Evaluation of Independence between Palm Vein and Fingerprint for Multimodal Biometrics

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Abstract: Multimodal biometrics provides high recognition accuracy and population coverage by combining different biometric sources. However, some multimodal biometrics may obtain smaller-than-expected improvement of recognition accuracy if the combined biometric sources are dependent in terms of a false acceptance by mistakenly perceiving biometric features from two different persons as being from the same person. In this paper, we propose our multimodal biometric prototype that captures a palm vein and three fingerprints simultaneously and we evaluate whether or not their combination is statistically independent. By evaluating false acceptance using the palm vein images and the fingerprint images collected with our prototype, we confirmed that the combination of the palm vein and the fingerprints is almost independent.

1 Introduction

Biometrics is a technology used to automatically identify individuals using physiological or behavioral features such as fingerprints, faces, veins, irises and hand geometry. In particular, the biometric identification technique (one-to-many matching) is remarkable as a key technology for the further expansion of the use of biometrics. Not only is it useful for users because they can be authenticated without the need for ID cards/license cards, but it can also prove that one person is unique among persons registered on a system. Therefore, in some developing countries where resident card and resident registration systems have not been completed, biometric systems are being introduced in order to manage all residents as identified individuals. In India, progress is currently being made with a unique identification project that provides identification for each resident across the country by collecting facial images, ten fingerprints and two iris images in addition to biographical data consisting of name, address, gender and date of birth [UIDAI12]. Identifications are supplied by proving that a resident is unregistered using one-to-many matching with collected biometric data. In Kenya, advances are being made with a feasibility test for the Health and Demographic Surveillance System (HDSS) by using palm vein and finger vein authentication [K11]. In these systems, the

biometric identification technique is applied in order to find duplicated registrations of individuals and to link records in the same data between different systems. Thus, the biometric technology enables those developing countries to link each resident to identification, and then it will contribute to early development of medical services and social infrastructures. In these cases, there is a need for biometric techniques with greater accuracy that can identify from one million to one billion persons for one country.

Multimodal biometrics integrating evidence from different biometric sources is often used in order to obtain high recognition accuracy. This has two types of combination of biometrics. One of these is simply to combine more than one existing biometric technique. For example, the Indian Unique Identification project employs face, fingerprint and iris recognitions. In addition, various combinations of existing biometric techniques have been investigated by many researchers [RNJ06]. On the other hand, in recent years there has been an increase in multimodal biometric techniques simultaneously capturing different biometric sources. For example, a whole-hand imaging system capturing fingerprints and palmprint simultaneously has been proposed [RUDP07]. A multimodal biometric prototype capturing hand vein, hand geometry, and fingerprint has also been proposed [SJR08]. This requires input from both hands. The fingerprints and hand geometry are captured from the right hand, while the dorsal hand vein (back of the hand) is captured from the left hand. In addition, there has been a proposal for a multimodal biometric technique capturing finger vein, fingerprint, and the shape of a finger [KPYK11]. These techniques can make the biometric systems more accurate without reducing their usability to input several biometric sources.

However, some multimodal biometrics confront various difficulties, if the combined biometric sources are dependent in terms of a false acceptance by mistakenly perceiving biometric features from two different persons as being from the same person. The biometric sources in multimodal biometrics are often assumed to be statistically independent in order to simplify the design of the fusion algorithm. Thus, those systems may obtain smaller-than-expected improvement of recognition accuracy (false acceptance rate: FAR). There have been some researches into the effects on the FAR caused by the dependence of biometric sources [NRJ09], [KWSD00], [KVP07]. On the contrary, if the combined biometric sources are independent, the FAR of their multimodal biometrics can be more easily estimated. For example, it is estimated by using a product of their FARs on the “AND” rule or a summation of them on the “OR” rule at the decision level fusion. To prove the independence between the combined biometric sources is very significant in terms of the design of the multimodal biometric systems. Especially, we are also able to estimate the FAR in the large-scale identification where it is difficult to evaluate it experimentally by collecting the real datasets.

In this paper, we show 1) a multimodal biometric prototype capturing a palm vein and fingerprints at the same time that we developed, and 2) evaluation results of statistical independence between the palm vein and the fingerprints using a dataset collected from 1,032 persons with our prototype. Finally, we confirmed that this combination of the palm vein and the fingerprints is suitable for multimodal biometrics.

2 Multimodal Biometric Prototype

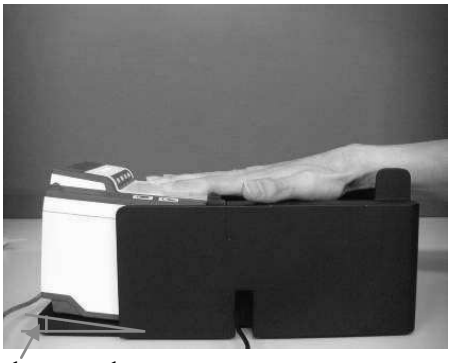
Figure 1 shows the structure of the capturing device to simultaneously obtain the palm vein and the fingerprints of a single hand. A palm vein image is acquired using the PalmSecure™ Sensor[1] developed by FUJITSU FRONTECH [FF112]. The deoxidized hemoglobin in the vein vessels absorbs light having a wavelength of about 760 nm within the near-infrared area. When the infrared ray image is captured, only the blood vessel pattern containing the deoxidized hemoglobin is visible as a series of dark lines. The PalmSecure™ sensor can capture the blood vessel pattern of the palm using near-infrared (NIR) light [W08]. A fingerprint image is acquired using an L Scan Guardian F sensor, which is an optical fingerprint sensor and developed by CROSSMATCH TECHNOLOGIES [CT12]. This fingerprint sensor is most widely used at borders around the world.

In order to capture the palm vein and the fingerprints at the same time, both sensors are deployed as shown by Figure 1 (a). A hand guide is attached on the left, right and bottom of the palm vein sensor at the same level as the fingerprint sensor in order to hold the hand horizontally. A finger guide is attached on the bottom of the fingerprint sensor in order to control direction of the fingers. In our device, symmetrically placed index, middle and ring fingerprints are captured simultaneously so that the fingerprints can be acquired from both left hand and right hand, as shown in Figure 1 (b). In addition, good palm vein images can be obtained together with capturing the fingerprints, since tilting the fingerprint sensor at a 5-degree angle (Figure 1 (c)) means that the fingerprint images can be obtained without any need to strongly press the fingers.

[1] The model name of PalmSecure™ Sensor is FAT13M1S1.

(a)

(b)



(c)

Figure 1: The proposed capturing device: (a) structure of the device, (b) example of capturing a hand (upper side), (c) example of capturing a hand (left side)

3. Evaluation of Independence between Palm Vein and Fingerprints

3.1 Approach of independence evaluation

This section explains our approach to statistically evaluating the independence between the palm vein and the fingerprint. $P(I_{pv})$ and $P(I_{fp})$ are the FAR of the palm vein and the fingerprint respectively, where these I_{pv} and I_{fp} represent false acceptance based on given thresholds of the palm vein matching and the fingerprint matching. If the following equation is true, we can confirm that the palm vein and the fingerprint are independent.

$$P(I_{pv} \cap I_{fp}) = P(I_{pv})P(I_{fp}) \tag{1}$$

The $P(I_{pv} \cap I_{fp})$ is a probability that the false acceptance in both the palm vein and the fingerprint occurs concurrently. The equation (1) is rewritten using their conditional probability as follows.

$$P(I_{pv}|I_{fp}) = P(I_{pv}) \quad \text{or} \quad P(I_{fp}|I_{pv}) = P(I_{fp}) \tag{2}$$

The $P(I_{pv}|I_{fp})$ is the probability that the false acceptance of the palm vein also occurs when the false acceptance of the fingerprint occurs, while the $P(I_{fp}|I_{pv})$ is the probability that the false acceptance of the fingerprint also occurs when the false acceptance of the palm vein occurs.

In this paper, we confirm the independence between the palm vein and fingerprints by evaluating the equation (2) using experimental results of the FARs of the palm vein matching and the fingerprint matching.

3.2 Experimental results

We were not able to locate any available database consisting of the palm vein images and the fingerprints images captured simultaneously, so the images for the evaluation were collected with the capturing device shown in Figure 1. The palm vein images were acquired from both hands of 1,032 persons that were collected based on the gender and age distribution of Japanese population, and 12 images were simultaneously acquired per hand. The palm vein images have one palm vein pattern, while the fingerprint images have three fingerprint patterns from the index, middle and ring finger. Four images per hand are used as templates, and the remaining eight images were used for test samples. In order to calculate $P(I_{pv})$ and $P(I_{pv}|I_{fp})$, matching scores are obtained by performing the palm vein matching and the fingerprint matching across all the pairs of two different persons using these images. We used a customized matching algorithm based on the

PalmScure^{TM} SDK developed by FUJITSU FRONTECH [FF212] for the palm vein matching and our original fingerprint matching software that is based on minutiae matching for the fingerprint matching. Both matching scores indicate similarity where matching pairs having higher scores are more similar, and are normalized by using the min-max normalization. The number of matching scores is 7,606,451. This number is less than the calculated value because some images with operation mistake were removed by visual checks.

Figure 2 shows the scatter plot of matching scores from the palm vein and the fingerprint of the middle finger. The x axis indicates the fingerprint matching score, and the y axis indicates the palm vein matching score. Both of the two matching scores are mostly distributed in lower score areas. There are some plots having either higher score of fingerprint matching or palm vein matching, while there are very few plots having both higher scores. Figure 2 shows that the dependence of the palm vein and the fingerprint is mostly low.

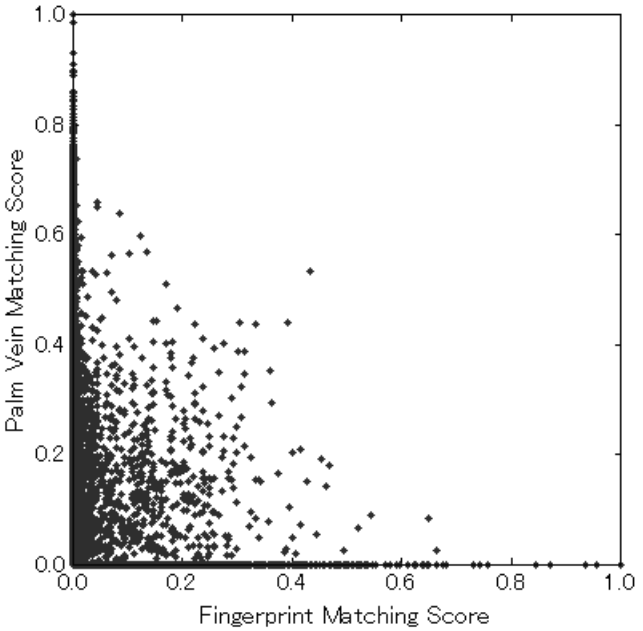


Figure 2: Scatter plot of matching scores from the fingerprint of middle finger and the palm vein. These matching scores are obtained by matching between two different persons.

Figure 3 shows the evaluation result of independence between the palm vein and the fingerprint of the middle finger. These plots indicate $P(I_{pv})$ and $P(I_{pv}|I_{fp})$. The x axis indicates the threshold of the score that provides FAR, while the y axis indicates $P(I_{pv})$

and $P(I_{pv}|I_{fp})$ provided by each score threshold. These FARs are shown as relative ratios of each FAR divided by $P(I_{pv})$ for the sake of simplicity. From Figure (3), these plots of $P(I_{pv}|I_{fp})$ at $P(I_{fp}) = 1\%$ and $P(I_{fp}) = 0.1\%$ are close to the plot of $P(I_{pv})$. Similar results were also obtained for the index and ring fingerprints. Thus, we were able to confirm that the palm vein and the fingerprints were statistically independent.

In addition to the experiment described above, independence between the ring and middle fingerprints was evaluated in accordance with the same rules. In general, it is said that a pair of fingerprints from neighboring fingers will be dependent. This evaluation result is shown in Figure 4. The $P(I_{fp,ring}|I_{fp,middle})$ are higher than $P(I_{pv}|I_{fp})$ in Figure 3 across each threshold. Furthermore, the $P(I_{fp,ring}|I_{fp,middle})$ becomes larger, as the $P(I_{fp,middle})$ decrease from 1% to 0.1%. We found that the pair of neighboring fingerprints is sometimes dependent. Similar results were also obtained in the evaluation of index and middle fingers.

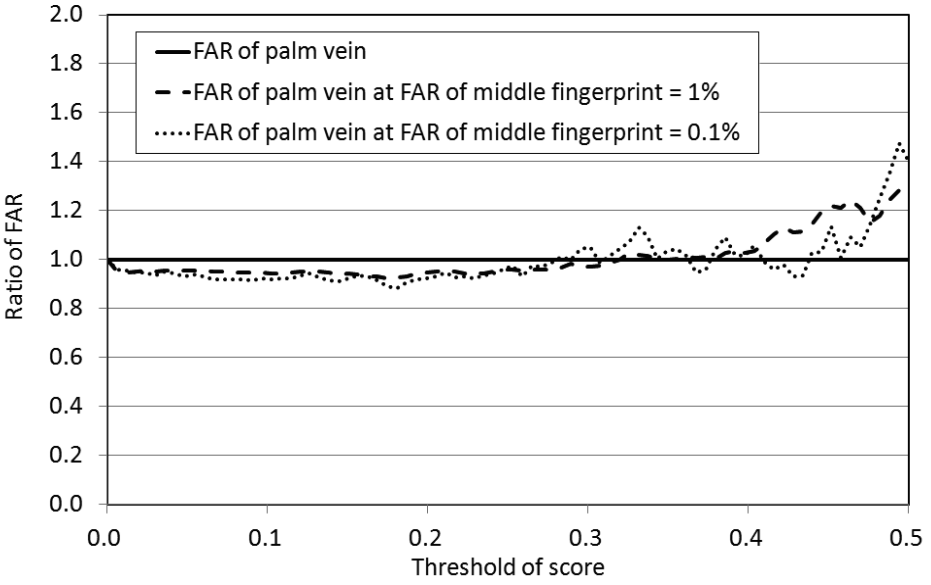


Figure 3: Evaluation results of independence between palm vein and middle fingerprint.

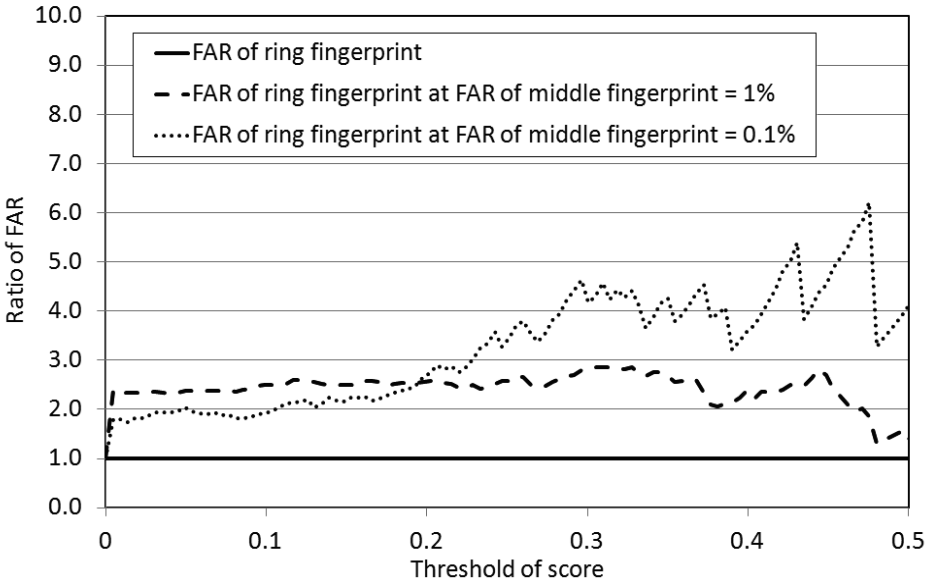


Figure 4. Evaluation results of independence between ring fingerprint and middle fingerprint.

4. Conclusions

We have proposed a multimodal biometric prototype that simultaneously captures the palm vein and the fingerprints, and we have evaluated their independence. By evaluating the false acceptance obtained by matching all the pairs of two different persons using the palm vein images and the fingerprint images collected with our prototype, we were able to confirm that the combination of the palm vein and the fingerprints was mostly independent. It also has lower dependence than the combination of neighboring fingerprints. In addition to their independence, the palm vein and the fingerprint sensors are able to capture good images without any interference simultaneously, because their capturing regions, the palm and the fingers, are located nearby in a same hand but are different. Thus, this combination of the palm vein and the fingerprints is suitable for multimodal biometrics.

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