Palm vein authentication

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Abstract.

This chapter discusses the palm vein authentication, which uses the vascular patterns of the palm as personal identification data. The palm vein information is hard to duplicate since veins are internal to the human body. The palm vein authentication technology offers a high level of accuracy, and delivers the following results: a false rejection rate (FRR) of 0.01% and a false acceptance rate (FAR) of less than 0.00008%, using the data of 150,000 palms. Several banks in Japan have used the palm vein authentication technology for customer identification since July 2004. In addition, this technology has been integrated into the door security systems and more.

1 Introduction

Palm vein authentication is one of the vascular pattern authentication technologies. Vascular pattern authentication includes vein pattern authentication using the vein patterns of the palm, back of the hand or fingers as personal identification data, and retina recognition using the vascular patterns at the back of the eye as personal identification.

The vascular pattern used in this authentication technology refers to the image of vessels within the body that can be seen as a random mesh at the surface of the body. Since everyone has vessels, vascular pattern authentication can be applied to almost all people. If vascular patterns were compared to the features used in other biometric authentication technologies, such as the face, iris, fingerprint, voice, and so on, the only difference would be whether or not the feature is at the surface of the body. Consequently, vascular patterns cannot be stolen by photographing, tracing, or recording them. This means that forgery would be extremely difficult under ordinary conditions.

Vein patterns are unique to each individual; even identical twins have different vein patterns. Furthermore, vein patterns do not change within a human's lifetime except in the case of injury or disease. Although these facts have not been medically proven, as with the fingerprint, iris, and so on, experimental results based on extensive data and large-scale practical results obtained from financial institutions prove that palm vein authentication has the merits of consistency and high accuracy for confirming a person's identity.

Among the vascular authentication technologies, retina recognition was the earliest to be studied. After the first paper (Simon and Goldstein 1935) was published in the US, a patent (Hill 1978) was disclosed and Eyedentify Inc. in US presented a product in 1984.

A patent of hand vein authentication was also disclosed in 1987 by Joseph Rice (Rice 1987) in the UK. The first device for palm vein authentication was presented by Advanced Biometrics, Inc. in the US in 1997, and in 2003, a remarkable contactless device was released by Fujitsu in Japan. Contactless palm vein authentication was introduced to Japanese financial institutions in 2004 to confirm the identification of customers. This was the first major application in Japan in which a private enterprise adopted biometric authentication for a service related to the general public.

2 Sensing and matching

2.1 Palm area
Veins are located everywhere in the human body. The parts used for vein authentication are all in the hand; the palm (Watanabe, Endoh, Shiohara and Sasaki 2005), the back of hand (Im, Park, Kim, Chung and Choi 2000), and the ventral side or dorsal side of the fingers (Kono, Ueki and Umemura 2002).

As a wide area and complex vein pattern are needed for the identificaiton process, the palm area is the best choice. Other parts of the hand could be used if authentication accuracy were increased by fixing the part to the sensor so as to maintain the capture repeatability rate and reduce the search space for matching in the case of
insufficient information for identification.

Another merit of the palm area, compared to the back of the hand or the dorsal side of the finger, is that the palm normally has no hair and thus eliminates an obstacle to capturing the vein pattern.

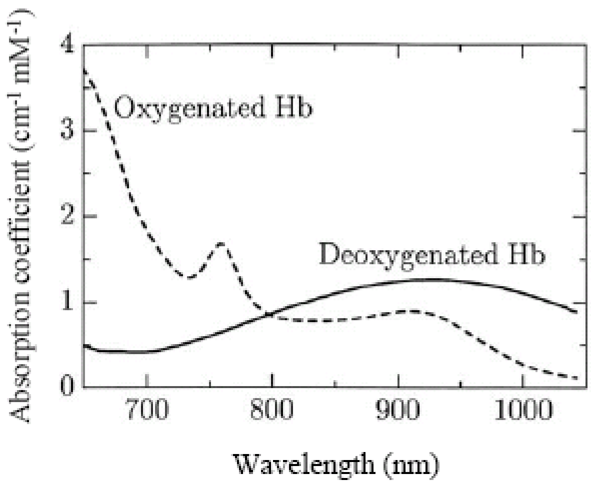

Fig. 1. Absorption spectra of hemoglobin; Adapted from (Wray, Cope, Delpy, Wyatt and Reynolds 1988) by Shimizu, K., Hokkaido University.

2.2 Sensing

The sensing technology used for vein patterns is based on near-infrared spectroscopy (NIRS) and imaging, and has been developed through *in vivo* measurements during the last 10 or so years (Kim, Xia and Liu 2005). That is, the vein pattern in the subcutaneous tissue of the palm is captured using near-infrared rays.

Blood conveys oxygen by means of the hemoglobin contained in it; the hemoglobin becomes oxygenated when oxygen attaches to it at the lungs, and it becomes deoxygenated when oxygen is lost at peripheral vessels in the body. In short, arteries contain oxygenated hemoglobin and veins contain deoxygenated hemoglobin. The two types of hemoglobin have different absorption

spectra (Wray, Cope, Delpy, Wyatt and Reynolds 1988; Cope 1991).
Deoxygenated hemoglobin in particular absorbs light having a wavelength of about 760 nm within the near-infrared area (Fig. 1). When capturing a body using near-infrared rays, the vessels will appear darker than other parts because only the vessels absorb the rays (Fig. 2).

Fig. 2. Infrared ray image of palm

The principle of capturing the vein pattern is easy to understand by thinking of the body as a murky lake. The near-infrared ray shining on the body penetrates the surface, and the reflected light disperses throughout the body and escapes to the outside. However, the light in the veins cannot escape because it has been absorbed.
This means that the parts in which the veins lie will appear darker than the other parts.

The shadows of veins lying near the surface can be seen, but those lying deeply cannot be seen, similar to an object lying in a murky lake. For example, the depth at which a 1-mm-diameter vessel can still be seen is about 3 mm in the case of imaging using near-infrared rays having a wavelength of 880 nm (Editorial Board for Visualization Techniques of Biological Information 1997). Therefore, only the veins on the capturing side can be seen regardless of the direction and position of the nearinfrared ray illumination; the palm vein pattern can be seen if it is captured from the palm side; the vein pattten of the back of the hand can be seen if it is captured from the back side of the hand. Similarly, even in the case of finger veins, only the ventral vein pattern can be seen if it is captured from the ventral side of the finger and only the dorsal vein pattern can be seen if it is captured from the dorsal side. Using the same principle, arteries are likely to be located deeper in the body than veins and can barely be seen in comparison.

There are two imaging methods used for veins; reflection and transmission. The reflection method illuminates the target part from the front and the transmission method illuminates the target part from the back, the side or the surface around the target. As the imaging principles differ between the two methods, the configuration of vein pattern capturing devices also differs.

In the reflection method, an illumination device and a capturing device can be combined because the direction of illumination and capturing is the same, but in the transmission method, those devices must be used separately because the direction of illumination and capturing differs. This would result in a smaller vein sensor using the reflection method compared to the one using the transmission method, and the vein sensor would have a three dimensional shape if the reflection method is adopted. For this reason, the palm vein sensor (Fig. 3) adopts the refelection method.

The palm vein sensor (Fig. 3) measures 35 mm deep by 35 mm wide by 27 mm high. Both the illumination device and capturing device are included in this compact sensor. Capture by this sensor is executed in a contactless manner. Users need not touch the sensor; they only have to hold their palm above it. To obtain a clear image of the palm vein pattern of a hand floating in the air, the capturing is controlled according to the movement and height of the hand, while the lighting is controlled according to the illumination around the sensor.

Implementation in a contactless manner takes into consideration the user’s attitude about hygiene and any emotional concerns. It enables application in environments where a high standard of hygiene is required, such as in medical facilities or food factories. In addition, sufficient consideration was given to individuals who are reluctant to come into direct contact with public-use devices.

Consideration was also given to safety; the intensity of the near-infrared ray emitted from the sensor is lower than that in the ‘Light and Near-Infrared Radiation’ guidelines of ACGIH (American Conference of Governmental Industrial Hygienists). The concept of the contactless sensor and its implementation was awarded the ‘Wall Street Journal's 2005 Technology Innovation Award for Security in Networks’ (Totty 2005).

Fig. 3. Contact-less palm vein authentication sensor

2.2 Matching

The palm vein pattern is extracted from infrared-ray images as dark lines. At first, edges are extracted from an infrared-ray image, and an oval shape is fitted to the edges to determine the palm area. The palm vein pattern is expressed as a line drawing which shows the valleys of brightness in the palm area by fitting a short line segment morphologically. Finally, the line drawing is cut at junctions and a feature data of the palm vein pattern is acquired as a set of strokes.

The matching is achieved by finding the best superimposition of a registered data and a data captured for authentication. The criterion of a superimposition is the distance of two line drawings. Distances between pixels composing two line drawings and differences between the directions of strokes of two line drawings are calculated. The best match is searched discretely in a two-dimensional affine space and is adjusted
in a three-dimensional perspective transform space by a linear approximation repeatedly.

The flow of processing is as follows:

Registration

1. Capture
Decide whether or not the user will hold his/her palm over the palm vein authentication sensor. If the palm is held, capture the infrared-ray image.

2. Extraction of palm vein pattern features
Extract the palm vein pattern from the captured infrared-ray image by image processing. Convert the palm vein pattern to palm vein feature data follow-ring the algorithm to determine the correspondence between the two palm vein patterns.

3. Storing of palm vein pattern features
Store the palm vein feature data to storage, smart card or hard disk, depending on the application.

Verification (one-to-one matching)

1. Capture
Decide whether or not the user will hold his/her palm over the palm vein authentication sensor. If the palm is held, capture the infrared-ray image.

2. Extraction of palm vein pattern features
Extract the palm vein pattern from the captured infrared-ray image by image processing. Convert the palm vein pattern to palm vein feature data following the algorithm to determine the correspondence between the two palm vein patterns.

3. Reading out of palm vein pattern features

Read out the palm vein feature data of the user to be verified from the storage, smart card or hard disk, depending on the application.

4. Calculation of similarity scores
Calculate the similarity score between the palm vein feature data that was captured and converted and the data read from storage.

5. Decision of correspondence
The user's identity is confirmed if the similarity score calculated is greater than or equal to the predetermined threshold. The user is considered to be an imposter if the similarity score calculated is lower than the threshold.
For an identification (one-to-many matching), calculate the similarity scores between the palm vein feature data that was captured and converted and multiple of the palm vein feature data registered in data storage, and confirm the identified user as the person whose palm vein feature data has the maximum similarity score.

3 Performance

Using the data of 150,000 palms from 75,000 people, we confirmed that the system has a false acceptance rate of less than 0.00008% and a false rejection rate of 0.01% providing that the hand is held over the device two times during registration. One retry is allowed for comparison during authentication.

In addition, the device's ability to perform personal authentication was verified using the following data: 1) data from individuals ranging from 5 to 85 years old, including people in various occupations, in accordance with the demographics released by the Statistics Center of the Statistics Bureau in Japan; 2) data from foreigners living in Japan in accordance with world demographics released by the UN; 3) data that traces daily changes in the palm vein pattern over several years; and 4) data taken in various situations in daily life, for example, after drinking alcohol, taking a bath, going outside, and waking up.

Palm vein authentication technology was evaluated in Round 6 of CBT, Comparative Biometric Testing, by IBG, International Biometric Group, in 2006. IBG's CBT evaluates the accuracy and usability of biometric products using scenario-based testing, and strives to understand biometric performance under real-world conditions. CBT Round 6 was the first major independent test to evaluate multiple vascular recognition technologies. Such assessments are typically based on a comparison of recognition samples and enrollment templates. In the case of the palm vein authentication, approximately 40,000 genuine comparisons and 50 million imposter comparisons were executed.

Results of the IBG study revealed that the palm vein authentication performed exceptionally well in the failure to enroll (FTE) testing; only one person out of 1,290 did not finish the enrollment process given the test criteria, a failure rate of only 0.08%. This extremely low rate indicates that the palm vein authentication is highly applicable for virtually every individual, and does not impose any physiological restrictions when users interface with the device. Additionally, the palm vein authentication achieved a median Recognition Attempt Duration of 2.13 seconds, significantly lower than that of iris recognition technology. This showing further indicates that the palm vein authentication has high usability, is easy for users to learn, and is ideal for high-volume and large-scale application deployment.

Most importantly, the palm vein authentication fared well when tested for authentication accuracy. The false acceptance rate (FAR) and false rejection rate (FRR) were extremely low, outperforming two competitor products at standard and high security. Performance differences between same-day and different-day transactions were also minimal when compared to other products in the evaluation. Thus, once users learned how to use the device, they were able to use it successfully on an ongoing basis. This data further confirms that the palm vein authentication features high accuracy and optimal usability, both of which are highly relevant to real-world conditions.

4 Implementation

When biometric authentication is more widely adopted, some people may initially feel concerned about how their own biometric data will be supervised. In fact, their own biometric data will not be able to be changed in their life time. This means the user would not be able to utilize biometric authentication any more in their life time if their own biometric data was abused, such as being divulged to other people, copied and utilized.

One management method for palm vein authentication involves storing palm vein feature data to a smart card so that users can manage their own data by themselves. This STOC (Store-On-Card) method provides users with a greater sense of security because having their data stored on the smart card means that it is not supervised by other people. A smart card also has an anti-tamper function as a countermeasure against external attacks. In the authentication matching process, however, the palm vein feature data in the smart card is output, making it more vulnerable. Therefore, the security of the matching process is ensured by encoding the data output and by executing the matching process in a highly secure processing unit that also has antitamper functionality. For even higher security, the MOC (Match-On-Card) method is used, in which the matching process between the palm vein feature data stored on the smart card and the captured and converted data for authentication is executed on the smart card itself.

People may also have concerns over the consequences of losing the smart card in which their palm vein feature data is stored. In actually, however, the palm vein feature data stored on the smart card cannot be accessed or read by others. But to eliminate concerns over losing the card, there is another method whereby the data is stored to a PC or the server of a client-server system. As with the smart card, the palm vein feature data is stored in a storage area that is highly secure with an antitamper function, and the security of the communication lines is also ensured. Moreover, the managers who have access to this data are verified. This method takes into consideration not only the people who worry about losing their smart card but also the people who are not comfortable with the idea of carrying a smart card for biometric authentication.

The two storing methods with and without smart cards bring different advantages to system administrators. In the case of adopting the smart card storing method, the cost to supervise user’s palm vein feature data can be reduced, and in the case of adopting the storing method without a smart card, the cost of a smart card and the labor cost to issue smart cards and reissue lost cards can be reduced.

5 Application

Palm vein authentication is utilized in various scenes such as for the door security system of offices, login management for PCs, access control for the entrance of apartments, and so on. In Japan, as the adoption of palm vein authentication at financial institutions, such as banks, are proceeds, the forecasts by JAISA, Japan Automatic Identificaion Systems Association, state that the shipment of vein authentication devices in 2005 reached 19,000, which is 3.8 times that of the previous year, and the growth in 2006 is expected to reach to 2.5 times as much. Vein authentication is the biometric authentication technology receiving the most attention in Japan compared to other biometric authentication such as fingerprint, iris, and face recognition.

5.1 Door security system

The palm vein authentication access control unit can be used to control entry and exit into and out of rooms and buildings. Figure 4 shows an example of a palm vein access control unit

. **Fig. 4.** Palm vein access control unit

This unit integrates the operation and control sections. The operation section has a key pad, indicators and a contactless smart card reader as well as a palm vein sensor over which the palm is held. The control section has a processing unit for the authentication including storage of palm vein features of enrollees. Because the operation section also issues commands to unlock the door, the system can be introduced in a simple configuration by connecting it to the controller of an electronic lock.

This unit executes verification when a user input his or her ID, and is also able to execute identification between enrollees when a user does not input ID. If ID is input using a contactless smart card for verification, the user does not need to touch this unit at all, because palm vein authentication is also a contactless type.

Palm vein authentication units are used to control access to places containing systems or machines that manage personal or other confidential information, for example, facilities such as machine rooms in companies and outsourcing centers where important customer data is kept.

Because of the present high rate of violent crime, some condominiums and houses have started using this system to enhance security and safety in daily life.

For both of these applications, the combination of the following features provides the optimum system: a hygienic conactless unit ideal for uses in public places, userfriendly operation that requires the user to simply hold a palm over the sensor, and a method that makes impersonation difficult.

5.2 Login authentication

Palm vein authentication can be integrated into laptop PCs by USB (Fig. 5), resulting in downsizing. It is utilized to control access to electronically stored information. Because login authentication using palm vein authentication can also be used for authentication using conventional IDs and passwords, existing operating systems and applications need not be changed. It is also possible to build the sensor into an existing application to enhance operability.

Fig. 5. An example of attachment to laptop PC

In the early stage of introduction, the sensors were limited to business handling personal information that came under the "Act for the Protection of Personal Information" enforced in April 2005 in Japan. However, use of the sensors has been extended to leading-edge businesses that handle confidential information.

5.3 Financial services

Financial damage caused by fraudulent withdrawals using identity spoofing with fake bankcards made using information from stolen or skimmed cards has been rapidly increasing in Japan, and it has emerged as a significant social problem. This has caused a sharp increase in the number of lawsuits taken out by victims against financial institutions for their failure to control information used for personal identification. The "Act for the Protection of Personal Information" came into effect on May 1, 2005, and in response, financial institutions in Japan have been focusing on biometric authentication together with smart cards as a way to reinforce the security of personal identification. Palm vein authentication is the form of biometric authentication most quickly introduced for customer confirmation at banking facilities since July 2004.

In implementation for financial services, a user's palm vein features are registered at the bank window, and are stored on a smart card, which has the advantage of allowing users to carry their own palm vein features and manage the usage of their smart card. Figure 6 shows an ATM with a palm vein authentication sensor. In the verification of an ATM transaction, a user's palm vein pattern is captured through the palm vein sensor on the ATM. The palm vein pattern is converted to palm vein features and transferred to the user's smart card, and then the matching between the palm vein features stored on the smart card and those transferred from the sensor is executed on the smart card. Finally, only the matching result is output from smart card without the user's registered palm vein features.

Besides Japan, Brazil has also already decided to adopt palm vein authentication for user identification in ATM banking transactions. Banco Bradesco S.A.

("Bradesco"), the largest private bank in Latin America, has been testing this financial solution of palm vein authentication. After researching various biometric technologies, Bradesco chose palm vein authentication for its outstanding features, such as having a high level of verification accuracy and being non-invasive and hygienic,
making it easier to be accepted by customers of the bank.

Fig. 6. ATM with palm vein authentication sensor unit

5.4 Others

Palm vein authentication is also applied to the confirmation of students in educational facilities.

Chiba Institute of Technology in Japan deployed the world's first student ID system that combines palm vein authentication technology and multi-functional smart cards to verify the identity of students and enable them to securely access their academic transcripts and other personal records through information kiosk terminals (Fig. 7) installed at various locations on campus.

Fig. 7. Information kiosk terminal with palm vein authentication sensor unit

As the first of its kind in Europe, palm vein authentication is deployed at Todholm Primary School in Paisley, Scotland as an exciting new way to pay for school meals. This pioneering biometric identification system for a school is developed by Yarg Biometrics Ltd. (Yarg) and Fujitsu.

This project is part of the Scottish Executive's "Hungry for Success" initiative to promote the health and social well-being of children in Scotland, with the focus on school meals. The system installation at the primary school addresses the need for a secure non-token or cashless system to provide electronic point of sale (EPOS) for their catering facilities. The system uses pre-registered palm vein patterns from the pupils and staff to manage individual accounts, thereby creating a cashless catering solution. The flexibility of Yarg's PalmReader (Fig. 8) design means that the technology can be expanded to provide leading-edge biometric access control applications to monitor truancy levels to facilitate accurate attendance at classes and overall better time management.

Fig. 8. PalmReader by Yarg Biometrics Ltd.

6 Conclusion

This chapter introduced palm vein authentication, a technology is highly secure because it uses information contained within the body. It is also highly accurate because the pattern of veins in the palm is complex and unique to each individual. Moreover, the contactless feature gives it a hygiene advantage over other authentication technologies. Some examples of financial solutions and product applications for the general market that have been developed based on this technology are also described. Many of our customers highly evaluated this technology and experienced no psychological resistance to using it. This has encouraged us to start developing new products for various solutions, starting with financial solutions followed by access control units and then login units.

7 Contact Information

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