as the one. The key differences between real iris and a textured contact lens are given below:

The structure of the rest of the paper follows the lines as given here: Section 2 explores the literature. Section 3 focuses on anti-spoofing approaches and the conclusion is given in Section 4.

2. Related Works

The latest research in this direction [26] reveals that the research community has accepted this challenge and started to act upon making iris recognition more robust and secure. Differentiating between the actual iris and textured contact lens can be thought of as a 2-way classification problem. Various studies in the literature [15, 17, 20, 23] have reported over 90% accuracy assuming accurate segmentation.

Wei et al. [2] suggested three techniques for counterfeit iris/contact lens detection. They proposed iris edge sharpness detection as boundaries of cosmetic contact lenses generally have a sharper edge. GLCM and texture classification were the other methods used by them. They concluded that the error rates are data-dependent and vary with the matchers involved. He et al. [4] experimented with statistical texture analysis for detecting a presentation attack. The authors used four GLCM based features namely, mean, standard deviation, contrast and angular momentum to constitute a feature vector and support vector machine for classification. The main finding of this study concluded that the GLCM feature vector needs large storage and therefore is inefficient. J. S. Doyle and K. W. Bowyer [5] used lens-type-disjoint soft computing technique using Binarized Statistical Image Features have shown that no accurate segmentation is required to differentiate between the actual iris and textured contact lenses. They developed a system to detect textured contact lenses using BSIF.

P. Silva et al. [6] used a convolutional neural network to develop a deep image representation for classification. They conducted experiments on two publicly available iris databases for contact lens detection: 2013-ND-CLD and IIIT-D-CLD [18]. They performed better than other state of the art approach they compared their results with. J. Komulainen et al. [7] presented a generalized case study on software-based contact lens detection. This study focused on device-independent validation along with the evaluation of contact lens detection algorithms and concluded that BSIF texture features outperform LBP texture features on the 2013-ND-CLD dataset. A. Czajka and K. W. Bowyer [9] have assessed state-of-the-art methods for presentation attack detection and performed a comprehensive survey. D. Yadav et al. [10] detected textured contact lenses using "DensePAD" – a deep learning-based convolution neural network system to handle presentation attacks in WVU unconstrained multi-sensor iris presentation attack database. The experiments evaluated error rates on different datasets available along with the proposed dataset. The authors also reported error rates for textured contact lenses of different manufacturers. S. Hsieh et al. [11] used spectral Independent Component Analysis for presenting a novel anti-spoofing approach to detect cosmetic contact lenses. S.E. Baker et al. [12] clearly showed that the presence of contact lenses degraded the performance in automated iris recognition. J. Galbally and Marta Gomez-Barrero [22] presented a survey on iris anti-spoofing techniques available in current literature.

The application of cosmetic contact lenses is used to spoof an iris recognition system, either to escape from being caught while being on a watch list or to masquerade as a certain identity. Current approaches for detecting the application of cosmetic contact lenses on the eye's outer layer are limited to lens detection and that too detecting lens manufactured by some particular manufacturing technology. These existing approaches also require prior knowledge of the particular texture printed on the lens or need a complete sequence of images to reach a decision. If the contacts are worn by the subject, the iris region appears as a convex surface while in the absence of the contacts, it appears as a coarse planer surface. Thus the problem of deciding the use of cosmetic contacts by a person becomes the problem of classifying the surface shape of the visible iris region. This is the first approach to analyze iris images in the context of 3D shape.

Automatic detection of novel types of cosmetic contacts in iris recognition is a complex pattern recognition problem, but the availability of related datasets has enabled researchers to work upon this problem recently only.

3. Anti-Spoofing Approaches

Spoofing in the context of iris recognition is some artifacts presented as genuine iris to the sensor and getting it falsely accepted. Anti-spoofing is to distinguish between real iris and the artifact presented as genuine iris. Being a very broad term, anti-spoofing is described by researchers as either liveliness detection or presentation attack detection. Generally, anti-spoofing approaches can be divided into two categories depending on the biometric system where they are to be used, namely, sensor-level techniques and feature level techniques.

Sensor level techniques-The earliest of the hints concerning iris spoofing and sensor level anti-spoofing measures for iris have been given by Daugman [1]. These are hardware-based approaches; focused on the estimation of the following features:

(a) Intrinsic properties of an original modality such as depth variation light field camera [13], conjunctival vessel detection, etc.

(b) Involuntary signs of an original modality such as Purkinje reflections, pupil dynamics, etc.

(c) Reactions to external signals or challenge-response schemes such as pupil contraction, eye-blink, etc.

Feature-level techniques-These are software-based techniques where the artifact is identified at features level i.e. the detection of the spoofed iris is done by extracting the textural features of the trait using soft computing and neural network techniques. The popular algorithms used for anti-spoofing at features level are LBP [3], GLCM [4], BSIF [5], ICA [11], FFT [16], LPQ [20], SVM [26] and Stereo Imaging [27].

Figure 2 shows a two-group classification of anti-spoofing methods.

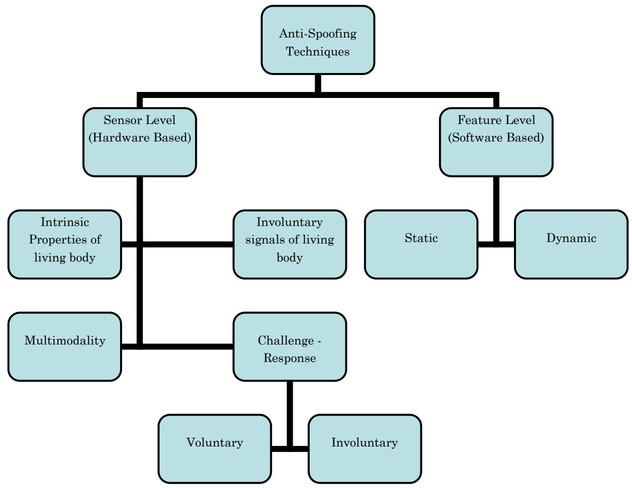

Figure 2. Classification of anti-spoofing techniques.

4. Conclusion

Although we have come a long way in iris recognition since its first appearance as a commercial tool to authenticate the identity of a person yet there are many new challenges for iris recognition. Spoofing with the help of contact lenses is such an issue. Therefore, textured contact lens detection as an anti-spoofing module is significant in making iris recognition a full proof solution for security and further it requires to be embedded with sensor interoperability for better automation of existing algorithms being used for the purpose as a fully automated commercial iris recognition system needs to handle iris input images enrolled through different sensors. Generally, the textured contact lens detection is preferably easy but differentiation between the real iris and non-cosmetic soft contact lens is a challenge.

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