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Smartphone based visible iris recognition using deep sparse filtering [☆]

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Good biometric performance of iris recognition motivates it to be used for many large scale security and access control applications. Recent works have identified visible spectrum iris recognition as a viable option with considerable performance. Key advantages of visible spectrum iris recognition include the possibility of iris imaging in on-the-move and at-a-distance scenarios as compared to fixed range imaging in near-infra-red light. The unconstrained iris imaging captures the images with largely varying radius of iris and pupil. In this work, we propose a new segmentation scheme and adapt it to smartphone based visible iris images for approximating the radius of the iris to achieve robust segmentation. The proposed technique has shown the improved segmentation accuracy up to 85% with standard OSIRIS v4.1. This work also proposes a new feature extraction method based on *deep sparse filtering* to obtain robust features for unconstrained iris images. To evaluate the proposed segmentation scheme and feature extraction scheme, we employ a publicly available database and also compose a new iris image database. The newly composed iris image database (VSSIRIS) is acquired using two different smartphones – iPhone 5S and Nokia Lumia 1020 under mixed illumination with unconstrained conditions in visible spectrum. The biometric performance is benchmarked based on the equal error rate (EER) obtained from various state-of-art schemes and proposed feature extraction scheme. An impressive EER of 1.62% is obtained on our VSSIRIS database and an average gain of around 2% in EER is obtained on the public database as compared to the well-known state-of-art schemes.

1. Introduction

Numerous factors such as affordable cost and advanced features meeting the consumers' expectation have contributed to significant rise in the usage of smartphones. In addition recent advancements have resulted in smartphones with cameras at par with the imaging capabilities of dedicated cameras which further adds to the attracting features for owning a smartphone. With all the advanced functionality provided, smartphones can also be used as a personal security device for authentication or identification. At the same time, due to high amount of personal data, the smartphone itself has to be secured. These growing concerns regarding the protection of personal information and smartphone as a security device has resulted in various active research. Physical access can nowadays be granted by near-field-communication (NFC) protocol for a smartphone, when it is positioned in the vicinity of gates to secured areas. Various online banking applications use smartphones as the authenticating device, while access to the token is at best controlled by a personal-identification-number (PIN). A more secure mode of authentication can be achieved by employing any biometric characteristic such as fingerprint, face, iris or palmprint. Motivated by the idea of using a smartphone for authentication, some of the key players in the smartphone market like Apple and Motorola have taken a step ahead to integrate fingerprint sensors into their smartphone products for authenticating the owner of device.

Along the same lines, facial biometrics (2D/3D) was implemented using data captured by smartphones [27,20]. Smartphone based real-life verification using contactless capture of fingerprint for authentication was proposed recently [19,25]. Contactless knuckleprint for identification [4] also supports the argument of using smartphone as a biometric capture device.

A more robust and reliable biometric characteristic is the iris with its unique patterns. The unique patterns present in the iris texture result in information with high entropy [7]. Owing to such high entropy, large scale systems such as India's Unique ID (UID) have employed iris biometrics. It has to be noted that the color of the iris differ based on the concentration of the melanin pigment. Higher concentration of melanin causes the eyes to be dark colored while the lower concentration results in lighter irises. Due to difficulty in resolving the texture pattern in the dark iris, traditional methods have employed near-infra-red (NIR) light for iris imaging. The visible spectrum iris

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recognition has been explored in the recent years [18]. Well known challenges like NICE II Iris biometrics competition [3] reiterate the increasing interest in visible spectrum iris recognition.

The possibility of imaging iris in visible spectrum further motivates the necessity to study the feasibility of smartphone based iris recognition. As any normal sensor, smartphones can be used as a standalone capture device to obtain iris images using built-in cameras of smartphones due to high quality of imaging. This work explores smartphone as a iris biometric sensor in detail. Particularly, this work contributes in three different aspects of smartphone based visible spectrum iris recognition, namely – (i). segmentation, (ii). feature extraction and (iii). construction of a new smartphone iris database in visible spectrum.

Traditional NIR iris recognition systems work with a known range of iris and pupil radius due to the restricted distance in the capture process. However, due to unconstrained nature of image capture in visible spectrum iris imaging, it is difficult to obtain the images of iris with known range of radius for iris and pupil. In this work, we propose an improved iris segmentation scheme for unconstrained iris acquisition in visible spectrum. We also present a novel feature extraction scheme for unconstrained visible spectrum iris recognition. The feature extraction scheme presented in this work relies on deep sparse filtering of the iris data followed by the pooling of the sparse filtered features. The feature data obtained from different sparse filters provide unique and robust features to obtain high recognition/verification rates. The proposed technique is evaluated on the publicly available smartphone iris dataset from BIPLab.[1] Further, the limited availability of datasets of iris images captured with smartphones in the visible spectrum has motivated us to compose a new database (i.e. the Gjøvik Visible Spectrum Smartphone Iris Database – VSSIRIS). In this work, we present the VSSIRIS database consisting of 560 iris images. We present an extensive analysis of the newly constructed database with state-of-the-art iris recognition techniques and compare them against the results obtained with the proposed feature extraction scheme.

The rest of the paper is organized as follows: Section 2 presents the details of the newly created iris database. Section 3 presents the details of the proposed iris recognition pipeline. Section 3.1 details the proposed method to estimate iris and pupil radius and Section 3.2 describes the proposed feature extraction technique. Section 4 provides the details of experimental protocols involved in evaluating the database using the new feature extraction technique. It also provides results obtained for various techniques along with the proposed feature extraction technique and finally, Section 5 presents the conclusions.

2. Smartphone iris database

Owing to the difficulty in pattern visibility of the iris in visible spectrum light, iris recognition in visible spectrum had not been popular until the recent years [18]. Advancements in the imaging sensors and algorithms to address the challenges in visible spectrum iris recognition have increased the interest of the research community to investigate more on visible spectrum iris recognition. Recent works in the visible spectrum iris recognition have demonstrated good performance in terms of verification accuracy and robustness [18,12,21]. However, there have not been many publications or reported works on smartphone based iris recognition which has resulted in non-availability of corresponding datasets except the database contributed by BIPLab. Motivated by this fact, this work intends to present a new database for visible spectrum iris research with iris images captured using two different smartphones. The VSSIRIS database has been acquired with two most recent and popular

Table 1
Camera parameters of smartphones.

Parameters	iPhone 5S	Nokia Lumia 1020
Resolution	3264 × 2448 Pixels	7712 × 5360 pixels
Color representation	sRGB	sRGB
Bit depth	24	24
F-Stop	f/2.2	f/2.2
White balance	Auto	Auto
Flash	No flash	No flash
Metering mode	Average	Average
File format	JPEG	JPEG
Focus	Auto	Auto
Illumination	Mixed illumination	Mixed illumination

phones – iPhone 5S and Nokia Lumia 1020. The images were captured using the rear camera of both smartphones. The specifications of the camera and operating environment are provided in Table 1. The images were acquired under the influence of mixed illumination constituted by artificial indoor illumination and natural daylight illumination. Thus, this database provides an opportunity to explore the challenges presented by the mixed illumination for iris recognition in visible spectrum.

As compared to the database provided by BIPLab [2], this database consists of images acquired from volunteers originating mostly from north European countries. Along with the various ethnicities provided in the BIPLab database, this database provides north European iris images which become important in measuring the performance of iris recognition systems with respect to different ethnicities. Using the two different databases, one can measure the robustness of various stages in an iris recognition pipeline such as segmentation and feature extraction and thus potentially identify dependencies with respect to the color of the iris or ethnicity of the person. Another important aspect is the choice of the smartphones employed in data collection for this database. This database is constructed using the most recent smartphones – iPhone 5S and Nokia Lumia 1020 providing a chance to benchmark them for iris recognition. Nokia Lumia 1020 provides the images in a spatial resolution of 41 mega pixels. To the best of our knowledge, this is the first work to employ these phones for iris recognition. Along with the other differences from BIPLab database, the VSSIRIS database is collected in the mixed illumination as compared to the images captured in BIPLab database under two different illumination conditions.

Fig. 1 depicts few sample images from the new iris image database. The VSSIRIS database consists of images acquired from 28 subjects in a single session which constitutes to a total of 56 unique iris instances. Each unique iris instance is captured in 5 different presentations per device in a single session under semi-cooperation from the subjects and under unconstrained conditions. A total of 560 images are present in the disclosed database. The participants in the VSSIRIS database consist of various nationalities originating from eastern, northern and southern European countries. The distribution of the iris color and

Fig. 1. Sample images from the VSSIRIS database acquired using two different phones.

[1] http://biplab.unisa.it/MICHE/index.html.