

Image Processing for Biometric Scanning of the Palm Vein Pattern



Lina Kh. Safiullina  and Rustem R. Maturov

Abstract Due to increased requirements for access control systems, the use of biometric recognition technologies is becoming a reliable solution for the protection of critical information. One of the best ways of personal identification is to use the palm vein structure. The chapter deals with improving accuracy in the problem of recognizing the palm vein pattern when comparing biometric templates using the Canny edge detection algorithm and the Gabor filter. 2D Gabor filter improves the adaptability of recognition and is therefore proposed to solve the problem of image blurring and select a threshold when the traditional Canny algorithm smoothes the edges. The results of experiments show that this filter can detect less pronounced edges and provides more complete information about the image, which has a positive effect on the result of biometric authentication. The similarity of two biometric templates is determined using the Minkowski metric. Experiments conducted on the original facility show high performance, as well as good results in false acceptance errors (FAR = 0%) and false rejection errors (FRR = 0.01%) based on processing 360 images captured from 26 people, which makes it possible to use the proposed method in the identification and authentication system at existing data security facilities.

Keywords Canny algorithm · Gabor filter · Biometrics · Vein pattern · Identification · Authentication

1 Introduction

This chapter discusses the method of recognizing a person by the palm vein pattern captured in the IR spectrum. Initially, infrared scanning was used in healthcare to form a vein map and diagnose venous disorders. However, after Fujitsu became

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interested in the scanning method, the first laboratory vein recognition system for human identification was installed in 2006 in the public library of the Japanese city of Naka. The widespread use of the palm vein pattern identification/authentication method began in Japan to prevent bank fraud around the mid-2000s, making it one of the youngest identification/authentication methods [1]. This technology is based on the fact that hemoglobin in the blood absorbs infrared (IR) radiation, i.e., when the palm is illuminated with IR light, veins, unlike other parts of the hand, do not reflect light and looks like dark parts. Thus, the unique pattern of the palm venous network can be captured using infrared radiation.

The technology of biometric user authentication based on the vein pattern has many significant advantages:

- possibility of contactless identification (which is more hygienic);
- high level of uniqueness;
- static biometric characteristic over a long time;
- high resistance to falsification due to the complexity of creating an artificial model of the user's vein pattern;
- the impossibility of stealing a biometric characteristic;
- low cost of hardware and the entire system,

which makes it applicable to many areas [2].

The main difficulty in implementing the vein pattern recognition method is the high-quality processing of images that highlight the structure of veins without foreign objects, not related to them: skin creases, the borders of IR illumination, the background behind the palm, the borders of the palm, etc. At the same time, the performance of a biometric human recognition system, represented by the following key indicators [3]:

- false acceptance rate (FAR);
- false rejection rate (FRR);
- failure to enroll (FTE);

should not exceed 0–0.05% for each of them.

2 Problem Statement

The purpose of this research is to improve the quality and performance of human recognition based on palm vein patterns, using the Canny algorithm and the Gabor filter.

2.1 Recognition Device Operating Principle

The designed hardware and software system (HSS) consists of a scanner, an application handler, and a program comparing biometric samples. The scanner creates an image of the palm of the user to be identified and then sends it to an application handler written in the built-in Matlab language, which, in turn, generates a binary pattern with an image of palm veins (biometric template). The resulting biometric template is processed by a program created in Microsoft Visual Studio 2018 in C++ that compares it with other templates contained in the database, and then the authentication results are sent to the ID scanner. If the palm image matches the existing templates, a corresponding message appears on the screen. The appearance of the device and its connection diagram is shown in Fig. 1.

The Arduino UNO microcontroller with an integrated development environment (Arduino IDE) was chosen as the programmer unit to control the whole set of device components. The Arduino UNO is connected to 6 IR diodes and a distance sensor. The diodes are positioned symmetrically on the card around the camera and point in the direction where the palm is brought. They are tilted towards the camera at a certain angle to focus their rays on the identification object, which is about 19 cm away from the lens. The programmer and camera are connected via a USB cable to a computer with all the necessary software installed.

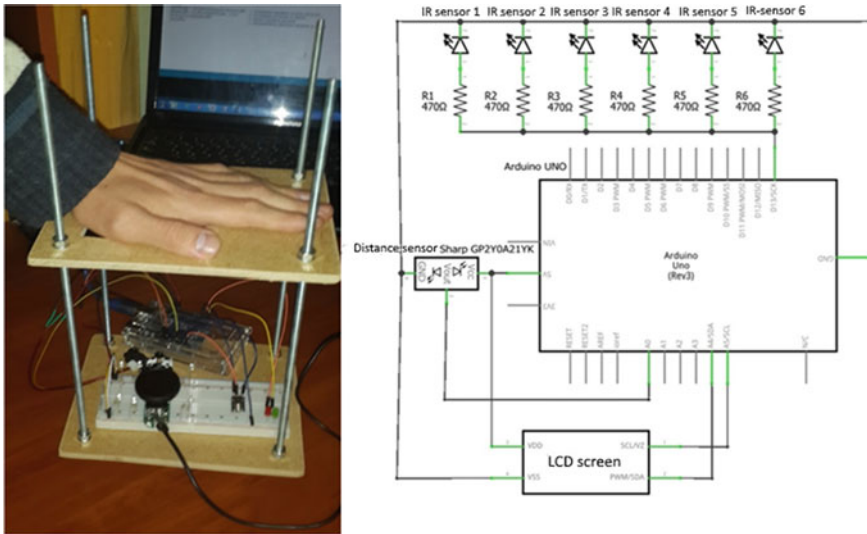


Fig. 1 Appearance (left) and diagram (right) for connecting components to the HSS programmer

2.2 Device Operation Algorithm

After switching on, the device goes into standby mode. In this operating mode, only the distance sensor is activated. It is directed towards the palm, and when the identifier (hand) approaches the device, the sensor sends information about the distance to the camera to the microcontroller. If the distance is the same as the value pre-programmed in the microcontroller, a disabling signal is sent to the sensor; the camera and IR illumination are switched on. At the same time, the distance sensor is disabled, because the light it emits to measure the distance to the object will create noise and interference to the camera, the lens of which will reflect its beam through an infrared filter along with an IR beam, which will create a “flash exposure” and adverse noise for the subsequent processing of the image.

It is enough to turn on IR illumination for two seconds after the camera is turned on and ready; this time suffices to focus the lens on the identification object and capture an image. After creating an image, it is better to disable the camera and the illumination; the image is sent for processing by one program, and the result of authentication comes from another program.

Next, the result is passed to the identification object: if positive, the signals are sent to the green LED; if negative, the signals are sent to the red LED. Then the device switches to the initial mode.

2.3 Image Processing

As mentioned above, one of the main problems in image processing is the separation of the edges of the vein map and the removal of papillary patterns, shadows, and reflections. The heterogeneity of the image and the angle of the light source create a sharp change in the color shade in the image. As a result of this difference, there is a probability of erroneous allocation of an area that is out of all relation to the vein pattern [4]. It might often be the case that the algorithm cannot distinguish the edges of small objects. As a rule, the borders of such “islands” are poorly defined and are absorbed by the objects against which they are located.

The Gabor filter and the Canny algorithm were used to filter the image and improve the quality of recognition. The Gabor filter, which belongs to the bandpass filter family, is a linear filter used for detecting borders. Frequency and orientation representations of Gabor filters are similar to those of the human visual system in terms of textural representation and discrimination [5]. In the spatial domain, the two-dimensional Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave. The formula for constructing a two-dimensional Gabor filter (1–3):

$$G(x, y) = \exp\left(-\frac{1}{2}\left[\frac{x_\phi^2}{\sigma_x^2} + \frac{y_\phi^2}{\sigma_y^2}\right]\right) \cos(2\pi\theta x_\phi) \quad (1)$$

$$x_\phi = x \cos(\phi) + y \sin(\phi) \quad (2)$$

$$y_\phi = -x \sin(\phi) + y \cos(\phi) \quad (3)$$

where σ_x, σ_y are the deviations of the Gaussian kernel along the x and y axes, which determine the length of the filter, θ is the frequency modulation of the filter, ϕ is the spatial orientation of the filter that determines its position relative to the main axes.

Image processing by the Gabor filter is achieved by averaging the values of the processed image over a certain area at each point. Accordingly, the imposition of the Gabor filter on the image has the form:

$$I'(x, y) = \frac{1}{n^2} \sum_{i=1}^n \sum_{j=1}^n I\left(x - \frac{n}{2} + i, y - \frac{n}{2} + j\right) \cdot G(i, j), \quad (4)$$

where $I(x, y)$ is the intensity of the source image at the point (x, y) ,

$I'(x, y)$ is the intensity of the new image at the point (x, y) ,

$G(i, j)$ is the Gabor function value, $i \in [0, n], j \in [0, n]$.

Before applying the filter, it is necessary to construct the mid-frequency and orientation fields using four gradations for the current image and then make a convolution in all points of each direction. The result of applying this filter is shown in Fig. 2.

The Canny algorithm generates an optimal smoothing filter based on the criteria for detecting, localizing, and minimizing multiple responses to a single edge [6]. The edge of the image can have different directions, so the Canny algorithm uses four filters to detect horizontal, vertical, and diagonal edges of the blurred image. The edge detection operator returns the value for the first derivative in the horizontal (G_x) and vertical (G_y) directions. From here, the gradient and direction of the rib can be determined:

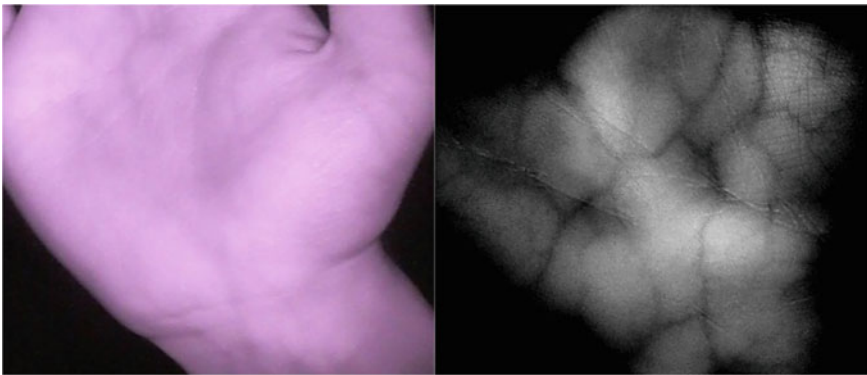


Fig. 2 Image before (left) and after (right) processing

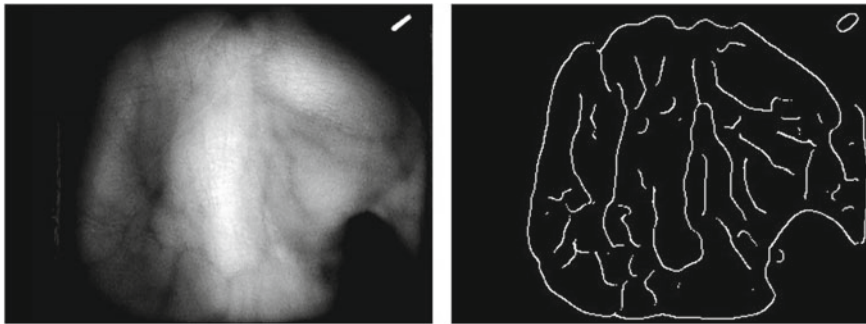


Fig. 3 HSS image before (left) and after (right) applying the Canny algorithm

$$\mathbf{G} = \sqrt{\mathbf{G}_x^2 + \mathbf{G}_y^2}, \quad \Theta = \text{atan2}(\mathbf{G}_y, \mathbf{G}_x), \quad (5)$$

where G is the length of the hypotenuse,

atan2 is an arc tangent function with two arguments.

The edge direction angle is rounded to one of the four angles that represent the vertical, horizontal, and two diagonals (for example, 0° , 45° , 90° , and 135°). The result of applying the Canny filter in this chapter is shown in Fig. 3.

The final binary pattern depends on the sensitivity of the *threshold value* and the standard deviation of the Gaussian filter (*sigma*) [7, 8]. The optimal values were assumed to be $\text{threshold} = 0.25$ and $\text{sigma} = 10$.

2.4 Comparison of Biometric Templates

As a result of applying the Gabor filter and the Canny operator, we get a binary pattern that is converted into a perceptual hash, which is used for further comparison with reference hash patterns. To obtain a perceptual hash, the following transformations over the images were sequentially performed:

1. Size reduction to 8×8 pixels.
2. Discoloration (i.e., converting all colors to grayscale gradients).
3. Binarization (i.e. converting each pixel to either black or white). In this case, the threshold of the binarization process is the obtained average color value.
4. Conversion of the resulting 64-bit pixel value into a hash.

After these transformations, two hashes are compared with each other using the Minkowski metric [9–12]:

$$\rho(x, y) = \left(\sum_{i=1}^n |x_i - y_i|^p \right)^{1/p} \quad (6)$$

where ρ is the Minkowski distance, i is the number of the corresponding symbol, x_i are symbols of the first number or word, y_i are symbols of the second number or words, p is a parameter, which equals 2.

The metric value is low when comparing samples of the same template and high when comparing samples of different templates.

A database of templates for all registered users is required to create a human identification/authentication system [13]. When each subsequent sample is received by HSS, the value of the Minkowski metric is calculated between the received hash and templates from the database corresponding to the person [14]. Then the average value of this metric is taken, estimating how similar the sample is to a specific person's template according to the accepted threshold value (Figs. 4 and 5) equal to 13 [3].

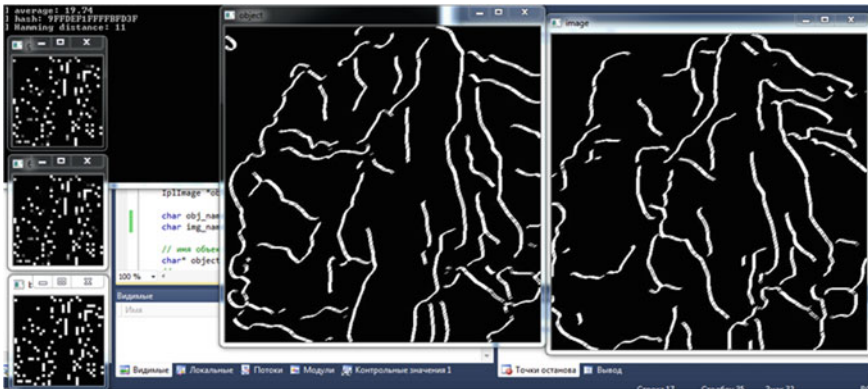


Fig. 4 Comparison of biometric templates for a single user (the value of the Minkowski metric is equal to 10)

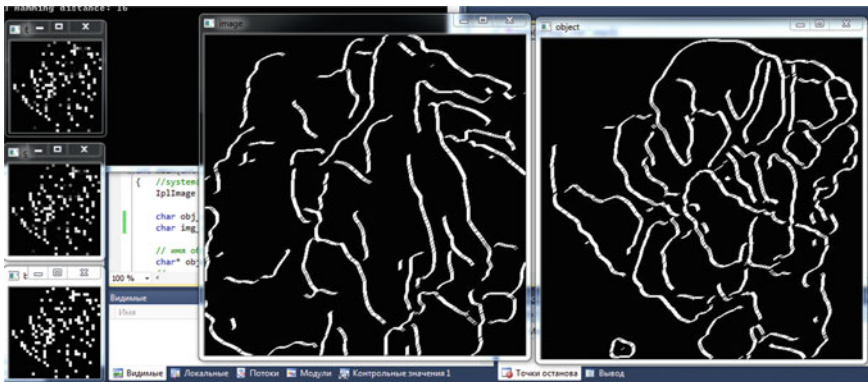


Fig. 5 Comparison of biometric templates of different users (the value of the Minkowski metric is equal to 24)

Table 1 Comparison of FAR, FRR and FTE indicators

Authors	Objects	Number of images to analyze	FAR (%)	FRR (%)	FTE (%)
Kulkarni et al. [17]	50	500	5.66	5.66	0
Chunyi et al. [18]	40	588	5.19	0.02	0
Qui et al. [19]	106	3816	0.1	0.09	0
Joseph [20] (matching without fuzzy retrieval)	156	6264	0.25	0	0
Joseph [20] (matching after fuzzy retrieval)	156	6264	0.17	0	0
This research	26	360	0	0.01	0

3 Results and Discussion

The results of recognizing and processing 360 images of 26 users were analyzed using three key indicators of biometric systems [15, 16]:

- False Access Rate (FAR)—the percentage threshold that determines the probability that a user will be incorrectly accepted;
- False Rejection Rate (FRR)—the probability that the biometric security system will incorrectly reject an access attempt by an authorized user.
- Failure to Enroll (FTE)—the probability that the user will not be able to be enrolled in a biometric system due to an insufficiently distinctive biometric sampling.
- A comparison of these indicators with data published in the scientific literature is presented in Table 1.

Despite the small number of images analyzed in this chapter, the method described above shows rather well values of performance indicators. In Kulkarni et al. [17], Chunyi et al. [18] error rates are too high. The FAR value is especially dangerous for the access control system because it shows the percentage of users who can access it without having the right to do so.

Results of Qui et al. [19], Joseph, Ezhilmaran [20] have good performance indicators, and the analysis was performed using a very large number of images, which reduces the probability of statistical error.

The authors of the chapter will continue to increase the biometric data bank and clarifying the performance indicators of the biometric system.

4 Conclusion

The results of a statistical analysis based on 26 users and 360 images for testing the HSS and the proposed recognition algorithm showed the following:

- false acceptance rate FAR = 0%;
- false rejection rate FRR = 0.01%;
- failure to enroll FTE = 0%,

which is within normal limits [3]. Therefore, the combination of the Canny operator and Gabor filter can be considered appropriate to improve the algorithm for recognizing a person by the palm vein pattern.

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