Feature Extraction of Palm Vein Patterns Based on Two-Dimensional Density Function

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Abstract. The pattern of blood vessels of a hand to build a biometric system will be presented in the article. Being a unique feature this pattern is impossible to be forged. Acquisition of a given biometrics will be described. The method to improve contrast of the input image based on three stages: the image histogram equalization, a smoothing operation of the filter and image normalization will be presented. The feature extraction method based on the two-dimensional density function will be shown. The location of blood vessels method based on the nearest neighbour matching method will be discussed. This paper contains a comparison of available in the scientific literature common methods used in the process of creating the biometric system based on the distribution of blood vessels in the hand.

Keywords: Palm vein patterns · The contrast enhancement · Density function · Authentication

1 Introduction

Biometrics consists of the variety of methods for identification or verification by analyzing physical and behavioral characteristics of a man. Nowadays biometrics can replace the weaknesses of the available ways of identification or verification such as a PIN, access card or password. Various identification cards can be scanned and reproduced, passwords can be monitored or broken, and PIN codes can be forgotten or stolen. The system that uses biometric features is not burdened with these defects as an access card or PIN employ a unique biometric feature of a human being [1].

Some systems based on biometric patterns, however, also have drawbacks such as a given quality missing in all people. Another disadvantage is the inability to measure the biometrics [2]. Such systems include the ones based on the

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distribution of fingerprint lines. Many cases of people suffering from a disorder called adermatoglyphia have been reported. Those affected by the disease lack a unique structure produced by the skin in the form of arching or looping ridges on the inner surface of the skin of hands and feet. Another example may be systems that use the iris pattern for identification or verification. To deceive such a system it is sufficient to have a printed image of an eye with a sufficient high resolution. The above-mentioned features are not only easy to be forged but the cost associated with the creation of a false pattern is also low.

A very interesting solution, largely resistant to these problems, is to use a pattern of blood vessels of the hand. The distribution of blood vessels in the hand being the only of its kind feature, even for identical twins, is also individual for the right or left hand. The biometric vein pattern is right under the skin so to get the image it is enough to use infrared light and a thermal imaging camera. The transmitted infrared light is partially absorbed by hemoglobin in the veins which finally results in the image of a natural contrast of veins. The infrared radiation causes no adverse effects in our bodies. There are no interferences from wrinkles, hand lines, hand roughness, dryness or other surface imperfections of the skin. In addition, the venous pattern does not change throughout life but the only parameter which undergoes changes is its size. The advantage of using the hand vascular biometric system is the inability to be forged or falsified. There have been no cases of forgery reported yet.

2 Related Work

The dynamic development of biometric systems makes applications do not have to remember a password or PIN. For this purpose we simply use biometric features individual for each person. An example of such a trait can be the above-mentioned pattern of blood vessels in the hand. This trait among all the other biometric features is distinguished by its stability, uniqueness and reliability. The pattern of blood vessels has gained interest among manufacturers of biometric systems as well as in research. The work [3] describes the structure of the verification system based on the pattern of blood vessels in the hand and presents various stages of the system with a description of the extraction methods based on Gaussian functions, and feature coding using a Hamming standardized distance.

The Gaussian function is often used in the process of feature extraction in blood vessels. Its application can be found also in the works by [4,5]. Apart from feature extraction the Gaussian function was applied to improve the image contrast as shown in [6] and [7]. The blood vessel pattern of the hand is extended enough to allow the use of different methods for extracting and coding features. In their research [8,6] suggested using the wavelet transform in the process of feature extraction.

To create biometric systems it is equally important to encode the pattern. The encoding method must be properly matched so that the process of verification or identification is accurate and quick. In the article by [9] the coding method based on minutiae can be found. This approach is used in the creation of biometric systems using fingerprints. In their research three characteristics of biometrics are referred to: ridge ending, bifurcation and ridge crossing. .

3 Description of the Test Stand and Photo Technique

The biometric vein pattern is located under the skin. To activate the image of the hand vascular system the infrared light and the active matrix infrared camera should be used. The near infrared light is partially absorbed by hemoglobin present in veins which creates a picture of the structure beneath the outer layer of the skin, presenting the natural contrast pattern of the blood vessels. The test stand consists of a CCTV active-matrix infrared camera, IR lamp, the tripod and a plate with five supportive wheels thanks to which during the acquisition the position of a hand is always the same, the picture is taken from the same distance. Our research considers the image of the palm section 256 x 256 pixels in size. Two bases of photos, the own one and CASIA MSPD [10] base have been used. Each of these contains data collected from 100 users, with 12 pictures of the left and right hand for each user.

4 Improving the Image Contrast

During the acquisition of the pattern of the hand blood vessels noise can be noticed. The blood vessels are not bulging enough which results in inaccurate feature extraction. To improve readability three operations to improve its quality are performed:

- histogram equalization operation (1)
- filter smoothing operation (2)
- image normalization process (3).

The first step is to use a histogram equalization method (1) which magnifies the visibility of blood vessels by aligning the components of the image. The next step is to apply the smoothing filter (2), which removes the noise generated during the acquisition of images. The last step is to normalize (3) the image after the contrast enhancement, which means limiting the image into the range of 0 - 255. Sample contrast enhancement shown in Fig.1.

$$D_i = \frac{\sum_{k=1}^{i} h_i}{\sum_{k=1}^{N} h_i} \tag{1}$$

$$w(x, y) * F(x, y) = \sum_{i,j \in W} w(i, j)F(x - i, y - j) \tag{2}$$

$$Z(x, y) = F_{\gamma}(x, y) \tag{3}$$

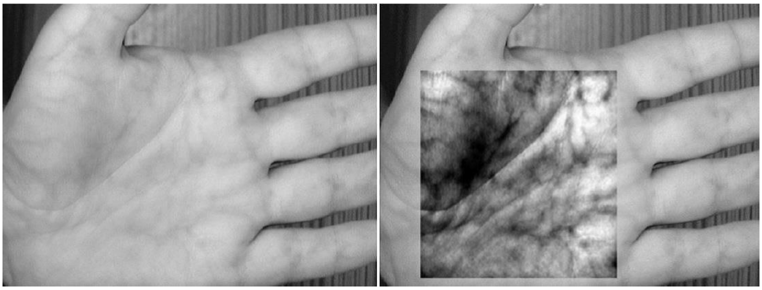

Fig. 1. Sample image of palm vein after using contrast enhancement

5 Extraction of Features

The pattern of palm blood vessels in the image looks like a dent, because the veins are darker than the surrounding area. Our method examines the entire profile of the hand, pixel by pixel, and finds its value over a specified threshold, in order to capture the curvature of the image. This method is based on a two-dimensional density function (4), which is presented below:

$$f(x) = \frac{1}{2\pi\delta^2} * exp\left(\frac{-(x_2 + y_2)}{2\delta^2}\right) \tag{4}$$

One of the first steps of our method is the initial location of curvature in the horizontal, vertical and both diagonal directions. For modeling the curvature localizing filter the first (5), (7), (9) and the second (6), (8) derivatives of the two-dimensional density function are used.

$$f'(x) = \left(\frac{-x}{\delta^2}\right) * f(x) \tag{5}$$

$$f''(x) = \frac{x^2 - \delta^2}{\delta^4} * f(x) \tag{6}$$

$$f'(y) = f'(x)' \tag{7}$$

$$f''(y) = f''(x)' \tag{8}$$

$$f'(x)(y) = \frac{x * y}{\delta^4} * f(x) \tag{9}$$

The filters are designed to locate all the existing curvature of the profile for the four directions. Filters for the horizontal direction (10), vertical (11) and two diagonal (12), (13) are described by the following formulas:

$$C(z) = \left(\frac{f''(x)}{(1 + f'(x)^2)^{\frac{3}{2}}}\right) \tag{10}$$

$$C(z) = \left(\frac{f''(x)'}{(1 + f'(x)^2)^{\frac{3}{2}}} \right) \tag{11}$$

$$C(z) = \left(\frac{0.5 * f''(x) + f'(x)(y) + 0.5 * f''(x)'}{(1 + ((0.5 * \sqrt{2}) * (f'(x) + f'(x)'))^2)^{\frac{3}{2}}} \right) \tag{12}$$

$$C(z) = \left(\frac{0.5 * f''(x) - f'(x)(y) + 0.5 * f''(x)'}{(1 + ((0.5 * \sqrt{2}) * (f'(x) - f'(x)'))^2)^{\frac{3}{2}}} \right) \tag{13}$$

The next step is to determine the local maximal points (14) along the cross-section of the input image for all 4 directions. These points indicate the central position of the veins. This operation can be defined as follows:

$$P(z_i) = C(z_i) \times N(i) \tag{14}$$

The variable N (i) is the width of the curvature area. At the same time the designated curvature maxima points are assigned to the plane V (x, y). The next step is to connect the designated vein centers. This is done basically by checking m pixels located to the right and left of (x, y). If the pixel (x, y) and the pixel value located on both sides is high (in terms of brightness), a horizontal line is drawn. But if the neighbouring pixel values are high, and the value of the pixel (x, y) is low, then it is treated as a gap between the veins. If the pixel value (x, y) is high and its neighbouring pixels have a low value, it is treated as an interference. This operation is used for all pixels designated in an earlier step. This action can be represented by the following formulas:

$$\begin{aligned} S_{d1} = min\{&max(V(x + (m-1), y), V(x + m, y)) \\ &+max(V(x - (m-1), y), V(x - m, y))\} \end{aligned} \tag{15}$$

$$\begin{aligned} S_{d2} = min\{&max(V(y + (m-1), x), V(y + m, x)) \\ &+max(V(y - (m-1), x), V(y - m, x))\} \end{aligned} \tag{16}$$

$$\begin{aligned} S_{d3} = min\{&max(V(y - (m-1), x - (m-1)), V(y - m, x - m)) \\ &+max(V(y + (m-1), x + (m-1)), V(y + m, x + m))\} \end{aligned} \tag{17}$$

$$\begin{aligned} S_{d4} = min\{&max(V(y + (m-1), x - (m-1)), V(y + m, x - m)) \\ &+max(V(y - (m-1), x + (m-1)), V(y - m, x + m))\} \end{aligned} \tag{18}$$

With so designated a vein line for all four directions considered, the final pattern of blood vessels is formed by means of the function (19).

$$F = max(S_{d1}, S_{d2}, S_{d3}, S_{d4}) \tag{19}$$

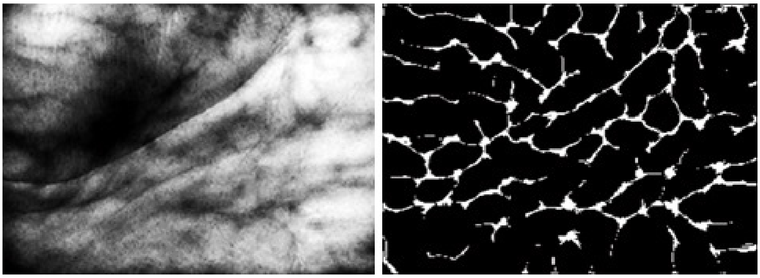

Fig. 2. The result of the detection method of palm vein pattern

The last step is to bring the early established pattern of blood vessels to binary function in order to reduce the amount of information contained therein. Binarization is performed by thresholding. The threshold value is determined by the mean value of all pixels within the image greater than 0. The result of these methods can be seen in Fig.2.

At this stage the resulting pattern of blood vessels has a lot of noise and redundant information for the feature encoding process. To eliminate unnecessary disruption and vein discontinuity four methods to improve the visibility of blood vessels have been applied. The first method is the dilatation (20), where the blood vessels are more protruded, which in time could result in a loss of relevant information about the position of the veins. The dilation function is as follows:

$$L'(m,n) = \max_{m_i,n_i \in B(m,n)} (L(m,n)) \tag{20}$$

Then the thinning operation is performed (21). This operation reduces the size of the blood vessels to one pixel, making it easier to locate the veins fork. This method is as follows:

$$T(I,B) + I - T_{HOM}(I,B) \tag{21}$$

After the dilation and thinning operations have been performed there are still some irregularities on the image and to smooth them out some operations are carried out which remove unnecessary forks and image noise. Fig.3 show the results of the dilation, thinng and nois reduction metgod.

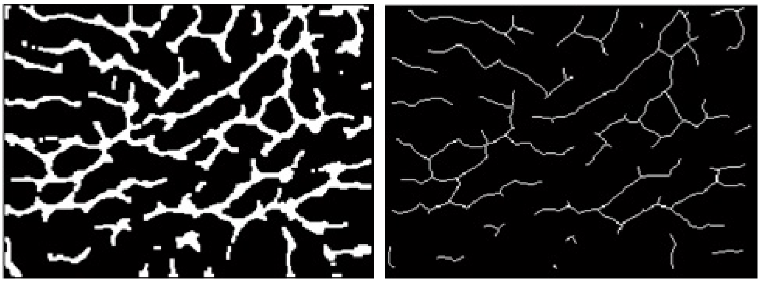

Fig. 3. The results of the dilation, thinning and noise reduction method

6 Encoding of Features and Matching

The studies included two ways of coding features [11]. The first method of coding features is to divide the image into sub-images of 8 x 8 pixels in size. Each of the sub-images is checked for the occurrence of the vein - white pixels. The feature vector equals one if in a given sub-picture there is one or a few fragments of veins. Otherwise the value equals 0. The following figure illustrates the way in which the feature vector was created. The feature vector consists of 1024 values of 0 or 1.

The second coding method is the division of the input image into sub-images of 8 x 8 pixels in size, the difference is that the sub-images are to check the number of white pixels. The sum of the pixels is assigned to each of the sub-images. The feature vector is of the same length as in the coding above. The difference consists in the values assigned to a given sub-picture. The feature vector being analyzed is compared with a vector in the database. The way in which the feature vector is created in this coding method is shown in the figure below.

7 Results of the Experiments

To carry out the experimental part two databases with images of blood vessels of a hand were used. As part of research a database with photos and widely available database CASIA MSPD were created. Each of them contains data collected from 100 users with 12 pictures of the left and right hand each. For the stage of studying 8 photos were used, and the remaining pictures were used in the tests. To check the level of security and accuracy of the systems two factors: the false rejection rate (FRR) and the false acceptance rate (FAR) were applied. The following table summarizes the results carried out for the left and right hand. The coefficients shown in the Table 1 were obtained in tests which take into account the second coding method.

Table 1. FAR and FRR results obtained by our method

Base	Left Hand		Right Hand	
	FAR [%]	FRR [%]	FAR [%]	FRR [%]
Our base	0.14	2.37	0.18	3.19
CASIA	0.26	4.12	0.29	4.00

In order to assess the overall performance of the system the coefficient equal error rate (EER) was calculated. The following Table 2 and plot Fig.4 shows the obtained results.

Table 2. ERR results obtained by our method

Base	Left Hand	Right Hand
	EER [%]	EER [%]
Our base	0.19	0.21
CASIA	0.38	0.25

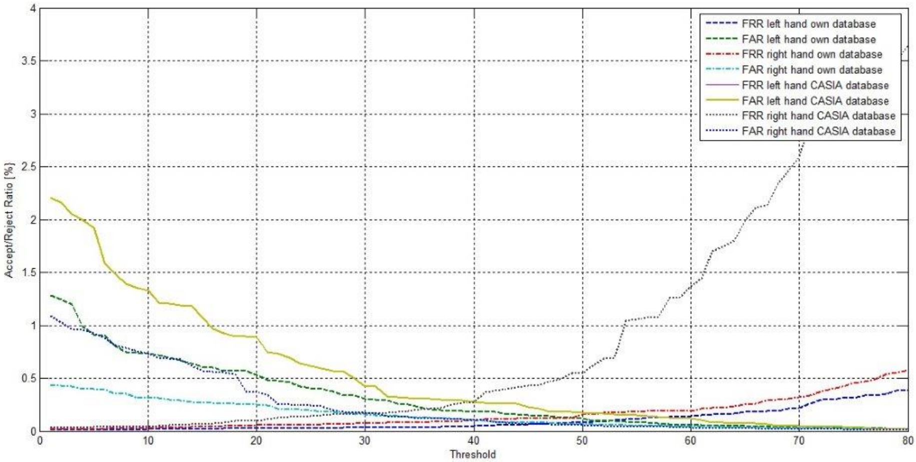

Fig. 4. Graph of comparing the FAR and FRR for the left and right palm

Review and Comparison of Various Techniques Used in Biometric Systems Based on Blood Vessels in a Hand

Several selected methods used in the creation of biometric systems, based on the distribution of blood vessels in a hand, are presented in the Table 3. The study shows that the choice of a suitable method for the initial analysis of the blood vessels in the image is of utmost importance when the final outcome is considered. The work which applied the initial analysis method based on Gaussian function or the Wiener filter the FAR and FRR coefficients are very low. The research where the median filter was used on the image of a preliminary analysis of the veins, the final result is not satisfactory. The final result of the research described by the FAR and FRR coefficients is several times higher than the result of studies that used a more complicated method for the initial location of blood vessels. The review also shows that the final steps in the process of creating a system, such as the extraction of characteristic points or the choice of the method of matching patterns do not have a great impact on the final results without the use of complex methods to locate veins.

The FAR and FRR coefficients for the left hand obtained in our study were used in the above table. In some publications you can find information that the distribution of blood vessels of the left hand should be used for the right-handedpeople.

Table 3. The comparison of our method with other works

Ref.	Thresh.	Bin.	Extraction of Veins Patterns	Minutiae extraction	Class.	Results [%]
[12]	Gaussian Low Pass and High Pass	Local Thresholding	Local Thresholding	-	-	FAR 0.01
[13]	Median	Local Thresholding	Wavelet Transform	-	-	FRR 1.5 FAR 3.5
[14]	Median	Local Thresholding	Local Thresholding	-	Hausdorff	FAR 0.4
[15]	Median	Iterative Thresholding	Local Thresholding	-	Rigid	FAR 0.02
[16]	Match Filter, Smoothing Filter	Seuillage Automatique	Quadratic Inference Function	-	Euclidean Distance	FAR 0.02 FRR 0.03
[17]	Laplacian	Local Thresholding	OTSU	Crossing Number Distance	Euclidean Distance	FAR 1.14
[18]	Match Filter, Wiener Threshold, Smoothing Filter	Automatic Tresholding	Cholesky Decomposition and Lancozos Algo	-	Euclidean Distance	FAR 0.5
[19]	Gaussien	Local Thresholding	Local	-	Euclidean Distance	FRR 0.03
[20]	Median	Histogram Equalization and Local Thresholding	OTSU	Crossing Number	-	-
Our method	Density Function	Local Thresholding	Local Thresholding	-	-	FAR 0.14 FRR 2.37

This assumption stems from the fact that the right hand is used more often than the left one. This hand is more exposed to scratches, scrapes, wounds or calluses. As a result, the image of the blood vessels can be hardly seen, which can result in a faulty verification or identification.

8 Conclusion

The pattern of blood vessels in a hand to build a biometric system was presented in the article. We have proposed a set of functions for analyzing images containing the distribution of blood vessels and the way of their acquisition. The work contains a description of the methods to improve the contrast of the image, the method of feature extraction based on two-dimensional density function. The method of locating veins based on the nearest neighbour matching. The research has been carried out on two bases: the own one and widely available on the internet CASIA. The results presented in the form of coefficients FAR, FRR and EER show that one of the important steps in the development of biometric systems based on the distribution of blood vessels in a hand is its acquisition.

References

1. Bobulski, J.: Acces control system using face image. Control and Cybernetics 41(3), 691–703 (2012)
2. Bobulski J.: A hybrid method for face detection. Pomiary Automatyka Kontrola, 1498–1500 (December 2010)
3. Shyr Wu, K., Chun Lee, J., Ming Lo, T., Chin Chang, K., Ping Chang, C.: A Secure Vein Recognition System. The Journal of Systems and Software, 2870–2876 (2013)
4. Miura, N., Nagasaka, A., Miyatake, T.: Extraction of Finger Vein Patterns Usng Maxmum Curvature Points in Image Profiles. In: Conference on Machine Vision Applicationa (2005)
5. Zhou, Y., Liu, Y., Feng, Q., Yang, F., Huang, J., Nie, Y.: Palm-Vein Classification Based on Principal Orientation Features (2014)
6. Al-Juboori, A.M., Bu, W., Wu, X., Zhao, Q.: Palm Vein Verification Using Multiple Features and Locality Preserving Projections. The Scientific World Journal (2014)
7. Kang, W., Liu, Y., Wu, Q., Yue, X.: Contact-Free Palm-Vein Recognition Based on Local Invariant Features (2014)
8. Park, K.R.: Finger Vein Recognition by Combining Global and Local Features Based on SVM. Computing and Informatic 30, 295–309 (2011)
9. Wang, L., Graham, G., Cho, D.S.Y.: Minutiae feature Analysis for Infrared Hand Vein Pattern Biometrics. The Journal of The Pattern Recognition Society 41, 920–929 (2007)
10. http://biometrics.idealtest.org
11. Kubanek, M., Smorawa, D., Adrjanowicz, L.: Users Verification Based on Palm-Prints and Hand Geometry with Hidden Markov Models. In: Rutkowski, L., Korytkowski, M., Scherer, R., Tadeusiewicz, R., Zadeh, L.A., Zurada, J.M. (eds.) ICAISC 2013, Part II. LNCS (LNAI), vol. 7895, pp. 275–285. Springer, Heidelberg (2013)
12. Sony, M., Gupta, S., Rao, M.S., Gupta, P.: A New Vein Pattern-Based Verification System. International Journal of Computer Science and Information Security 8(11), 58–63 (2010)
13. Rajalakshmi, M., Rengaraj, R.: Biometric Authentification Using Near Infrared Images of Palms Dorsal Vein Patterns. International Journal of Advanced Engineering Technology 2(14), 384–389 (2011)

14. Kavitha, R., Flower, L.: Localization of Palm Dorsal Vein Pattern Using Image Processing for Automated Intra Venous Drug Needle Insertion. International Journal of Engieering Science and Technology 3(16), 4833–4838 (2011)
15. Pal, M.M., Jasutka, W.R.: Implementation of Hand Vein Structure Authentication Based System. Bioinfo Computer Engineering 2(11), 19–21 (2011)
16. Nandini, C., Ashwini, C., Aparna, M., Ramani, N., Kini, P., Sheeba, K.: Biometric Authentication by Dorsal Hand Vein Pattern. International Journal of Engineering and Technology 2(15), 837–840 (2012)
17. Rajankar, V.A.S.O.: Dorsal Hand Vein Biometry by Independent Component Analysis. International Journal on Computer Science and Engineering 4(17), 1338–1344 (2012)
18. Sathish, G., Saravanan, S., Narmadha, S., Maheswari, S.U.: Personal Authentication System Using Hand Vein Biometric. Computer Technology and Applications 3(11), 383–391 (2012)
19. Zhang, X.H.: Feature Extraction of Hand Vein Patterns Based on Ridgelet Transform and Local Interconnection Structure Neural Network. Intelligent Computing in Signal Processing and Pattern Recognition, 870–875 (2006)
20. Moffette, O.: Extraction des Informations Nutritionnelles D'une Etiquette Alimentaire Par Vision Artificielle, Ecole de Technologie Superieure (2011)