Evaluation on palm vein recognition of children in growing

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***Abstract*— This document reports the investigation result of chronological changes effect in the vein information of growing children between the ages of 4 to 14 who were followed up for up to 12 years. The author studied changes in vein patterns in 20 subjects who were able to observe their veins annually for 12 years and more than five years throughout 12. Hand size was measured as an index of growth and compared the images of the vein patterns on an annual basis. Comparing results of the annual vein pattern images showed that the vein pattern during the growth process gradually changes, and the amount of observable vein information increases. However, the structure of the basic vein pattern remains the same.**

I. Introduction

Biometric authentication is a personal identification technology that identifies individuals based on physical characteristics, such as the face, fingerprints, and iris, and behavioral characteristics, such as voiceprints and signatures. While other personal authentication technologies that use passwords and ID cards pose security risks such as theft, loss, and loan to others, biometric authentication has the advantage that it is difficult to impersonate someone by theft or counterfeiting. As security awareness increases in recent years, biometric authentication technologies are being used in various fields, and it is expected that the scope of the application will expand in the future.

Vein authentication works by comparing the vascular pattern under the skin, which are unique to each individual. Since vascular patterns exist inside the body, vein authentication has some advantages over other biometric techniques:

1. It is less susceptible to changes in the user's hands and environment, such as skin contamination. Thus, stable operation can be realized.
2. The vein pattern, which is the authentication feature, cannot be seen with the visible light usually seen by humans. This means that it is difficult for a malicious third party to steal authentication features without being noticed by the person. This is an essential feature in the authentication field where high security is required.
3. Vein authentication can be performed in a non-contact manner. Users can authenticate without touching the authentication device main body. This is an advantage of hygiene and psychological security in an authentication device used by the public.

Vein information can be obtained from various body parts, but it is currently mainly used in the veins around the hands, palms, fingers, and back of the hands [1]. Here, we focus on the palm vein. The palm vein has the following advantages compared to other parts. First, the palm is larger and has a more random pattern of running blood vessels than the fingers. In addition, compared to the fingers, the palm is less affected by coldness, even in cold weather. As a result, high authentication accuracy can be stably realized without depending on environmental conditions. Compared to the back of the hand, the palm has the advantage of allowing the authentication operation to be performed naturally. In addition, the back of the hand is often blocked by a large amount of body hair, making it challenging to be authenticated, but the palm does not, so it is used for various purposes because anyone can use it. Application to a wider age group, e.g., to a younger age group such as a child, has been desired with the spread of applications.

Facial and fingerprint biometrics have long been the subject of research, and there are some examples of such biometrics that span a wide range of ages. Regarding fingerprints, Jain et al. examined infants' fingerprints, and showed that children even at the age of 0 could be collected and recognized even when they are older [2]. Galbally et al. studied fingerprint quality over a lifetime and showed that fingerprints could be classified into four age groups according to quality [3]. Preciozzi et al. show that fingerprints of children and adults can be matched [4]. As for faces, Ginoya et al. reported on face recognition at different ages, and is conducting a survey including the age of children [5]. There is also a study on facial recognition of very young children such as toddlers and pre-school children [6,7].

On the other hand, the vein pattern is said to be constant throughout life [8], but most tests are for adults, and there are few studies on growing children. Lu et al. reported on constructing a database of finger veins for a wide range of age groups but did not include data for people under ten years [9]. Cao et al. built sensors for the dorsal veins of the hand and collected data from a wide range of age groups. The data set includes about 74 children under the age of six and evaluates the accuracy of authentication for these children [10]. Tome et al. constructed and opened a dataset for the palm vein, but it does not include patients under 18 years of age [11].

A data set is needed to study the palmar veins of children. Few publicly available veins databases [11, 12, 13], and children are not included. We are interested in the palm veins of growing children. So, we collected our own data and analyzed it.

II. DATA ACQUISITION

A total of 20 subjects were recruited each year, mainly at the age of 4 to 14 years during the growth period, and vein images were collected annually for 12 years. However, participants were not always able to participate annually, and they were replaced after age 14. Of the 50 individuals collected over 12 years, 20 individuals for whom data were available for more than five years were used for evaluation. In addition, one individual was selected among them; image vein was observed once a week for eight years from the age of 6 to 13.

A method of capturing a vein image of a data set will be described. No special equipment was used to capture, and general camera and illumination on the market were used. Fig. 1 shows a configuration of a capturing system.

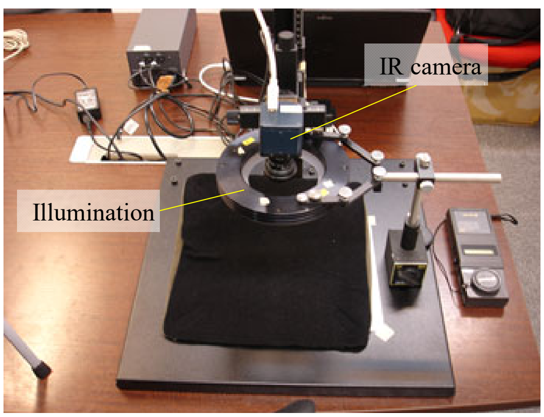


Fig. 1 Capturing system

A USB-connected IR camera with a resolution of VGA or higher and an 850 nm light ring illuminates the palm against a black cloth on a desk. The right and left hands were captured several times separately. Fig. 2 is an example of a vein image captured by the imaging system of Fig. 1.

III. EVALUATION PROCESS

A. overview

The collected vein images are subjected to image processing to extract and compare the vein pattern. The goal is to investigate trends in the children's veins, not to develop algorithms specifically for them. Therefore, the processing methods from extraction to comparison were realized by combining the general algorithm, which is open to the public without any contrivance. The processing method is described below.

Fig. 2 Capturing sample

B. pre-processing

As pre-processing of extraction and comparison of vein patterns, determination of ROI for extraction and key point setting for collation alignment are performed.

In previous studies, a rectangular region was defined as the ROI based on key points [14, 15]. However, because this paper aimed not to investigate local vein information but to investigate chronological changes in vein information of the entire palm, key points were used only for alignment. Following the precedent case, the key points were between the index finger and the middle finger and between the ring finger and the little finger (Fig. 3 (a)). This time, some of the images were not in good condition, so they were automatically determined and then corrected manually. In the following processing, the image size is normalized by the interval of the critical points to normalize the resolution parameters.

To determine the ROI, the hand region is first extracted. Since the image is taken with a black cloth placed on it, the

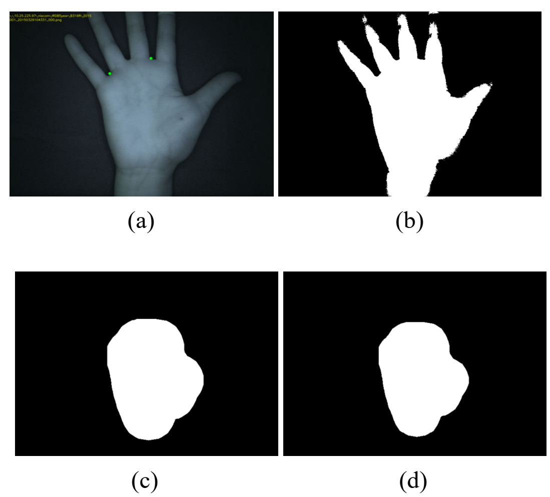


Fig. 3 pre-processing: (a) Key point, (b) binarized image, (c) opening by Morphological Transformations, (d) final ROI by erosion of (c) area of the hand can be determined by simple binarization. The binarization threshold was determined by Otsu's algorithm [16] (Fig. 3 (b)). Then, the fingers and wrists are removed by opening (erosion and dilation) using an elliptical kernel, and a mask of the palm part is created (Fig. 3 (c)). Finally, the mask is eroded by a smaller elliptical kernel to provide a final ROI (Fig. 3 (d)) so as not to capture the contours of the palm in the vein extraction process.

C. *extract vein pattern*

As methods for extracting vein patterns, algorithms using Gabor filters [17, 18, 19] or Miura's algorithm [20, 21] have been proposed. However, in this paper, we extract vein patterns using Sato [23], which is one of the commonly used Ridge filters [22, 23, 24] implemented in the scikit-image library (Fig. 4 (a)).

D. *comparison*

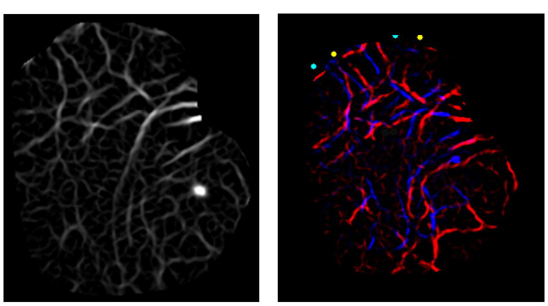
The normalized cross-correlation ZNCC (Zero-mean Normalized Cross-Correlation) between the enrolled pattern and the comparison pattern was calculated. The correlation value obtained was used as an evaluation index. A correlation coefficient R (x, y) is calculated for a comparison pattern image I (x, y) of an image size W × H and a enrolled pattern image T (i, j) of an image size w × h. The maximum value of R (x, y) is set as a correlation value.

$$R(x,y)=\frac{\sum_{j=0}^{N-1}\sum_{i=0}^{M-1}\big((I(x+i,y+j)-\bar{T})(T(i,j)-\bar{T})\big)}{\sqrt{\sum_{j=0}^{N-1}\sum_{i=0}^{M-1}(I(x+i,y+j)-\bar{I})^2\cdot\sum_{j=0}^{N-1}\sum_{i=0}^{M-1}(T(i,j)-\bar{T})^2}} \quad (1)$$

where:

$$\bar{T}=\frac{\sum_{j=0}^{N-1}\sum_{i=0}^{M-1}T(i,j)}{w\cdot h},\ \bar{I}=\frac{\sum_{j=0}^{N-1}\sum_{i=0}^{M-1}I(x+i,y+j)}{w\cdot h}$$

When calculating the correlation value, the position, rotation, and scale are combined by the Affine transformation so that key points of the enrolled pattern and the comparison pattern overlap. However, since the key points include errors due to finger opening or other factors, the highest correlation value is determined as the final value by scanning the position, rotation, and scale from the first aligned position (Fig. 4 (b)).



(a) (b)

Fig. 4 extraction and comparison of vein pattern: (a) extracted pattern by Sato-filter, (b) comparison patterns before alignment

IV. EVALUATION RESULT

Fig. 6 and 7 show the results of hand width and correlation values obtained for 40 hands of 20 persons by the method described above. The hand's width is the value manually measured from the image taken simultaneously with the hand (Fig. 5).

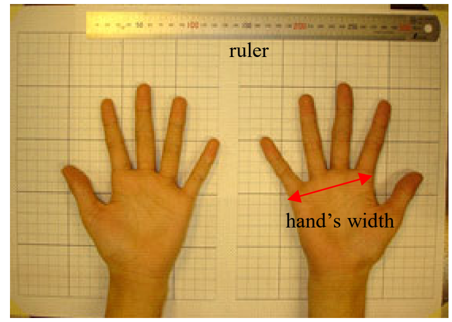


Figure 5. measuring of hand width

The hand width has continued growing throughout the survey period, and the correlation value has also been changing overall. Because the growth of subjects varies with age, and the imaging conditions (hand posture) vary with each sample, annual measurements show large distributions and only general trends, but some changes in the vein pattern occur during the growth of the body, and the correlation value decreases with that changes.

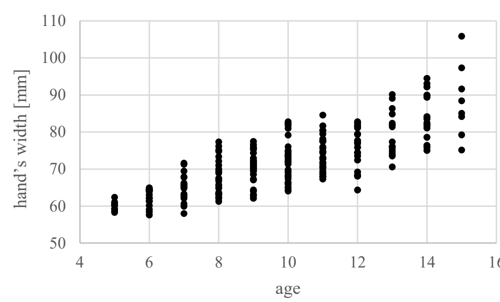


Fig. 6 hand width

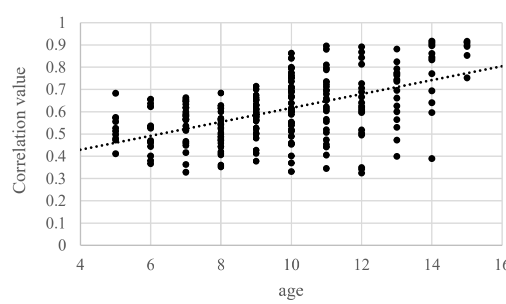


Fig. 7 correlation value

As reference information, Fig. 8 shows a case in which data was collected once a week by picking up only one child. The figure shows that hand width and correlation values change from 5 to 10 and a half years of age, but after that, both hand width and correlation values changeless. Since the data are only for one child, the accuracy is not high, but it can be said to be an example that the change of the correlation value corresponds to the body.

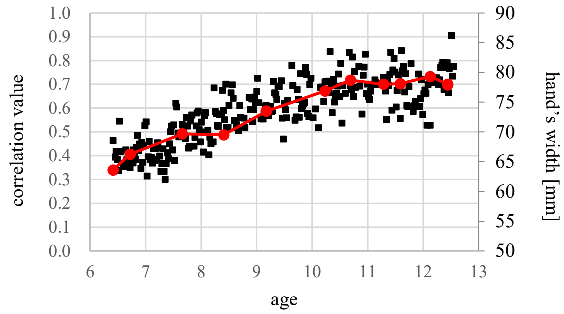
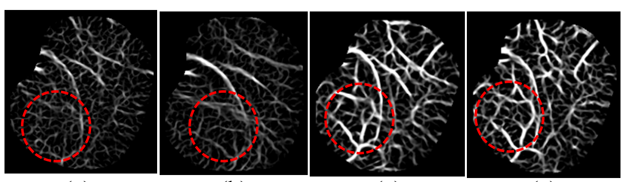


Fig. 8 hand width and correlation value

In order to investigate what kind of change occurs in the vein pattern during the growth process of the body, one case of vein patterns were picked up in Fig. 9.



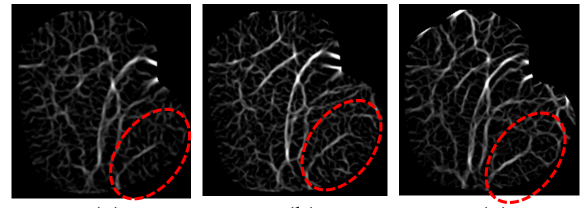
(a) (b) (c) (c)

Fig. 9 an example of extracted vein image: (a) 5 years old, (b) 8 years old, (c) 11 years old, (d) 14 years old

In Fig. 9, vein patterns of ages 5, 8, 11, and 14 were picked up from the observation period of 5 to 14 years of age. Changes can be seen in which veins, which were visible only thinly at an early age, become increasingly evident as they grow. For example, in Fig. 9, the pattern of the portion surrounded by a red circle is gradually clarified. The vein pattern does not change shape but gradually becomes larger, and more observable. In the case of preschool children around five years of age, as shown in Fig. 9 (a), the veins may be underdeveloped and it may be challenging to observe them, but in many cases, they can be observed by the time as they grow.

Another example is shown in Fig. 10. Fig. 10 shows the case of a slightly elder child, picking up the vein patterns of ages 10, 12, and 15 from the observation period of 10 to 15 years of age.

Again, we can see how the vein pattern gradually becomes more distinct. In this case, there is a common vein at all ages, and the structure of this common pattern does not change as it grows, and the veins visible from the beginning can be



(a) (b) (c)

Fig. 10 an example of extracted vein image: (a) 10 years old, (b) 12 years old, (c) 15 years old

identified as it grows. On the other hand, there is a change in which veins, which were seen only thinly at a young age, gradually become evident as they grow. For example, it can be seen that the pattern of the portion surrounded by a red circle in the figure is gradually becoming clear.

It is reasonable to assume that the pattern becomes clear because cardiopulmonary function develops with growth and veins become thicker. However, the exact reason is not addressed in this paper because the medical investigation is required. From the perspective of vein authentication, it is important that the number of veins that can be observed increases with growth and the correlation value changes.

Show the analysis from a different angle. Fig. 11 shows the result of obtaining a correlation value between the data on the same day of enrollment. Figure 12 shows the result of obtaining a correlation value between the data compared after one year from the enrollment. In the same day in Fig. 11,

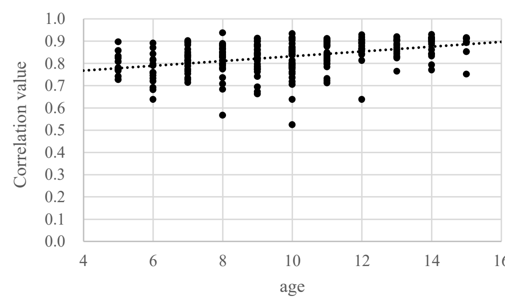


Fig. 11 correlation value against same year template

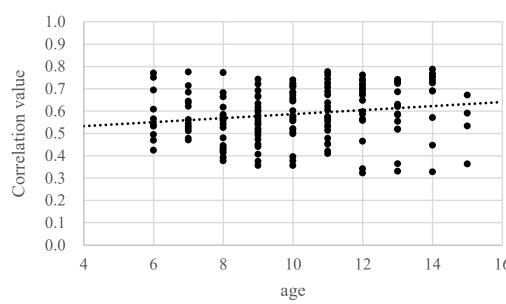


Fig. 12 correlation value after 1 year from enrollment there is a high correlation, but it tends to become more stable as age increases. As shown in Fig. 9 and 10, it can be assumed that the higher the age, the greater the growth and the greater the amount of vein information. Fig. 12 shows that the correlation value has declined significantly after one year. It can be considered that the pattern change (increase), as shown in Fig. 9 and 10, occurs in the growth process, and the correlation value decreases.

V. Conclusion

Twenty subjects aged 5 to 14 years were followed for more than 5 years for the effects of aging on palm vein images.

It was found that the correlation value of vein patterns changed during growth, and the correlation value tended to settle as growth became saturated. Visual inspections of the collected images confirmed that this was because the amount of vein information images became more apparent over time, and the amount of visible vein information increased with growth. However, the structure of the basic vein pattern did not change with growth.

References

[1] ISO/IEC 39794-9:2021 Information technology — Extensible biometric data interchange formats —Part 9: Vascular image data
[2] Anil K. Jain, Sunpreet S. Arora, Kai Cao, Lacey Best-Rowden, Anjoo Bhatnagar, Fingerprint Recognition of Young Children, IEEE TRANSACTIONS ON INFORMATION FORENSICS AND SECURITY, VOL. 12, NO. 7, JULY 2017
[3] Javier Galbally, Rudolf Haraksim, Laurent Beslay, A Study of Age and Ageing in Fingerprint Biometrics, IEEE TRANSACTIONS ON INFORMATION FORENSICS AND SECURITY, VOL. 14, NO. 5, MAY 2019
[4] Javier Preciozzi, Guillermo Garella, Vanina Camacho, Francesco Franzoni, Luis Di Martino, Guillermo Carbajal, Alicia Fernandez, Fingerprint Biometrics From Newborn to Adult: A Study From a National Identity Database System, IEEE TRANSACTIONS ON BIOMETRICS, BEHAVIOR, AND IDENTITY SCIENCE, VOL. 2, NO. 1, JANUARY 2020
[5] Sanskruti D. Ginoya, Harshadkumar B. Prajapati, Vipul K. Dabhi, Survey on Cross-Age Face Comparison, 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS)
[6] Pratichi Basak, Saurabh De, Mallika Agarwal, Aakarsh Malhotra, Mayank Vatsa, Richa Singh, Multimodal Biometric Recognition for Toddlers and Pre-School Children, 2017 IEEE International Joint Conference on Biometrics (IJCB)
[7] Sahar Siddiqui, Mayank Vatsa, Richa Singh, Face Recognition for Newborns, Toddlers, and Pre-School Children: A Deep Learning Approach, 2018 24th International Conference on Pattern Recognition (ICPR)
[8] Masaki. Watanabe. Palm Vein Authentication. In NaliniK. Ratha and Venu Govindaraju,editors, Advances in Biometrics, pages 75–88. Springer London, 2008.
[9] Yu Lu, Shan Juan Xie, Sook Yoon, Zhihui Wang, Dong Sun Park, An available database for the research of finger vein recognition, 2013 6th International Congress on Image and Signal Processing (CISP)
[10] Jie Cao, Weisong Shi, Abdulbaset Salim, Paul Kilgore, MyPalmVein: A Palm Vein-Based Low-Cost Mobile Identification System for Wide Age Range, 2016 IEEE First International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE)
[11] Pedro Tome, Sebastien Marcel, Palm Vein Database and Experimental Framework for Reproducible Research, 2015 International Conference of the Biometrics Special Interest Group (BIOSIG)
[12] https://www.kaggle.com/ryeltsin/finger-vein, accessed in 2021.
[13] https://www.kaggle.com/oboyraz/suas-dorsal-hand-vein-database accessed in 2021.
[14] Yingbo Zhou, Ajay Kumar, Contactless palm vein identification using multiple representations, 2010 Fourth IEEE International Conference on Biometrics: Theory, Applications and Systems (BTAS)
[15] D. Zhang, W. Kong, J. You, and M. Wong, Online palmprint identification, IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 25, no. 9, pp. 1041-1050, Sep. 2003.
[16] N. Otsu, A Threshold Selection Method from Gray-Level Histograms, IEEE TRANSACTIONS ON SYSTREMS, MAN, AND CYBERNETICS, VOL. SMC-9, NO. 1, JANUARY 1979
[17] J. Wanga, Y. He, J. Zhua, X. Gaoa, Y. Cuib, Palm Vein for Efficient Person Recognition Based on 2D Gabor Filter, Optical Engineering Vol. 50, Issue 8 (Aug 2011)
[18] L. Ye, H. Wang, M. Du, Y. He, L. Tao, Weber Local Descriptor with Edge Detection and Double Gabor Orientations for Finger Vein Recognition, Proc. SPIE. 11069, Tenth International Conference on Graphics and Image Processing (ICGIP 2018)
[19] Z. Meng, X. Gu, Hand vein identification using local Gabor ordinal measure, Journal of Electronic Imaging Vol. 23, Issue 5 (Sep 2014)
[20] Naoto Miura, Akio Nagasaka, Takafumi Miyatake, Extraction of Finger-Vein Pattern Using Maximum Curvature Points in Image Profiles. Proceedings on IAPR conference on machine vision applications, 9, pp. 347-350, 2005.
[21] Pedro Tome, Matthias Vanoni, Sébastien Marcel, On the vulnerability of finger vein recognition to spoofing, 2014 International Conference of the Biometrics Special Interest Group (BIOSIG)
[22] A.F. Frangi, W.J. Niessen, K.L. Vincken, M.A. Viergever (1998, October). Multiscale vessel enhancement filtering. In International Conference on Medical Image Computing and Computer-Assisted Intervention (pp. 130-137). Springer Berlin Heidelberg.
[23] Yoshinobu Sato, Shin Nakajima1, Nobuyuki Shiraga1, Hideki Atsumi1, Shigeyuki Yoshida, Thomas Koller, Guido Gerig and Ron Kikinis(1998). Three-dimensional multi-scale line filter for segmentation and visualization of curvilinear structures in medical images. Medical image analysis, 2(2), 143-168.
[24] E. Meijering, M. Jacob, J.C. Sarria, P. Steiner, H. Hirling, M. Unser (2004). Design and validation of a tool for neurite tracing and analysis in fluorescence microscopy images. Cytometry Part A, 58(2), 167-176.