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A framework for liveness detection for direct attacks in the visible spectrum for multimodal ocular biometrics☆

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ABSTRACT

In this research a new framework for software-based liveness detection for direct attacks in multimodal ocular biometrics across the visible spectrum is proposed. The framework aims to develop a more realistic method for liveness detection compared to previous frameworks proposed in the literature. To fulfil the above highlighted aims in this framework, intra-class level (i.e. user level) liveness detection is introduced. To detect liveness, a new set of image quality-based features is proposed for multimodal ocular biometrics in the visible spectrum. A variety of transformed domain (focus related) aspect and contrast-related quality features are employed to design the framework. Furthermore a new database is developed for liveness detection of multimodal ocular biometrics, which has the prominent presence of multimodal ocular traits (both sclera and iris). Moreover this database is comprised of a larger variety of fake images; those were prepared by employing versatile forging techniques which can be exhibited by imposters. Therefore the proposed schema has dealt with versatile categories of spoofing methods, which were not considered previously in the literature. The database contains a set of 500 fake and 500 genuine eye images acquired from 50 different eyes. An appreciable liveness detection result is achieved in the experiments. Furthermore, the experimental results conclude that this new framework is more efficient and competitive when compared to previous liveness detection schemes.

1. Introduction

The eye offers a wide variety of biometric traits.[1] Among the eye traits, iris biometric is the most reliable and promising one [6]. Regardless of their usefulness, iris traits exhibit some limitations with regards to their universal applicability [8,9]. This is the case in uncontrolled environments and specifically with the change of gaze angle of the eye and in non-ideal eye images.

In order to mitigate this challenge, multi-modal biometrics are proposed in the visible spectrum, combining iris traits with ocular vessel patterns or sclera blood vessel patterns [10,11]. Traditional multimodal ocular biometric authentication systems are not equipped to discriminate between impostors (those who can illegally duplicate genuine traits and take the privileges to access a system as a genuine user). Therefore, in order to enhance the security and reliability of these biometric systems, liveness detection is a necessary step to prevent threats from intruders.

Liveness detection refers to the different techniques used as a countermeasure to overcome the threat of physical spoofing of biometric samples. The liveness detection methods may scrutinise physical properties of a living body in terms of density, elasticity, electrical capacitance, etc. or spectral reflection and absorbance, visual (colour, etc.) or may analyse body fluids (DNA, etc.), involuntary signals of a living body such as the pulse, blood pressure, etc. Bodily responses to external stimuli, for instance smiling or the blinking of an eye can also employed to establish liveness.

Most of the eye liveness detection work and the associated databases that were developed were aimed at incorporating iris liveness. In those datasets, iris images in the infra-red spectrum were acquired. However, for multimodal eye biometrics, the acquisition of iris and sclera traits is required in the visible spectrum (because the sclera vessel patterns are not prominent in Infra-red images). Furthermore, in these well-known existing databases, (Biosec [13], Clarkson [22], NotreDame [5], Warsaw [3] and MobBIO [24]), the sclera vessel patterns are not visible due to the image acquisition approach adopted while developing them. Moreover the fake images included in these databases were developed from printed eye images and

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[1] http://clinfowiki.org/wiki/index.php/Ocular_biometrics.

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artificial lens patterns. Whereas, nowadays several other sophisticated techniques such as portable screens and mobiles can be used by intruders to forge the highlighted multimodal ocular system in the visible spectrum.

Therefore, the way forward is the development of a new database acquired in the visible lighting range, which consists of original and fake images (populated from printed images and portable screen images). Additionally, in this research, we aim to propose a quality image measure framework for software-based liveness detection for ocular biometrics in the visible spectrum.

Furthermore, a class level/user level-based liveness framework is proposed in this work. In a real life scenario, liveness detection is required only for those query images which are recognized correctly. Therefore, the liveness detection problem can be clearly reduced to a two-class classifier problem at the intra-class level/user level rather than the inter-class level/database level. A class level liveness detector not only reduces the complexity of the schema, but also makes the quality features more useful to classify the genuine and fake data. The reason behind the improvement is the fact that each class has an individual feature represented by a threshold of the quality feature score (different thresholds per user were obtained).

The organization of the rest of the paper is as follows. In Section 2, the existing literature on liveness detection is reviewed, Section 3 describes the proposed framework and the various new quality-based features employed. Section 4 contains the details of the supporting experimental results and describes the proposed database utilized for experimentation. Finally, Section 5 draws the overall conclusions and the future scope of the work.

2. Literature review

Many approaches for identifying forgeries and establishing liveness have been investigated in the literature. In [21], the authors identified two types of attacks that can be adopted by intruders while penetrating a biometric system: Direct and Indirect.

Direct attack: Direct attacks are committed at the sensor level. It relates to the generation of synthetic biometric samples (for instance, iris, face images or videos) in order to fraudulently access a system.

Indirect attacks: Indirect attacks are performed at the digital level intercepting the data flow [21], which attacks the feature extractor, the matcher or the weak points in the communication channels.

The proposed solutions and specific countermeasures proposed in the literature can be categorized into two groups of techniques [14] as follows.

Software-based techniques: In this schema, fake biometric traits are detected once the sample has been acquired with a standard sensor. Subsequently, image quality features, body movement features, motion features, and physical properties are employed to realize liveness.

Hardware-based techniques: In this schema, specific devices are added to the sensor in order to detect particular properties. As an example this may include the detection of live fingers in a fingerprint recognition system via blood pressure.

Furthermore, it can be noted in the literature that the methods of liveness detection can be classified into four categories. This categorization is based on the approach adapted to feature the biometric trait and liveness as well as the timing of measurement [25].

As mentioned previously, among the ocular biometrics, the iris is the most promising trait. So, various examples of research for liveness detection of iris biometrics can be found in the literature. The potential approaches for forging iris-based systems that are highlighted in the literature are:

Eye image/video: Scanning an image/video from a probable screen.

Printed images: Scanning a high resolution printed image of an artificial eye.

Lens: Glass/plastic artificial lenses etc.

The feasibility of these attacks has been investigated and some researchers have reported that it is actually possible to spoof iris recognition systems with printed iris images and well-made colour iris lenses [4,6,19].

In the context of iris liveness detection the potential of quality assessment to identify genuine and fake iris samples acquired from a high quality printed images has been explored as a way to detect spoofing attacks in [14]. In their work, a strategy based on the combination of several quality-related features has also been used for spoofing detection in the context of iris liveness. This work also proposed a framework of feature selection. Another approach for quality-based features assessment has been used for liveness detection in the context of iris images [17]. One more example for assessing the iris image quality based liveness measures, such as occlusion, contrast, focus and angular deformation can be found in [2].

The use of texture analysis of the iris liveness is recorded in [16]. The analysis of frequency distribution rates of some specific regions of the iris can be found in [20]. Some significant developments in iris liveness detection can be found in the competition (Livedet),[2] organized to record the recent developments in this research domain. Some well-established texture assessment-based measures were used by the participants to establish liveness detection. In the context of previous research pertaining to liveness, manual segmentation was adopted to find the region of interest, which is quite unrealistic. A recent work, [23] investigated and concluded that automatic segmentation does not influence the liveness detection measure. Moreover databases for iris liveness research are also proposed in the literature, such as Biosec [13], Clarkson [22], NotreDame [5], Warsaw [3] and MobBIO [24]. In another research [12], multi-angle based liveness is proposed for sclera biometrics. In this work, combinations of multi-angle sequences were employed for liveness detection. Frequently in the literature, most of the seminal and recent works concerning liveness detection [1] in fingerprint-based recognition systems [15] have employed image quality features for liveness detection. Another approach for software-based liveness detection of direct attacks, by challenge-response framework embedded into the visual or audio-visual signal is reported in [18]. Several properties of a living body such as bodily responses to external stimuli are reported in [18] for real-time face detection and motion analysis.

Similar idea can also be implemented for the ocular liveness scenario by asking blinking left eye, opening mouth, rotating head, etc. in an unknown sequence. However, it may increase the complexity of the model and may reduce the user friendliness of the proposed system (as it requires user participation to give the response with respect to the challenges prompted by the system). In this work making a trade-off, we have developed a model that is simple. Therefore, by analysing the above fact in our framework, we have endeavoured to propose our subject-specific image quality-based feature and its combination for liveness detection.

The specific contributions of the proposed liveness detection schema are as follows:

(1) A new realistic framework for liveness detection, as shown in Fig. 1(b), is proposed at the intra class level/user level, which

[2] LivDet-series, available online at http://livdet.org/.