Imaging Simulated Smeared Fingers with a Sensor Based on Scattered-Light Detection

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Fingerprint identification is susceptible to the surface conditions of a finger. We studied the effect of image degradations with our sensor technology based on scattered-light detection. To simulate a smeared finger, we printed small black dots on a transparent sheet and inserted it between a finger and our sensor. With a green light-emitting diode (LED) as its light source, the rate of successful identification decreased constantly as the number of black dots increased. With a near-infrared LED, the rate remained almost constant when the total area covered by the black dots was less than 1% of the input area. The infrared LED generated a clearer image for oily fingers than the green LED as well. We attribute these findings to the presence of an internal fingerprint pattern, which near-infrared light can probe better.

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1. Introduction

Surface conditions of a finger can deteriorate the quality of fingerprint images. Dry fingers, wet fingers, smeared fingers, are all problematic because they can be falsely identified as someone else’s finger. It is also known that many people do not have clear fingerprints; the height differences between ridges and valleys may not be adequately large and/or there may be some disturbing surface structures such as wrinkles. Consequently, conventional fingerprint sensors are not necessarily capable of acquiring high-quality images for everyone at all times.

For a robust fingerprint identification system, it is advantageous to use a fingerprint pattern inside a finger, which is not influenced by the surface conditions in principle. There are two sensor technologies related to this matter. The first configuration employs a red light-emitting diode (LED) illuminating the dorsal part of a finger and the light escaping from the other side of the finger is captured by a camera.1) In the second configuration, multiple LEDs emitting in the visible range and a color camera are added to a conventional prism-based fingerprint sensor.2) The LEDs illuminate a finger through the prism and the light scattered by the finger is captured by the color camera placed near the LEDs. A second camera looking into the prism obliquely captures the usual fingerprint image. Contrast of a fingerprint image captured by the second camera is enhanced by total internal reflection (TIR) of light at the prism-finger boundary. Because there is no such optical mechanism for the light reaching the first camera, contrast of an image captured by this camera is much lower. The researchers simulated a dry finger by exposing a finger to a clay-desiccant and reported that their fingerprint enrollment and identification performance was improved by the use of multi-spectral information. In addition, the spectral information may be utilized for rejecting an artificial finger, leading to a secure biometric system.3) However, degree of dirtiness or dryness of a finger should be taken into account for a quantitative discussion. For a robust imaging system, the effect of ambient light also needs attention because it can degrade the contrast of fingerprint images in these two sensor technologies utilizing visible LEDs.

There is yet another optical configuration based on scattered-light detection reported earlier.4,5) It is reproduced in Fig. 1 from ref. 5. Here, light enters a light-guide from its edge and propagates inside by repeated TIR. The ridges of a finger in contact with the light-guide scatter the propagating light whereas the valleys do not. A part of the scattered-light leaks out of the light-guide and the camera placed below captures it. The light also enters the finger from the ridges and is scattered inside. Using LEDs emitting visible light, we can record color variation in a series of finger images during an input action. Because it reflects the blood movement inside a finger, this information can be utilized to reject artificial fingers.5,6) This system has been successfully tested with several types of artificial fingers.7) It functions properly under the illumination level of 3050 lux although this is achieved at the expense of increased optical power for the light source.8) This sensor configuration is potentially more compact than the first configuration and employs a smaller number of components than the second configuration. Because the light is also scattered by some internal structure of a finger, it should be capable of detecting an internal fingerprint pattern.

In this paper, we report the progress made on the sensor configuration shown in Fig. 1. For a quantitative discussion, we simulate a smeared finger in an experiment and examine the relation between the degree of smear and the rate of successful identification. The results obtained with LEDs emitting in the visible and infrared range are compared.

2. Imaging Smeared Fingers

2.1 Sensor construction

We constructed the sensor shown in Fig. 1 with readily-available components. The light-guide was a 5 mm-thick, 35 × 60 mm-area transparent plate made of poly(methyl

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methacrylate) (PMMA). In the first experiment, light source was the dual-LED emitting in the green and red (Model No. ALC-F343FX, Asyck Co., Japan) as described in detail in ref. 7. A standard color camera (Model No. QV-60HS, Logicool, Japan) was placed below the light-guide. Its output signal was sent to a personal computer and its focus was adjusted so that a clear fingerprint pattern was recorded. In the second experiment, we replaced the dual-LED light source with a near-infrared LED with a peak emission at 880 nm (Model No. DNP325-4, Stanley Electric Co., Japan). Because the color camera had an infrared-cut filter, we replaced it with a monochrome camera without such a filter (Model No. SV9M001M, Argo Corp., Japan). The image format was set to VGA (640 x 480 pixels) with 8-bit gray levels in both experiments. Typical images acquired by the two sensor configurations are compared in Fig. 2. A fingerprint pattern is clearly visible in both cases and visual inspection does not reveal a noticeable difference in image quality.

2.2 Simulating smeared fingers

To simulate a smeared finger we used a transparent film on which a number of small black dots were printed randomly. These dots represented foreign materials attached to the finger or scratches made on the finger surface. They could partially mask the fingerprint pattern and might affect the identification process. An example of such a film is shown in Fig. 3. The film used here was a 0.1-mm-thick OHP transparency film developed for laser printers (Model No. LPCOHPS1, Seiko Epson, Japan). We avoided similar OHP transparency films developed for inkjet printers because they lacked clarity. Random patterns of 0.25 mm-diameter black dots were generated in a 20 x 30 mm area. The number of dots defined the degree of smear and varied from 8 to 300. Ten different patterns were printed for each setting. Each of these films was attached to the light-guide of the sensor with index-matching oil designed for glass (n = 1.52).

Sample images captured by the two sensor configurations are compared in Fig. 4. In these particular examples, the number of black dots was 24. Fingerprint patterns and black dots are clearly observed in both cases and no significant difference in image quality is observed by a quick visual inspection. However, a closer observation may show that the black dots in Fig. 4(a) are clear while those in (b) are slightly blurred. This observation may not be convincing but it is consistent with the fact that the black dots are located slightly nearer to the camera than the internal fingerprint pattern, which the infrared light can probe more efficiently.

The images in Figs. 2 and 4 are a direct output of our sensors and the ridge-valley contrast is significantly lower than that of a conventional prism-based sensor. As discussed