Performance Improvement of User Verification Using Intra-Palm Propagation Signals

1st Tomoaki Oku
Graduate School of Sustainability
Tottori University
Tottori, Japan
m20j4006k@edu.tottori-u.ac.jp

2nd Kohei Fujita
Graduate School of Sustainability
Tottori University
Tottori, Japan
m19j4042b@edu.tottori-u.ac.jp

3rd Isao Nakanishi
Faculty of Engineering
Tottori University
Tottori, Japan
nakanishi@tottori-u.ac.jp

***Abstract*—In this study, we focus on biometric authentication using intra-palm propagation signals, which are biometric information that is not exposed to the body surface. A pair of electrodes is placed on the palm to generate an intra-palm propagation signal as an input. A weak electric current is passed between the electrodes, and a leakage electric field is generated around the electrodes. This field propagates through the palm and is detected as a change in voltage as an output. We propose a new propagation signal and a dedicated measurement device to improve the authentication rate.**

***Index Terms*—Biometric Authentication, Intra-Palm Propagation Signal, Amplitude Spectrum, Second-Order Difference Phase Spectrum**

I. Introduction

In recent years, biometric authentication has become one of the most commonly used personal authentication technique. The advantage of biometric authentication is that it uses a body part for authentication; therefore, users do not need to remember passwords or carry Integrated Circuit (IC) cards. Therefore, the burden of the user is less than when using other authentication systems. Moreover, biometric authentication has the advantage of not being susceptible to information loss. However, it has a drawback. Biometric authentication using biometric information exposed on the body surface can be forged and misused. To solve this problem, we have studied biometric authentication using intra-palm propagation signals [1], [2]. In this paper, we propose a new propagation signal and a dedicated measurement device to improve the authentication rate and evaluate the verification performance.

II. Verification using intra-palm propagation signals

As shown in Fig. 1, two pairs of electrodes are placed on the palm, and current is passed through the electrodes at the transmitter side. The current flowing through the electrodes creates a leakage electric field around the electrodes; the field propagates through the palm and is detected as a change in voltage by the receiver. This detected signal is called the intra-palm propagation signal and our original biometric modality. As the biometric information obtained using intra-palm propagation signals is not exposed outside the body, it is highly confidential and suitable for use in biometric authentication. The International Commission on Non-Ionizing Radiation Protection guidelines [3] stipulate that the current allowed to be applied to the human body is "up to 20 mA in the band of 100 kHz–110 MHz." Therefore, the current should be maintained below 20 mA during the measurement.

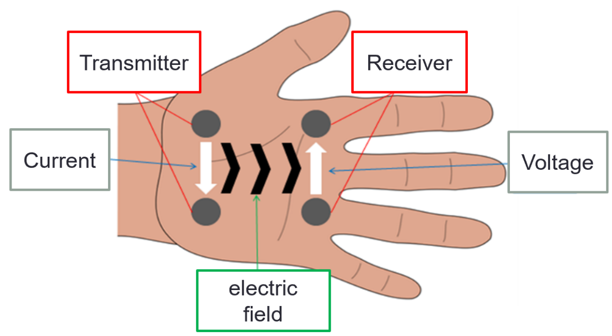


Fig. 1. Intra-palm propagation signal

Conventional propagation signals follow a compound sine waveform, which comprises sine waves with the same amplitude and zero phase. The compound sine wave, $F(t)$, can be expressed by Eq. (1), where f is the frequency of the fundamental wave, t is the time, k is the order of the harmonics, and $k_{\max}$ is the maximum order of the harmonics.

$$F(t) = \sum_{k=1}^{k_{\max}} \sin(2\pi k f t) \tag{1}$$

The waveform is shown in Fig. 2, where $f = 10\,\mathrm{MHz}$ and $k_{\max} = 10$. The amplitude of the signal changes at each frequency level, and a time delay or advance occurs when the signal is propagated on the palm. Then, the signal is subjected to a fast Fourier transform (FFT), from which the amplitude and phase spectra are derived. If these spectra are different for each individual, they can be used as features for personal verification. With regard to the phase spectrum, as we assume that the signal after propagation is not detected synchronously with the signal before propagation, it is impossible to equalize the waveform cutout timing for the FFT analysis for each measurement. Even if the cut intervals are the same , the phases calculated from waveforms with different cutout timings become different. Therefore, in an environment where synchronization is not possible, obtaining an absolute phase spectrum is impossible. We have proposed to use the differences of the phase spectra at adjacent frequencies instead of the absolute amount of the phase spectrum. The second-order difference of the phase spectra is called the second-order-difference phase spectrum and had been used as a feature [4].

As a part of the authentication process, the detected signal is subjected to FFT to derive the amplitude and phase spectra. These spectra are pre-processed by smoothing and normalization and compared with pre-registered template data for verification. The Euclidean distance is used for verification, in which, the distance between the pre-registered template data and the test data of a user is calculated. If the distance is smaller than the threshold, the user is accepted correctly, and if it is larger, the user is rejected.

III. Proposed new signal

In an A/D converter, the amplitude of the input signal is discretized in fixed intervals. This is called quantization, and the width of the interval is called the quantization width. The quantization width is determined based on the amplitude resolution of the converter. The A/D converter used in this study has a amplitude resolution of 8 bits. Therefore, the resolution is 1/256. The quantized value has an error corresponding to the analog amplitude value. This is called the quantization error, which is similar to Gaussian noise and is almost uniformly distributed throughout the Nyquist domain [5]. The signal waveform in Fig. 2, that had been used in our conventional studies [1], [2], [4], shows a temporary increase in amplitude, and the remainder of the waveform has a very small amplitude. Therefore, the quantization error is assumed to be large for signals that vary marginally compared with the minimum quantization width.

The reason for the temporary increase in the amplitude of the conventional signal is that the sine waves are combined with the zero phase so that the maximum amplitude of the sine wave of each frequency level is concentrated around 0–$60\,\mathrm{ns}$ or 940–$1000\,\mathrm{ns}$ as shown in Fig. 2. To avoid this phenomenon, we propose a new propagation signal. The initial phase of the sine wave is adjusted for each frequency level to disperse the areas where the maximum amplitudes overlap. To set up the initial phase, the fundamental period of the compound sine wave is used as a reference. The fundamental period is divided into equal intervals, and the initial phase of the sine wave for each frequency is set based on the fundamental period. Specifically, the fundamental period, T [ns], is divided equally based on the maximum number of compound sine waves, $k_{\max}$. The divided interval is $\mathrm{T}/k_{\max}$. Next, the interval is varied according to the order, k, of the complex harmonics. In other words, $k\mathrm{T}/k_{\max}$. Finally, time is converted to phase, and Eq. (2) is obtained.

$$\theta = 2\pi \cdot \frac{k\mathrm{T}}{k_{\max}}\frac{k}{\mathrm{T}} = \frac{2\pi k^2}{k_{\max}} \tag{2}$$

Equation (2) represents the initial phase corresponding to each harmonic. Using this phase, we can express the new propagating signal as Eq. (3).

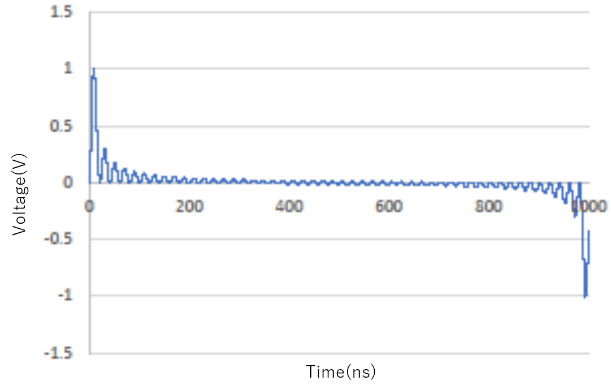


Fig. 2. Shape of the propagation signal.

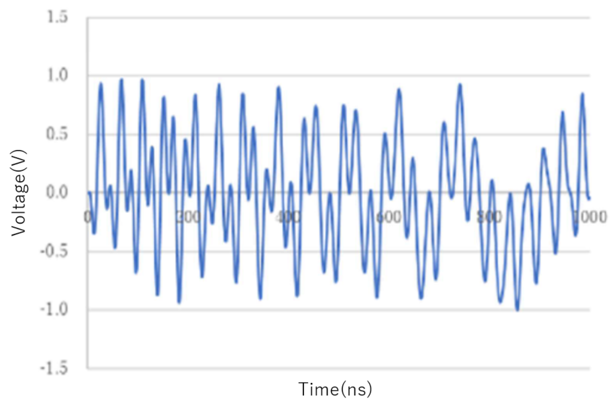


Fig. 3. Proposed propagation signal.

$$F(t) = \sum_{k=1}^{k_{\max}} \sin\left(2\pi k f t + \frac{2\pi k^2}{k_{\max}}\right) \tag{3}$$

Figure 3 shows the proposed signal, where $f = 10\,\mathrm{MHz}$ and $k_{\max} = 10$. It is clear that there are few parts with small fluctuations in the amplitude; therefore, this is expected to improve the quantization error problem.

IV. New measuring device

The conventional measurement device comprises a pair of transmitter electrodes and a pair of receiver electrodes (Fig. 1). However, in reality, a transmitter and a receiver are driven by a household power supply, and ground (GND) electrodes are common (short-circuited). Therefore, the ground electrodes at the transmitter and receiver sides can be unified; therefore, and the ground electrode at the transmitter side is deleted.

When electrodes are attached to the surface of a living body, they are not electrically bonded as in the case of metal-to-metal contact, and a potential difference or impedance occurs between the electrode and the living body. The potential difference and impedance can cause fluctuations in biometric measurements. In addition, the impedance changes depending on the contact pressure of the electrode. To solve these problems, we create a new device that maintains a constant

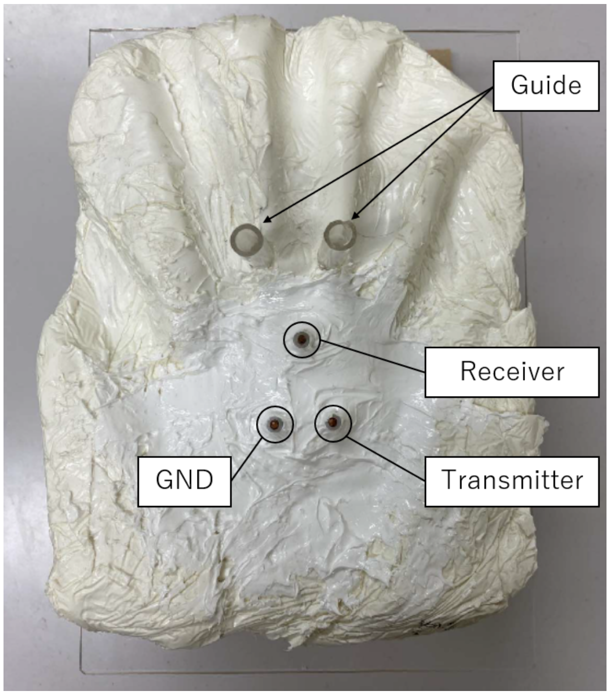


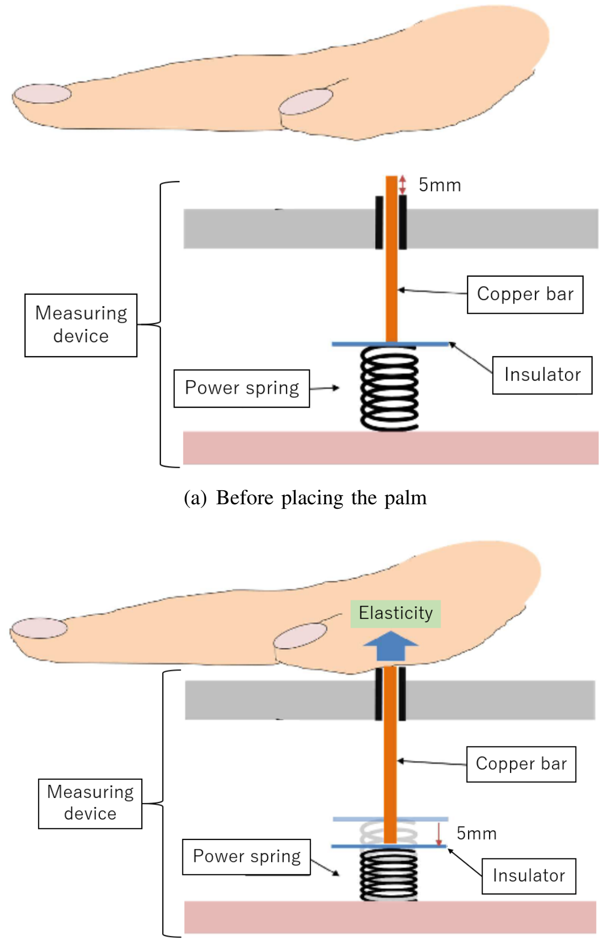
Fig. 4. New measurement device.

contact pressure with the electrode using the elastic force of a spring (Fig. 4). Users place their right hand so that the middle finger comes between the guides. The mechanism of this measurement device is shown in Fig. 5. Before placing the palm on the device, the spring installed at the bottom of the device is fully extended, as shown in Fig. 5 (a). When placing the palm on the device, the spring contracts, as shown in Fig. 5 (b), and the electrodes are pressed against the palm by the elastic force generated by the spring. As the distance of the spring contraction is $5\,\mathrm{mm}$, the elastic force is constant regardless of the person. This makes the contact pressure uniform for each measurement.

V. Ingenuities for more detailed performance evaluation

As phase is relative, it is not possible to obtain the phase spectrum based on only the signal after propagation. Therefore, we have used the second-order-difference phase spectrum. However, if we can obtain the signal before propagation synchronized with the signal after propagation, we can obtain the true phase spectrum. We refer to this phase spectrum as the synchronous phase spectrum for convenience and use it as a reference for evaluating discrimination performance.

In addition, we try to separate shape and quantity features from the spectrum and evaluate them separately. To extract the shape features of the spectrum, we use a normalization method known as Z-score, which converts the mean of the population to 0 and the standard deviation to 1. In general, normalization is used for relative evaluation. It helps compare differences in spectral shape regardless of the amount of spectrum. The quantitative characteristics of a spectrum are defined by taking



(a) Before placing the palm

(b) After placing the palm

Fig. 5. Structure of the new measurement device.

the average of the spectra in a certain band. For example, if we consider the average of all the spectral bands, we obtain one quantitative feature. In this study, we evaluate three cases by varying the number of band divisions to 1, 5, and 10. This facilitates the comparison of features as absolute quantities, regardless of differences in the spectral shape.

VI. Experiment and evaluation

A. Measurement conditions

The number of experimental subjects was 17. The measurement was performed twice a day for 10 days at a minimum interval of 4 hours, and as a result, there were 20 data per subject. From the 20 data, 10 data were used for making a template and 10 were used as test data.

B. Verification results

Using the aforementioned features, we performed personal verification using the Euclidean distance. The results are listed in Table I, where the Equal Error Rate (EER) are given. The EER is generally used for evaluating the biometrics performance. Smaller EER indicates better performance. We can observe that the amplitude spectrum is improved by $4\,\%$,

TABLE I

EER[%] BY A SINGLE FEATURE

Features	EER[%]	Conventional EER[%]
Amplitude spectrum	27.8	31.9
Amplitude spectrum shape	32	
Amplitude spectral quantity (1 division)	29.4	
Amplitude spectral quantity (5 divisions)	28.2	
Amplitude spectral quantity (10 divisions)	27.8	
Synchronous phase spectrum	30.0	
Synchronous phase spectrum shape	31.6	
Synchronous phase spectrum quantity (1 division)	30.6	
Synchronous phase spectrum quantity (5 divisions)	30.0	
Synchronous phase spectrum quantity (10 divisions)	30.0	
Second-order difference phase spectrum	45.9	
Second-order difference phase spectrum (5 dimensions)	26.7	35.6

and the second-order differential phase spectrum is improved by 9％ by using the new propagation signal and measurement device. The numbers of subjects in this study and the previous study are different; however, it can be implied that the improvements in the proposed signal, and measurement device have a general effect. For the amplitude and synchronous phase spectra, the EER was smaller for the quantity features than for the shape features, indicating that the quantity features were more effective for discrimination.

VII. Conclusion

We have studied the intra-palm propagation signal as a new biometrics. However, there were two problems in our conventional approach. One was the influence of quantization errors of a AD converter on the propagated signal, and the other was the fluctuations of contact condition in a measuring device. To avoid the influence of quantization errors, we proposed a new signal whose phase is adjusted for each frequency, such that it does not become negligible. To obtain stable contact condition of the palm to the measurement device, a new measuring device was developed, such that the contact pressure between the palm and the electrode would be constant during the measurement. Furthermore, we introduced a synchronous phase spectrum for a reference and classified the spectral features based on shape and quantity for evaluation. The results showed that the EER based on the Euclidean distance was improved in the amplitude spectrum and the second-order differential phase spectrum. The quantitative features were found to be more effective than the shape features on the discrimination performance. In future, we will aim to improve the verification performance by integrating multiple features.

References

[1] I. Nakanishi, T. Inada, and Y. Sodani, “Performance Evaluation of Intra-Palm Propagation Signals as Biometrics,” Proc. of 2013 International Conference on Biometrics and Kansei Engineering (ICBAKE2013), pp. 91-94, Jul. 2013.

[2] I. Nakanishi, I. Ogushi, R. Nishi, and T. Murakami, “Effect of propagation signal and path on verification performance using intra-body propagation signals,” Proc. of 2017 International Conference on Biometrics Engineering and Application, pp. 50-54, 2017.

[3] International Commission on Non-Ionizing Radiation Protection. “Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz),” Health physics, Vol. 74, No. 4, pp. 494-522, 1998.

[4] K. Fujita, Y. Ishimoto, and I. Nakanishi. “Person Verification Using Intra-Palm Propagation Signals with A New Phase Spectrum,” 12th International Conference on Knowledge and Smart Technology (KST2020), pp. 86-90, 2020.

[5] Bennett, William Ralph. “Spectra of quantized signals,” The Bell System Technical Journal, Vol. 27, No. 3, pp. 446-472, 1948.