Demo Abstract: Using Fingerprint Scanner for On-Body Messaging

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ABSTRACT

Fingerprint scanners are widely used in security applications. In this work, we demonstrate that capacitive fingerprint scanners can also serve as universal communication devices. In this demonstration, we show that a reliable data transmission channel can be established between a wearable device and the fingerprint scanner, using the human body as the medium. We also envision several promising applications that arise from this new opportunity.

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1 INTRODUCTION

Fingerprint recognition systems have become integral to modern security applications. These systems use fingerprint scanners to capture fingerprint images, which contain biometric information that can be used for user identification. Traditionally, fingerprint scanners have been used solely as imaging devices.

Existing research has shown that capacitive fingerprint scanners can function as signal output devices [2]. This is because the scanners apply voltage signals to their surface during operation to enhance imaging. The authors demonstrated that this capability could be used to send modulated voltage signals to the finger and to wearable devices in contact with the human body, thereby enabling a *scanner-to-wearable* communication channel.

In this work, we explore the potential of using fingerprint scanners as a more universal communication device. Specifically, we propose a method that leverages fingerprint scanners to receive signals from the human body, enabling *wearable-to-scanner* data transmission. While capacitive fingerprint scanners are already receiving devices (*i.e.*, they sense the ridges and valleys of fingerprints), using them for this purpose is not straightforward. First, the primary purpose of the scanner is fingerprint imaging, and its low refresh rate limits the sampling rate. Second, the scanner is designed to ensure reliable fingerprint imaging, which makes it highly resistant to environmental changes, including fluctuations in human body signals.

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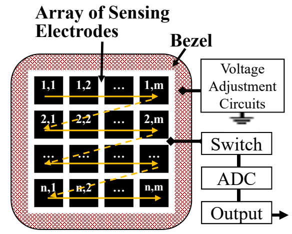


Figure 1: Capacitive Fingerprint Scanner.

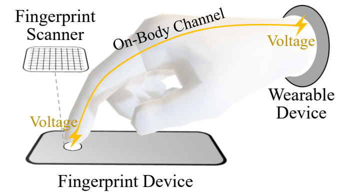


Figure 2: Sensing On-Body Voltage Signals with Scanner.

2 WEARABLE-TO-SCANNER CHANNEL

2.1 "Rolling Shutter" Scanner

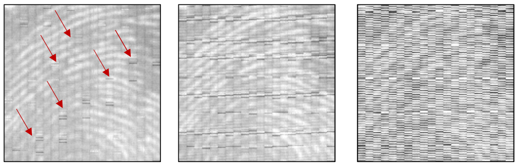
Our work is based on the imaging principle of capacitive fingerprint scanner. As shown in Figure 1, a typical capacitive fingerprint scanner consists of two main components: the sensor and the control circuit. The sensor contains an array of capacitive sensing elements, each with an electrode and a default capacitance value. When a user places their finger on the scanner's surface, the ridges and valleys of the skin create different capacitance values. The controller selects the elements row by row, and an ADC digitizes the capacitance values (scanning them sequentially reduces circuit complexity and cost [1]). This process generates a 2D image in which the pixel intensity corresponds to the capacitance values of the sensing elements.

It is worth noting that the fingerprint scanner captures the image line by line, similar to the operation of a CMOS image sensor, which can result in a rolling shutter effect [3]. This means that by performing line-by-line unwrapping of the sensor's image, it is possible to achieve a temporal sampling rate that far exceeds the frame rate.

2.2 Imaging with On-Body Voltage Signals

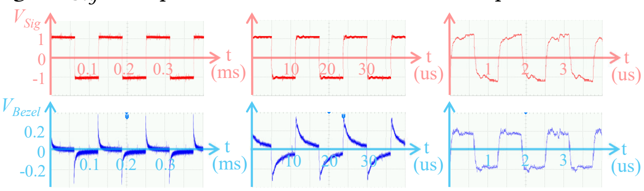
Capacitance, which represents the ability to store electrical charge, cannot be directly measured. Therefore, scanners typically apply a known drive voltage to the electrodes and infer capacitance variations by detecting changes in the resulting voltage across them. This raises an intriguing question: Since capacitive sensors are sensitive to variations in electric potential, could a voltage signal applied to the human body through a wearable device, as shown in Figure 2, be captured by the sensor?

We apply an on-body voltage V_{Sig} to a participant's wrist by a wearable device and collect output images from various fingerprint scanners. We have the following observations. First, a constant V_{Sig} does not affect the output image. This is caused by the scanner's discharge mechanism. As shown in Figure 1, the border surrounding the sensor array is referred to as the bezel. The bezel helps dissipate electrostatic charge, preventing V_{Sig} from affecting imaging.



(a) 8 kHz (b) 80 kHz (c) 800 kHz

Figure 3: Impact of On-body Voltage V_{Sig} on Fingerprint Images. V_{Sig} is a square wave and set to different frequencies.



(a) 8 kHz (b) 80 kHz (c) 800 kHz

Figure 4: Impact of On-Body Voltage V_{Sig} on V_{Bezel}.

Second, when a varying voltage signal V_{Sig} is applied, it causes interference in certain regions of the output image, and the extent of this interference depends on the frequency of V_{Sig} (Figure 3). This can be explained by Figure 4. The control circuit of the scanner continuously tries to balance the voltage on the bezel, which is in contact with the skin. When the input signal voltage V_{Sig} reaches high frequencies (*e.g.*, 800 kHz), the discharge speed can no longer keeps up. The voltage measured by the electrodes will then be biased by the voltage from the finger, and the output image will be primarily driven by V_{Sig}. Further, when the frequency is not high enough, at the moment of sampling, the scanner may encounter situations where V_{Sig} has not fully discharged. That is why the image in Figure 4(a)(b) may still occasionally contain interference at lower frequencies of V_{Sig}.

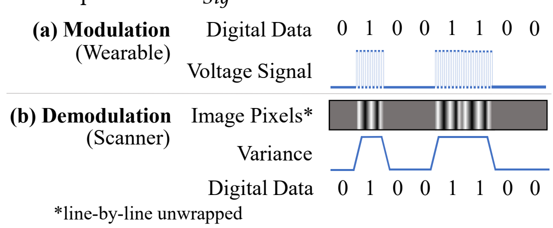


Figure 5: Modulation of Wearable-to-Scanner Channel.

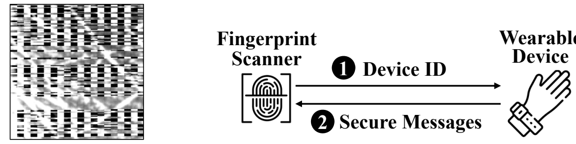
2.3 Modulation and Demodulation

Based on the findings above, as shown in Figure 5, we use on-off modulation to convey bits. The wearable device applies a high-frequency V_{Sig} to represent bit "1" and mutes V_{Sig} to 0 V for bit "0". The high-frequency signal creates a distinct footprint in the fingerprint image. To extract the bits, we first unwarp the pixels line by line according to the imaging time sequence. Then, we use the variance of the pixel values to differentiate between bit values. While fingerprint ridges also contribute to the variance, their effect is significantly smaller than that of the modulated voltage.

3 PROTOTYPE AND DEMONSTRATION

3.1 Prototype

As shown in Figure 2, our demo prototype consists of a fingerprint device and a wrist wearable. They can communicate by using the human body as the medium. The fingerprint device includes a host computer and a fingerprint scanner. We designed an STM32 board to directly connect the scanner's SPI interface to the host, where we use Python to demodulate the wearable-to-scanner messages. It is worth noting that our design is also compatible with commercial scanners, using their provided data interfaces, such as serial ports, or even utilizing the microcontroller of a commercial scanner. This approach was chosen primarily for development convenience, as custom interfaces can offer higher data rates. The wearable is a soft wristband equipped with electrodes that make contact with the skin's surface. We use a laptop to control the voltage signal on one of the electrodes for wearable-to-scanner transmission. The other electrode collects the voltage signal from the skin's surface via an ADC, which supports scanner-to-wearable communication. We achieved a data rate of about 200 bps on the wearable-to-scanner channel, while on the scanner-to-wearable channel, we achieved a data rate of about 6.7 kbps.



(a) Fingerprint Image in the Presence of Modulated On-Body Voltage (b) Using the On-Body Channel to Convey Secure Messages, e.g., PIN.

Figure 6: Live Demonstration.

3.2 Live Demonstration

In this demo, we aim to engage the audience in understanding the mechanism behind using a fingerprint scanner to receive time-domain signals and explore its potential applications.

1. *Displaying Fingerprint Images in the Presence of Modulated On-Body Voltage* We will deploy the prototype, where users wear our wristband. By controlling the wearable device, we generate voltage signals with varying frequencies and modulation on the user's skin. When the user places their finger on the scanner, the captured fingerprint image, as shown in Figure 6(a), will be displayed in real-time on the screen.

2. *Secure On-Body Messaging:* By utilizing the scanner-to-wearable channel from existing work [2] and the wearable-to-scanner channel we developed, we enable convenient bidirectional communication between fingerprint scanners and wearables. This approach offers unique advantages over traditional device-to-device communication. For example, on-body signals are relatively near-field and can seamlessly integrate with fingerprint authentication applications. As shown in Figure 6(b), we demonstrate an application where messages are exchanged to enhance fingerprint authentication security. The wristband stores a shared secret, like a PIN, and embeds it into the fingerprint image during verification. This allows the scanner to authenticate both the fingerprint and the PIN, adding an extra security layer. A lock UI on the screen provides feedback on the verification result.

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