A Simply Integrated Dual-sensor based Non-intrusive Iris Image Acquisition System

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Abstract

We describe an image acquisition system based on an integrated dual-sensor with a visible and infrared spectrum, which enables a multimodal biometric system, including non-intrusive iris recognition. To implement this as capable of simultaneously acquiring facial and iris images, a beam splitter for reflecting or transmitting visible and infrared light representing an image of a target object is used along an identical ray path divided into different bands. Namely, the beam splitter divides incident light from an object into the dual-sensor. Accordingly, an image of the iris area and an image of the facial region can be simultaneously acquired from a single image acquisition system, and an iris image can be acquired from a relatively long distance. The iris biometric system is implemented by using the facial detection and iris recognition SDK. In experiments, we have successfully evaluated the performance of the proposed image acquisition system with a non-intrusive iris recognition algorithm.

1. Introduction

Currently, commonly used authentication schemes that control the access to personal devices or secured areas are based on passwords, smart cards and biometrics. Passwords are very convenient for users, easier and inexpensive to implement, but can be stolen or hacked [1]. Therefore, biometrics has now become a practical alternative to traditional authentication or identification methods in many application areas. A biometric system may be defined as authentication techniques that rely on specific physiological or behavioral characteristics, which can be automatically checked [2, 3]. Major methods of biometrics, fingerprint, face, hand geometry and iris recognition, have received lots of attention as a way of securing personal information and industrial facilities [3]. Among them, the iris biometric system is the most accurate but has a drawback of low utilization due to inconvenient interfacing between the user and the devices in the process of iris image acquisition.

However, iris recognition is a matured technology in biometric fields. There are many commercial products and technologies have already been developed [3-15], but most of the systems have small capture volume and need users to fully cooperate with the devices. In general, the biometric images used in personal identification have a weakness in that they can be mimicked or hidden maliciously. In order to overcome this, a method to identify individuals at a distance without the cooperation of users is human ID technology. Early human ID studies were supported by DARPA [16], and the first demonstration of iris recognition at a distance was performed by Sanoff in 2005 as a part of the human ID program [9, 16, 17]. Recent innovations in iris biometric systems have demonstrated systems operating beyond three meters [9, 17]. The demonstrated systems usually consist of one or two wide field of view cameras to find a user's face and a narrow field of view camera with a pan-tilt control unit for capturing eye images [9, 10, 17, 18, 19].

Applications of biometrics include the identification of criminals, identification cards, financial security, border control, healthcare, access control in facilities and mobile products [2, 3]. However, it has been difficult for biometrics to achieve a recognition accuracy of 100% for one feature or sometimes to obtain a specific biometric feature needed. In addition, each biometric method has adequate application domains according to its accuracy and other features. Hence, it has been necessary to select a kind of biometrics for each application, and synergistic effects through a multimodal biometric fusion are required. Also, a multimodal biometric fusion can be used to support environments in cases where one type of biometric information is not available or one biometric feature is superior to the others. Nowadays, the field of face and iris recognition is evolving into a multimodal face and iris biometric technique, because these two biometric data sets can be acquired from a single object. Moreover, the fields of two different biometric types can complement each other.

In this paper, we propose an image acquisition system for capturing facial and non-intrusive iris images based on an integrated dual-sensor. The image acquisition system consists of two sensors: one with a low-resolution and a wide field of view and the other with a high-resolution and a narrow field of view. It is capable of capturing two different types of image sequences simultaneously, low-resolution facial images with visible light and high-resolution eye images with infrared light. The sensors for capturing face and iris images are combined by using a beam splitter. The image acquisition system allows images of an object to pass along the same single path of the camera system, thereby minimizing the error to a phase difference, which may occur when facial and iris images are captured at a distance. To verify the performance of the proposed system, a prototype system with iris recognition software was implemented and tested at a relatively long distance successfully. As such, the proposed system confirms implementation of a low-cost and non-intrusive iris biometric system by using a simply integrated dual-sensor.

2. Image Acquisition for Iris Recognition

Personal identification by biological characteristics used for iris recognition started in the early 19th century, and Daugman [7] developed and patented the first actual algorithms that underlie most current commercial implementations of an iris biometric system. These algorithms became widely licensed through a series of companies: IriScan, Iridian, Sarnoff, LG-Iris, Panasonic, Oki, Sagem, Securimetrics, L-1 Identity (now owned by Morpho), etc. [9, 17]. The iris is a thin circular diaphragm lying between the cornea and the lens, and it has a complex structure with many minute characteristics. Iris texture is a phenotypical feature that develops during gestation and remains unchanged after birth. The iris patterns of the two eyes of an individual or those of identical twins are completely independent and uncorrelated because of a completely random process during fetal development [12].

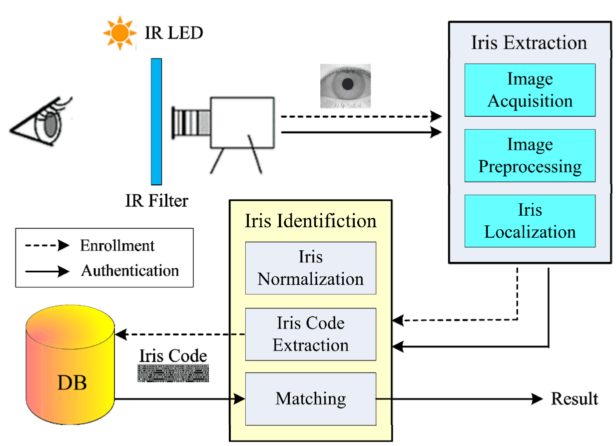

Figure 1: Components of the iris biometric system

Figure 1 shows an iris biometric system using our iris recognition SDK [13, 14] used in this study. The iris SDK consists of the iris extraction and identification components. The first step in iris recognition is to capture a high-quality image of the eye and to extract the iris region. The next step is to extract the features of the iris region and match these features with known patterns in the feature database. Namely, the key modules of iris recognition include eye image acquisition, iris localization, iris code extraction and matching. In the SDK, the iris localization module was implemented by using well-defined mask templates [13], and the feature vector was extracted from a normalized image of the iris region by a cumulative-sum based change analysis method [14]. The performance of the iris SDK was evaluated with the CASIA iris database [13, 14].

The human iris is fairly small, about 1 cm in diameter, so capturing a well-focused and clear iris image in real-time is very difficult [17]. Also, the performance of iris biometric systems depends on how well the iris acquisition device captures the rich texture details of the iris. This requires the iris to be within the focus volume of the acquisition device [20]. In the acquisition device, DoF (Depth of Field) can be defined as a range of distance between the nearest and farthest objects that appear acceptably sharp. If the distance of object is not in the DoF of the focus lens, the captured image is defocused and the specular reflection size becomes smaller or bigger as shown in Figure 2. Thus, it is difficult to determine the object’s position because is hard to discriminate the blurred image that is out of the DoF, as shown in Figure 2 [21]. Likewise, an iris image acquisition device is very important for automated iris biometric systems.

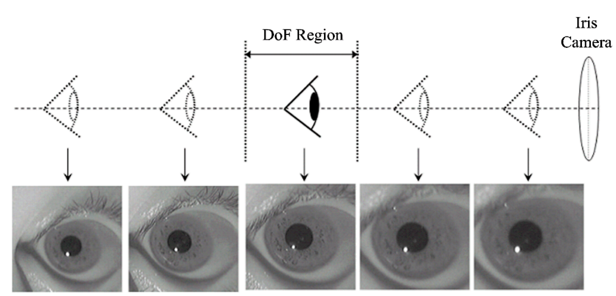

Figure 2: The DoF region vs. the defocused region [21]

The standard for iris images, ISO/IEC 19794-6 [22], considers a resolution of more than 200 pixels across the iris to be of “good quality” and 150–200 pixels across the iris to be of “acceptable quality”. In addition, an iris image is generally captured by a close-up picture, and a fixed focal lens is usually used in iris image acquisition devices. Hence, acquisition of a sufficient quality iris image is challenging, particularly from a distance [17]. An iris acquisition device with a fixed focal lens must capture the iris image again and again if the focus is blurred until a clear iris image is obtained. This is not only gives a very uncomfortable feeling to users, but also takes a long time to get a clear iris image. A variable focal lens has a relatively large DoF region, but additional devices and an auto-focusing algorithm are required. The standard for iris recognition also recommends a mix of wavelengths in the near infrared with controlled illumination in the 720–900 nm range [9, 22].

3. Facial and Iris Image Acquisition System

In order to obtain an iris image at a distance, it is necessary to consider various optical elements such as image sensors, lenses, illuminators, etc. To acquire facial and iris images simultaneously, a facial image acquisition device and an iris image acquisition device are separately required as shown in Figure 3 [9, 10, 18, 19]. The facial image acquisition device and the iris image acquisition device are usually provided with respective cameras and adjust incident the angles of their corresponding cameras arranged at upper and lower locations to capture facial and iris images respectively. Therefore, the method using a facial image acquisition camera and an iris image acquisition camera may be susceptible to error due to the differences in incident angles and phases and in the capturing areas.

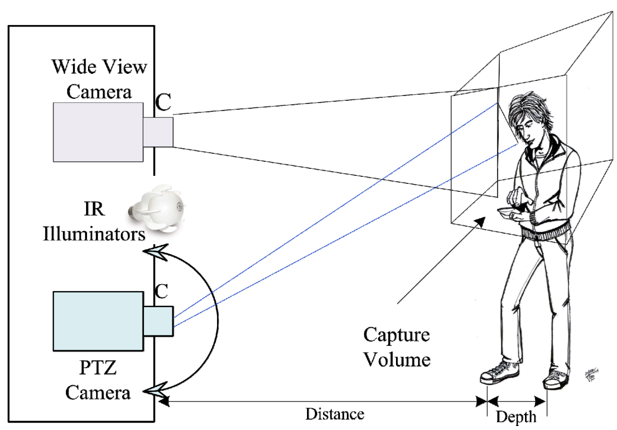

Figure 3: Common method of an image acquisition system for non-intrusive iris recognition

Conventional iris image acquisition cameras use a cold mirror positioned in front of the camera lens, and imaging an incident image on the lens enables a user to directly check the location of the eye to be imaged from a short distance, e.g., less than 40 cm. Although a cold mirror is useful to check an incident image over a short distance, appropriate training is required for the convenient use of the cold mirror. To solve these problems, we propose an image acquisition system capable of simultaneously acquiring facial and iris images from a relatively long distance and minimizing errors attributable to the phase difference that occurs when capturing facial and iris images along the same ray path. The architecture of the proposed facial and iris image acquisition system based on a dual-sensor is shown in Figure 4. As can be seen in the figure, the most important component in the image acquisition system is a beam splitter for reflecting or transmitting the rays of the facial and iris, representing an image of a target object provided along an identical ray path split into different bands. The first is an image sensor for imaging the iris area by capturing an infrared image, which has been transmitted through the beam splitter; the second is an image sensor for imaging the facial region by capturing a visible image, which has been reflected from the beam splitter. Also, there is an interface module for controlling the first sensor and the second sensor and providing the images obtained by the first sensor and second sensor for the multimodal biometric system.

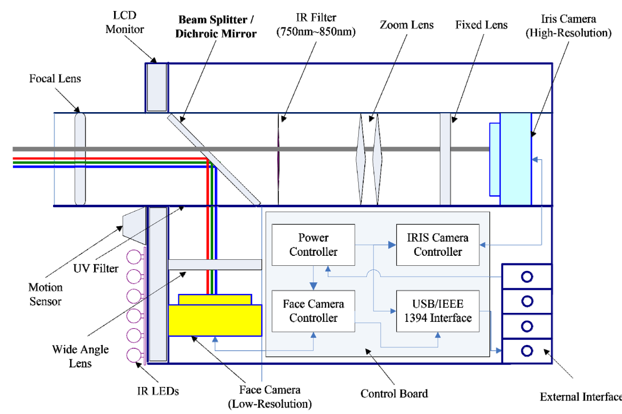

Figure 4: Architecture of the proposed facial and iris image acquisition system based on a dual-sensor

In Figure 4, the focal lens can be used to improve the parallel light for the incident light of a target object for image acquisition along a single ray path. The incident light includes infrared rays, represented by a thick solid line, and visible rays, represented by thin solid lines in the figure. In general, an image for facial recognition uses the visible band while an image for iris recognition uses the infrared. Therefore, the infrared illuminator array, along with the iris image sensor, is arranged on the front surface of the image acquisition system and used to capture an iris image. The infrared illuminator array emits infrared lights in a specific wavelength, e.g., from 750 nm to 850 nm. The infrared lights reach the target object and are then reflected to the image acquisition system as image light representing the target object. The intensity of the infrared illuminator array for iris image capture needs to be strengthened in proportion to the distance between the target object and the image acquisition system.

In addition, a beam splitter or a dichroic mirror can be used for reflecting and transmitting the multi-spectrum image lights to different bands. For the application of the beam splitter, it is preferable to design the beam splitter to reflect the multi-spectrum image lights in the entire visible band on the basis of a specific wavelength and to transmit infrared light over a specific band. For the application of the dichroic mirror, it is preferable to design the dichroic mirror to have an infrared filtering function. The infrared filter can also be provided in a case where a beam splitter is used, and is required for the acquisition of a more desirable iris image in the iris image sensor to which light in the infrared band is provided. In order to recognize the iris, the diameter of an iris area needs to be larger than, e.g., 150 pixels; thus, it is necessary to enlarge and capture the eye area in a facial region. A zoom lens can be employed to guarantee such image quality of the enlarged and captured eye area, and the focusing control of the zoom lens under the control of the control module allows enlarging and capturing an iris image.

The iris image sensor serves to obtain an iris image from a fraction of the infrared light, and a high-resolution image sensor, more preferably a low-speed and high-resolution monochrome CCD or CMOS sensor, can be used as the iris image sensor. A lens with a narrow field of view can be used to acquire the iris image. A UV filter may be provided to improve the facial image in the visible band reflected from the beam splitter. Further, a wide field of view lens can be provided to improve the facial image and acquire a facial image that is a specific size. The facial image sensor can be used for facial image acquisition from a fraction of the visible light, and a high-speed image sensor, more preferably a high-speed and low-resolution CCD or CMOS sensor, can be used as the facial image sensor.

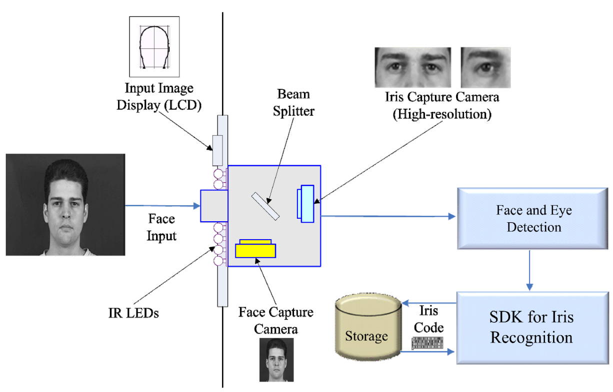

Figure 5: Usage of the proposed image acquisition system

Figure 5 shows an example usage of the proposed image acquisition system for a multimodal biometrics including non-intrusive iris recognition. As can be seen in the figure, a display unit is attached to the front of the image acquisition system and is used to accurately locate a facial image in order to efficiently acquire facial and iris images. The display unit may be implemented with a liquid crystal display (LCD). For example, in a case where an LCD is used as a display unit, a reference screen having an area of interest may be employed so that the facial region of the facial image to be located on the LCD is located in the area of interest. In order to accurately capture the eye area, the facial region needs to be accurately located when the resolution of a sensor module is low or it is necessary to enlarge the eye area at high magnification. Additionally, the image acquisition system is connected to the biometric system, and the biometric system functions to control the display unit and the image acquisition system and, also, to recognize or authenticate the iris and facial images acquired by the image acquisition system with appropriate iris and facial recognition software.

4. Implementation and Discussions

The image acquisition system with a non-intrusive iris recognition that has been implemented in this study consists of an LCD-based external monitor, infrared illuminator array, motion detector, facial and iris image acquisition device, and control unit. A 1/4 inch CMOS QXGA sensor for iris image acquisition and a 1/3 inch CCD VGA sensor for facial image acquisition were used, and fixed focal lenses (focal length = 33.2 mm and f = 4.3 for iris image, and focal length = 13.2 mm and f = 1.4 for face image) were used to enable a secure DoF of 65–75 cm. A beam splitter used for separating the facial image and iris image can reflect over 90% of visible light in the 380–770 nm range and can allow passage of more than 92% of infrared light in the 800 nm range or more. Also, 192 infrared LEDs with 850 nm infrared lights were used to allow the acquisition of an iris image at a distance of 70–100 cm. Figure 6 shows a prototype of the image acquisition system for multimodal biometrics including non-intrusive iris recognition.

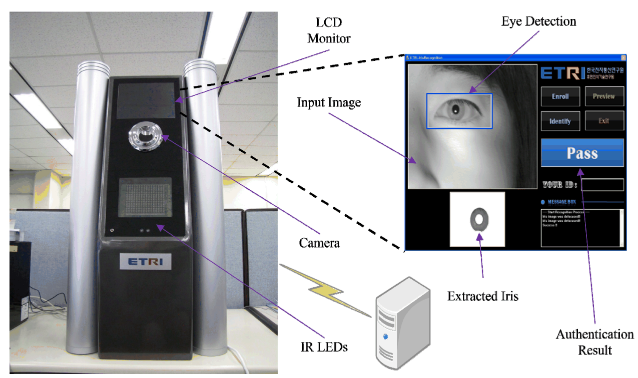

Figure 6: A prototype of the image acquisition system for multimodal biometrics including non-intrusive iris recognition

The iris biometric system employed the iris recognition SDK [13, 14], and the fuzzy difference-of-Gaussian method [15] and an iris image quality assessment method [6] have been also used for the noisy iris images at a distance. In the experiment, the iris biometric system shows a performance for stable acquired iris images that is similar to the current system at distances of 8–25 cm [13]. As a result, the proposed system allows images of an object to pass along the same single path of the camera system, thereby minimizing the occurrence rate of errors attributable to a phase difference, which may occur when facial and iris images are captured using two separate facial and iris acquisition cameras. Furthermore, the system can be configured such that a telescopic lens is added in front of the acquisition system. In this way, facial track/recognition and iris recognition can possibly be performed from a long distance, and efforts to bring a user's eye to a location near a guidance area within the cold mirror of the acquisition system to perform iris recognition can be reduced, with the result that it is expected that the usability of the facial and iris image acquisition or recognition system can be considerably increased. However, the 3.1 mega pixels of the iris sensor with a USB 2.0 interface show a problem in terms of the limitation of frame rates, and the DoF of the fixed focal lenses was not enough to acquire a stable, high-quality iris image.

5. Conclusions

We have described an image acquisition system for multimodal biometrics with non-intrusive iris recognition, which can effectively acquire an iris region and a facial image at the same time. A prototype system that includes a dual-sensor combined with a beam splitter, which is based on the principle of the interferometer, was implemented. The beam splitter divides an incident ray from an object such that it is detected by two different sensors, and the dual-sensors capture the separated incident rays at different wavelength and resolutions that include geometrically corresponding image frames. Moreover, an iris image can be acquired from a relatively long distance (identical to the distance from which a facial image is captured) without requiring a cold mirror. The trend of current iris biometric systems is the development of long distance recognition techniques, and, in the future, such techniques will become an important part of the development of intelligent video security technologies such as video surveillance systems.

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