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An empirical study on iris recognition in a mobile phone

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ABSTRACT

The iris recognition on a mobile phone is different from the conventional iris recognition implemented on a dedicated device in that the computational power of a mobile phone and the space for placing NIR (near infrared) LED (light emitting diode) illuminators and iris camera are limited. This paper raises these issues in detail based on real implementation of an iris recognition system in a mobile phone and proposes some solutions to these issues. An experimental study was conducted to search for the relevant power and wavelength of NIR LED illuminators with their positioning on a phone for capturing a good quality iris image. Subsequently, in view of the disparity between the user's gazing point and the center of the iris camera which causes degradation of acquired iris images, an experiment was performed to locate the appropriate gazing point for good iris image capture. A fast eye detection algorithm was proposed for implementation under the mobile platform with low computational facility. The experiments were conducted on a currently released mobile phone and the results showed promising potential for adoption of iris recognition as a reliable authentication means. As a result, two 850 nm LEDs were selected for iris illumination at 1.1 cm away from the iris camera for the size of a 7 cm × 13.7 cm phone. In the performance, the recognition accuracy was 0.1% EER (equal error rate) and the eye detection rate with the speed of 17.64 ms on a mobile phone was 99.4%.

1. Introduction

According to the authors (Jobanputra, Kulkarni, Rao, & Gao, 2008; Li, Clarke, Papadaki, & Dowland, 2014) the mobile phone is one of the most widely used electronic devices today. Advanced functions such as camera, e-mail, and mobile finance services in modern phones have broadened their usages and applications way beyond our imaginations from just a decade ago. The diverse use of mobile phones has also brought up many issues relating to mobile phone security (Dorflinger, Voth, Kramer, & Fromm, 2010). In most existing mobile phones, the frequently adopted personal identification number (PIN) and pattern lock have begun to reveal crucial security flaws (Alpar, 2015; Cheong, Ling, & Teh, 2014; Dorflinger et al., 2010; Li et al., 2014). Moreover, they have become more inconvenient as their construction gets more complicated at high security levels. For these reasons, biometric technology such as fingerprint recognition has recently been adopted to enhance mobile phone security (Clarke & Furnell, 2007; Clarke & Furnell, 2005; Clarke, Furnell, & Reynolds, 2002; Dorflinger et al., 2010; Guerra-Casanova, Sánchez-Ávila, Bailador, & de Santos Sierra, 2012; Hoang, Choi, & Nguyen, 2015; Jobanputra et al., 2008; Li et al., 2014; Wang & Liu, 2011).

The touch based sensing interface although convenient could pose hygienic problems, and thus cause users to resist such fingerprint technology. Moreover, the performance of the touch based fingerprint system could be readily degraded by substances on the sensor surface and by the small-sized sensors on recent mobile phones. Even worse, it has been shown that the fingerprint recognition system of a recently released smart phone was vulnerable to fake fingerprints (Charles, 2014; Diaz, 2013; Yang & Han, 2014). In contrast to fingerprint recognition, an iris recognition (Daugman, 1993, 2004) system is non-intrusive since it uses a touchless sensor, and has a higher recognition rate than that of a fingerprint recognition system. In addition, an attack using a fake iris is difficult due to the problems associated with acquiring iris images from a non-cooperative user. In view of these considerations,

Abbreviations: CED, Circular Edge Detection; CPU, Central Processing Unit; EER, Equal Error Rate; FAR, False Accept Rate; FRR, False Reject Rate; FTA, Failure to Acquire; FTE, Failure to Enroll; HD, Hamming Distance; LED, Light Emitting Diode; LOOCV, Leave-One-Out Cross-Validation; NIR, Near-Infrared; PIN, Personal Identification Number; RAM, Random Access Memory; RED, Rapid Eye Detection; ROC, Receiver Operating Characteristic; ROI, Region of Interest.

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this paper proposes an iris recognition system for mobile phone security.

Existing mobile iris recognition systems can be divided into three categories: (1) systems using dedicated devices (Faddis, Howard, & Stracener, 2011; IOM RapID-Cam™ II Handheld Biometric System; IriShield™ Series; IRISPASS-h, 2011; Kang & Park, 2009) (2) systems connecting additional hardware to a mobile phone (Lu, Chatwin, & Young, 2011; MORIS; Stratus MX) (3) systems attaching a near-infrared(NIR) camera with illuminators (Iris on Mobile Solution). Systems which use a dedicated device for iris recognition are very costly and limited to particular purposes. On the other hand, systems that connect additional hardware or attach with an NIR camera and illuminators can be used for purposes such as user authentication and mobile finance services. Among systems which connect a piece of additional hardware to smartphones, the system of Lu et al. (2011) uses the 'Eye Cup' to capture an iris image with uniformly distributed illuminance from a certain distance. MORIS and Stratus MX connect a portable iris recognition system to a mobile phone. However, it is inconvenient to carry the additional device in addition to the mobile phone. Iris on Mobile Solution installs an NIR camera with illuminators plus a mirror within a mobile phone to capture iris images. This largely solves the problem of needing to carry additional hardware for iris imaging.

Implementing the system on a mobile phone has raised some new issues related to performance degradation caused by illumination, user's gazing point, and the low central processing unit (CPU) capability within a mobile phone. Moreover, the iris recognition system on a mobile phone is mainly used for data security or unlocking the mobile phone for a single user. In this case, iris recognition is performed whenever the user operates the mobile phone, generally dozens of times a day. Therefore, both computation time and user friendliness are just as important as recognition rate. Hence, this paper proposes to study and attempt to address some of these problems.

Above all, a mobile phone has limited space for the installation of illuminators on top of various existing components such as display, microphone, antenna, and so on. Moreover, the power supply for illumination is limited due to the limitation of current battery technology. Hence, an adequate illumination may not always be available during image acquisition with a mobile phone. The captured eye images without adequate illumination may thus contain extreme image brightness variations. In the first part of this study, we analyzed the variation of iris image quality with respect to imaging wavelength as well as the installation position of illuminators within a mobile phone.

In the second part of this study, we investigated the likely event of non-frontal iris image. In mobile iris recognition, it is often difficult to capture a frontal iris image. Apart from the uncontrolled environment, the camera is often located above the display such that a user has to look downward to see his or her eye shown on the display for the iris image capture where occlusion by upper eyelashes and eyelids often occur. Moreover, the shape of iris viewing from the downward angle shows an elliptical distortion. This phenomenon is called the off-angle distortion and is caused by the disparity between the user's gazing point and the center of the camera. In addition, looking downward feels less comfortable than looking straight ahead which makes the system less user-friendly. Therefore, this paper suggests an optimal gazing point which minimizes both occlusion and off-angle distortion in a user-friendly manner. An eye-shaped guide template is presented on the desired portion of the screen to lead the user's gaze naturally. This also helps the user to find the focusing position. Since the focus distance is fixed based on the guide template's size, a constant size of captured eye image can often be maintained. Thus using a fixed size guide helps the user to locate the eye within the focus distance, and this eases the iris image capture process.

Finally, an eye detection algorithm is proposed to reduce the computational cost of the system in view of the low CPU facility within a mobile phone. Particularly considering the case when a user captures an iris image with a mobile phone by him or herself, it would also be difficult to detect the eye from an input image in real time if the processing speed was too slow. The slow computational speed would in turn result in a poor quality image capture due to insufficient time for detecting the eye region. Even worse, the long image capturing time could be inconvenient for the user. If the speed of the system is fast enough, not only will the system capture a good quality iris image, it will make the user feel more at ease, a multiple matching can be attempted to improve the recognition rate based on multiple images. Since most existing eye detection methods (Kim, Lee, & Kim, 2010; Viola & Jones, 2001; Wilson & Fernandez, 2006) take a lot of time detecting an eye from an input image on a mobile phone, a fast eye detection algorithm is proposed in this paper. The proposed eye detection algorithm uses four classifiers consisting of one main block and two neighboring blocks in four directions, i.e. horizontal, vertical, and diagonal. The average intensity of the main block is compared to that of the neighboring blocks.

The main contributions of this paper are as follows:

- An optimal operating wavelength and an installation position of illuminators for capturing iris images with clear patterns and outer boundaries are proposed.
- An optimal user's gazing point which minimizes occlusion and off-angle phenomena is proposed. An eye-shaped guide is displayed at the proposed position to lead the user's gaze naturally where the speed of eye detection can be increased by selecting the area around the guide as the region of interest (ROI).
- An eye detection algorithm for high resolution near infrared image is proposed. The algorithm uses four classifiers consisting of one main block and two neighboring blocks.
- An empirical study and analysis of the mobile iris recognition system and the practical guidelines in the development of this system are provided.
- The *BERC mobile-iris database* consisting of 500 images from 100 irises is collected by the iris recognizer implemented on a mobile phone. It can be shared with others for research purposes.

The rest of this paper is organized as follows: the proposed mobile iris recognition system is described in Section 2. Our analysis and solutions for the presented problems are described in Section 3. The experimental results and performance evaluation are shown in Section 4. Finally, conclusion and future works are presented in Section 5.

2. The proposed mobile iris recognition system

2.1. Overview of the mobile iris recognition system

The proposed mobile iris recognition system consists of a mobile phone, NIR illuminators, and an NIR camera. The hardware structure of the proposed system is shown in Fig. 1. NIR camera is installed in ①, NIR illuminators are installed in ②, and the eye-shaped guide is displayed in ③. Two 850 nm wavelength LEDs are used for illumination and a camera with a resolution of 1280×960 pixels is used. A band pass filter, which passes the light with a wavelength between 765 and 850 nm, is attached to the NIR camera for blocking the visible light. The focus distance of the proposed system is 20 cm and the iris diameter of an input image is 170–200 pixels at this distance. According to Int. Std. ISO/IEC 19794-6 (2011), an iris image is considered as good quality if the