Fusion of Amplitude and Phase Spectra in Person Authentication Using Intra-palm Propagation Signal

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***Abstract*—In this study, person authentication is performed using intra-palm propagation signals. This system detects leakage electric fields that occur when an electric current is passed through electrodes placed on the palm, and verifies individuals by these signals. In previous studies, the amplitude and phase spectra were extracted as individual features, and each was verified by machine learning. In this paper, we propose to fuse the amplitude and phase spectral features of an intra-palm propagation signal for verification using machine learning with dimensionality reduction based on variance ratio. Cross-validation is also introduced to improve the reliability of the verification performance.**

I. INTRODUCTION

In recent years, biometric authentication has become a popular method of person authentication. Unlike passwords and physical keys, biometric authentication has the advantage of not being easy to forget or lose, and does not require the user to keep it with him/her at all times. However, authentication using biometric information exposed on the surface of the body is susceptible to forgery. In addition, conventional authentication is one-time-only authentication at the start of use, so it cannot handle a change of users after authentication. To solve these problems, we have studied person authentication techniques using the intra-palm propagation signal [1]-[3], which is a novel biometric modality based on the intra-communication technology [4]. Recently, similar research inspired by our work has been conducted [5].

In this paper, we propose to fuse the amplitude and phase spectral features of an intra-palm propagation signal for verification using Support Vector Machine (SVM) with dimensionality reduction based on variance ratio, which is superior to Principal Component Analysis (PCA). Cross-validation is also introduced to improve the reliability of the verification performance.

II. PERSON AUTHENTICATION USING INTRA-PALM PROPAGATION SIGNAL

A. Intra-Palm Propagation Signal

In Fig. 1, three electrodes are placed in contact with the palm, and a current is applied to the electrodes on the transmitter side. This generates a leakage electric field around the electrodes, which propagates through the palm and is detected as a change in voltage at the receiver side. This is called intra-palm propagation signal [1].

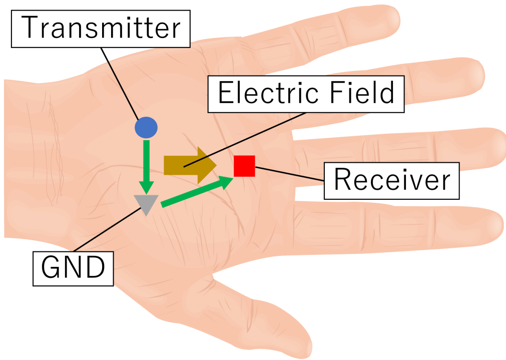

Fig. 1. Intra-palm propagation signal

B. Feature Extraction

The Fast Fourier Transform (FFT) is applied to the propagation signal to extract the amplitude and phase spectra. Each spectrum is then smoothed by ensemble averaging. Since the propagated signal is not synchronized with the signal before propagation, even if they are the same, the different timing of cutout for FFT in them causes the different phases. In other words, the phase spectrum cannot be obtained in a nonsynchronized environment.

Therefore, the second-order difference between the adjacent phase spectra is called the second-order difference phase spectrum, and is used instead of the phase spectrum [2]. In this study, we concider second-order difference phase spectra as phase spectra.

C. Dimensionality Reduction by Variance Ratio

The extracted spectral features are used for verification of users by SVM, a type of supervised learning. However, the verification performance by SVM may be deteriorated when the number of dimensions of the data is large. Therefore, the number of dimensions is reduced using the variance ratio. At each frequency bin, an inter-individual variance is calculated from spectral values of all users and an infra-individual variance is calculated from spectral values of each user. If the ratio of the inter-individual variance to the infra-individual variance is larger than one, it suggests that the frequency bin is effective for verifying individuals. Thus, only the frequency bins of which the ratio is larger than one in all users are used for verification. In general, PCA is used for dimensionality reduction, but this method was confirmed to be superior to PCA.

D. Verification

The SVM verifies individuals using the dimensionality-reduced features. Since the SVM is a two-class classifier that finds the separation boundary that maximizes the distance between two classes, it must be extended when applied to multi-class classification problems such as distinguishing a user from other users. Therefore, one-versus-one (1vs1) SVM is basically applied. In the learning stage, one 1vs1 SVM model is learned to distinguish one user form another user, and the 1vs1 SVM models for a user are generated as many as the number of other users. The 1vs1 SVM models for each user are prepared for all users. In the verification stage, whether a user is genuine or not is verified using SVM models related to the user. Final decision is made based on the majority voting of the verification results of the SVM models. If the number of SVM models which decide the user is genuine is greater than a threshold which is preliminary determined, the user is regarded as genuine.

E. Fusion

Total decision is performed by the three fusion methods: feature-, score- and decision-level fusion.

1) Feature-level Fusion: Feature-level-fusion is the method that fuses two features; the amplitude and phase spectra, which are simply concatenated and used for training and verification by SVM.

2) Score-level Fusion: Score-level-fusion is the method that fuses two scores by verification using SVM in the amplitude and phase spectral features. In this study, weighted average operation is applied, in which the scores from the amplitude and phase spectral features are weighted and averaged.

3) Decision-level Fusion: Decision-level-fusion is the method that fuses the verification results by SVM in the amplitude and phase spectral features. In this study, AND and OR operations are applied for the decision-level fusion. In AND fusion, the user is regarded as genuine when both decisions of two features declare that the user is genuine. In OR operation, the user is regarded as genuine when at least one decision declares that the user is genuine.

F. Evaluation

The Equal Error Rate (EER), where the False Acceptance Rate (FAR) is equal to the False Rejection Rate (FRR), is used for evaluation of verification performance. The FAR is a ratio of the number of cases, where other users are mistakenly accepted as a genuine user to the number of cases, where other users are verified. The FRR is a ratio of the number of cases, where genuine users are mistakenly rejected as forgers to the number of cases, where genuine users are verified. The smaller the EER is, the better the verification performance.

G. Introducing Cross-Validation

In our previous study [2], the combination of measured signals used for learning and verification has been fixed. However, the verification performance obtained might depend on the combination. Therefore, we introduce cross-validation, where the combination of measured signals for learning and verification is randomly changed in each evaluation. The evaluation is performed several times and the average of EERs obtained in all evaluations is used as the EER.

TABLE I
EER AFTER INTRODUCING CROSS-VALIDATION

Feature	EER(%)
Amplitude Spectrum	**30**
Phase Spectrum	**25**

TABLE II
EER WITH FEATURE-LEVEL FUSION

Fusion Method	EER(%)
Concatenation	**28**

TABLE III
EER WITH SCORE-LEVEL FUSION

Ratio(Amplitude : Phase)	EER(%)
0.5 : 0.5	**27**
0.45 : 0.55	**27**
0.3 : 0.7	**26**
0.1 : 0.9	**26**

TABLE IV
EER WITH DECISION-LEVEL FUSION

Fusion Method	EER(%)
AND	**20**
OR	**31**

III. EVALUATION OF VERIFICATION PERFORMANCE

The database of intra-palm propagation signals measured in the previous study [3] was used.

A. Cross-Validation

Table I shows the EERs from the amplitude and phase spectra when cross-validation is introduced. Ten cross-validations were performed in this case.

B. Feature-level Fusion

Table II shows the EERs by feature-level fusion. As a result, the verification performance was not improved.

C. Score-level Fusion

Table III shows the EERs by score-level fusion. As a result, the verification performance was not improved.

D. Decision-level Fusion

Table IV shows the EERs by decision-level fusion. As a result, the verification performance was improved by AND fusion. Conversely, the verification performance degraded with OR fusion.

E. Consideration

The result in decision-level fusion suggests that in performance evaluation using each feature, it is more likely that persons who were not genuine users were mistakenly accepted than that genuine users were rejected; therefore, regarding users as genuine only when both features considered the users genuine improved the verification performance. On the other hand, to regard users as genuine when at least either of two features considered the users genuine degraded the verification performance. Therefore, other fusion methods were ineffective in this study.

IV. CONCLUSION

In this paper, we proposed to fuse the amplitude and phase spectral features of an intra-palm propagation signal for verification using SVM with dimensionality reduction based on variance ratio, which is superior to PCA. Cross-validation was also introduced to improve the reliability of the verification performance. As a result, the EER was improved by 5% comparing with those by each single feature in the case of AND fusion. In the future, we will examine other fusion methods to further improve the verification performance. In addition, we are currently rebuilding the database, and will reevaluate the verification performance as soon as it is completed.

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