A Low Cost System for Dorsal Hand Vein Patterns Recognition Using Curvelets

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Abstract—Biometric identification systems based on the recognition of the hands vein pattern are better than the other systems such as fingerprint identification, face, iris, retina, and hand geometry features for using not visible images to the eye, having high acceptability to users and do not require physical contact. This paper presents an identification system based on the dorsal hand vein pattern recognition, using a low cost camera to capture images with near-infrared (NIR), curvelet transforms for feature detection of images and random forest classification method. The proposed method was tested on a database of 1240 images captured by the authors and the system results presented classification about recognition with low Equal Error Rate (EER)

Keywords—Vein recognition; Vein pattern; Biometric identification; Hand Vein; Curvelets transform.

I. INTRODUCTION

Advanced security systems increasingly require strict control of physical and logical access of its users. The identification with the use of magnetic cards, cards with barcodes, or cards via radio communication technology using PIN (Personal Identification Number) are used in security systems but do not guarantee that the user is the owner of this card in use. One way to ensure identification is the use of biometrics, which is defined as the measurement of human characteristics. Biometrics can be defined as the physiological or behavioral characteristics that identify a person.

The main physiological biometric techniques are reading the patterns of fingerprint, facial recognition, pattern recognition of retinal veins, hand geometry and iris texture analysis. Behavioral biometrics include standard static and dynamic signature, voice pattern and keystroke dynamics and all these characteristics, both biological and behavioral, should have the following properties in order to be used as biometrics: universality (everyone in the world should have the feature), permanency (this feature should remain lifelong), collectability (should be a feature that can be read by some process), acceptability (people must accept to undergo the process of reading the feature), avoidance (the system should interfere as little as possible) and uniqueness (feature must be unique for each person) [1].

All these methods have been intensively studied and the results showed several deficiencies regarding guarantees for identifying people. Multimodal methods were created in an attempt to improve results and can actually reach them [2], [3], but in many cases end up adding the failures of individual techniques such as poor quality of the captured images, noises from the environment where the installed equipment, noise caused by the biometric sensor itself used and orientation of the face or hand in capturing the image, increasing the cost of implementation and increasing the processing time. Biometric techniques based on face, iris or fingers were intensively studied and developed [4]–[6].

Biometric systems based on hand vein pattern is relatively recent compared to the systems mentioned above, since their study by MacGregor and Weldford in 1991 [7], [8], and began to become popular from the 2000s when the Fujistu Company presented their research results and showed that only six people have similar patterns of veins in a population of one million people, thus proving that this is a feature that can be used [9].

Two different methods of identification with different light sources are used [10], NIR (Near Infrared Light) and FIR (Far Infrared Light). For capturing images, NIR works on the principle that the hemoglobin in the blood absorbs infrared light of wavelength near to the spectrum of visible light, whereas the bones, muscles and nerves of the hands suffer no part of this light stimulation. Based on this principle, using a special camera able to capture NIR images only of the light spectrum between 600 nm and 1100 nm is possible to capture images of the hands, whether the palm, the dorsal part of the hand or wrist with a high contrast between the structures and veins, the veins appear dark in this case by having absorbed NIR light.

For systems that use FIR, the basic principle of operation is based on the fact that human veins generally has a higher temperature compared to other structures of the hand, and using a thermal imaging camera in the visible light spectrum is possible to have the identification of these veins, showing the brighter in the acquired image [11]. This
system has shortcomings when used in open areas, because all the heat radiated into the environment can cause noise in the captured images.

The purpose of our work is to present a biometric identification system based on image capture based on NIR with low cost, using a conventional camera model ST-CAM001 for the Cyber Comp modified to be able to perform the capture of images. Several tests were performed before image acquisition of setting a database because it comes from a camera adapted to capture infrared light, the quality of the captured images could provide low quality directly affects final results of the research [12], [13].

To this project, proposals were heading in different lighting, different levels of illumination and arrangements that would provide the user with a better hand positioning equipment in order to ensure a good quality image.

II. PROPOSED SYSTEM

In our proposal, we use the following steps to correct identification of the person:

- Image acquisition with low cost camera;
- Image Enhancement (noise reduction);
- Region of interest extraction (ROI);
- Pattern of veins extraction;
- Training System / Matching.

A. Recognition of the pattern

In Fig.1, is presented the registration flowchart of the new users and the method of identification. The project is based on a low-cost device, so the camera is not chosen a specific NIR camera for applications where we want to capture only the light from an image in the infrared spectrum. For this, we selected a conventional camera model ST-CAM001 for the Cyber Comp with 470k resolution pixel, at a cost of approximately $ 10. Research on specific NIR cameras in Brazil showed us costs of approximately $ 500 to $ 1000, depending on model. Since this is a conventional camera, its use is capturing images in the visible light spectrum and to eliminate any kind of light, for example infrared and ultraviolet.

Our first step was to remove the infrared filter which was located on the camera lens just above the image pickup sensor for the camera to allow the passage of this type of light, and adapt a high pass filter, blocking the visible light to the eye thus allowing only the passage of infrared light.

In Fig.2 (a) is presented the modified camera and in the center of Fig.2 (b) is presented the CMOS sensor. The Fig.3 (a) show inside the housing of the camera lens where the infrared filter was installed (at center) and Fig.3 (b) show the removed filter from the camera in order to allow the passage of this type of light.

In order to capture the images, we created a prototype (Fig.4) for housing the camera and facilitate the understanding of the user for the correct positioning of the hands. We create a base for supporting the hands without the need to touch, simply by appropriately bringing the hand to this base. Just below the base we did an arrangement of LEDs (Light emitting diode) with light radiating in the infrared spectrum IR and an electronic circuit to control the emitted light by the LEDs.

First of all, we use two different types, the first radiating peak at 850 nm and the second radiating peak at 940 nm in order to verify what device would generate an image with
more contrast and definition. After these tests, we chose the 850 nm model.

B. Image Acquisition

We installed a plastic base on LEDs and realized that the images were distinctly lighter at the regions of the LEDs. To prevent this problem, a white filter was installed with the intention of spreading the light emitted toward the hand, and the results were satisfactory. The LEDs were arranged on a plate in the palm and dorsal of the hand region, no matter the region of the fingers as one of the stages of the project is to define a region of interest (ROI) and at this stage the fingers would be eliminated. In Fig. 5 (a) is presented the open base with LEDs inside and the Fig. 5 (b) show the closed base with the diffusion white filter and a hand correctly positioned. Our equipment is implemented with a base for positioning of the hand. As we make the acquisition of images, we found that most users would not know how to put your hand on the device, properly position the hand, and should support the hand at the base of the equipment. To minimize this problem, we installed a board with a photo next to the device, with an image of a hand properly positioned in the equipment to facilitate the use.

Compounds also installed four sets of ten LEDs at the top of our prototype, positioning the light with direct hand-incidence as can be seen in the Fig. 6.

The Fig. 7 show the position of the LED array installed on top of the device, focusing light in the forward direction by hand. With this arrange we have indirect light through the user’s hand and direct light applied over the hand. Independent electronic circuits were constructed to control the brightness adjust. For the entire process of capturing an image, fifty infrared LEDs were used: ten LEDs at the base of the device used to light through the hand, and forty LEDs on the top cover, forming four sets installed at right, left, front and bottom of the device. In Fig. 8 is shown a set of captured images during the process of adjusting brightness of each LED array, looking for the best performance of the device.

C. Image Enhancement

The first step in our project is to convert the image to gray-scale. Although we installed the filter to prevent light in the visible spectrum to arrive at the camera sensor may still be levels that will be removed in this step. The results were very subtle and can be seen at the Fig. 9 (b), and can be compared with the original image presented in Fig. 9 (a), almost that showing the captured image has no component of light in the visible spectrum. The next step is to enhance the contrast of the captured image equalizing the histogram to reduce the inhomogeneity of illumination. The results are
shown at Fig.9 (c). All procedures were performed using Matlab® software. The results of histogram equalization are shown in Fig.10.

D. Region of interest (ROI) extraction

The region of interest was defined experimentally by media, extracting the largest possible area of the dorsal side of the hand, and it was extracted by software in fixed positions, width and height constant in the x and y axis. The data to be extracted will be obtained from this region. The Fig.11 (a) show the selected area to be extracted as a ROI, and the Fig.11 (b) show the ROI extracted. The Fig.12 show the input image in MATLAB® software (processing). The Fig.13 show only the display with the results of the first scale and the first angle. It’s important to comment that in our study were determined four scale parameters and eight angular parameters, so this figure represents only one of the items discussed. The Fig.14 show the coefficients extracted from one of cells. Not all screens with coefficients generated in the extraction of image characteristics were presented.

E. Feature detection

The curvelet transform is shown as the most appropriate feature extraction anisotropic biometric images with angles, lines and points [13]–[15]. The 2D Fast Fourier Transform (FFT) must be applied to the image before the implementation of the curvelet transform, because the 2D frequency plane is divided into wedges that are nothing more than the results of partitioning the Fourier plane in radial division and angular division. Concentric circles are responsible for decomposing the image into multiple scales defined by j and angular divisions defined by l.

In the spatial domain each wedge corresponds to a given curvelet at scale and angle. The values of the curvelet coefficients are determined in relation to alignment with the actual image, the more accurate the alignment of a curvelet with a curved image, the higher its value coefficient [16]. The curvelet transform of a function f is expressed as shown in Eq.1.

$$c(j,l,k) = <f, \varphi_{j,l,k}>$$  \hspace{1cm} (1)

Where $\varphi_{(j,l,k)}$ is the curvelet, j, l e k are the scale parameters, directions and position, respectively [17]. In this work, the discrete curvelet transform was applied to four scale parameters and the angular parameter having value eight.

F. Matching

To verify the performance of data taken after using the curvelet transform descriptors and characteristics, we used the Random Forest classifier, implemented in the WEKA platform (Waikato Environment for Knowledge Analysis).

The Random Forest classifier was selected for this task by presenting good results in image classification [18]. The Random Forest classifier is a decision tree where each grows using some sort of randomization tree.

This algorithm has a high ability to process large amounts
of data with high speed in the decision based on where each will give a vote trees workout step indicates that the decision on which class belongs the data analyzed, and the object will be classified according with the largest number of these decisions trees. In this step, the method of rotation (n-fold cross validation) was applied to the value n=10. This method uses 90% of the training data and the remaining 10% of the data for test step.

III. RESULTS

The Tab. I show the comparison between our proposed method and the method proposed and commented by [19], [20]. It’s possible to verify in the table that our method outperforms the other four methods in terms of EER.

We acquired five images of each user, with a total of 248 users, generating a database of 1240 images. The process described in this paper was applied to the entire database, and the results after tests showed the index EER (Equal Error Rate) of our work was estimated at 3.15% using the ROC (Receiver Operating Characteristics) curve, which was low compared with the literature about correct identification of system users, using a low cost system.

When we made the capture of images, we store user data such as age, weight, gender, ethnicity and use of hands (right or left hand) to perform analysis on a future project about the existence of some relationship with these values and false rejection and false acceptances generated in order to enhance the system.

IV. CONCLUSIONS

In this paper, we present a method of biometric identification using the hands vein pattern. No works that used exactly the same procedures in the analysis of images from the dorsal part of the hand were found.

The curvelet transform coefficient generates many data and to improve the speed of the system, it is proposed

<table>
<thead>
<tr>
<th>METHOD</th>
<th>EER</th>
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<tbody>
<tr>
<td>Our method</td>
<td>3.15%</td>
</tr>
<tr>
<td>Curvature</td>
<td>3.86%</td>
</tr>
<tr>
<td>Line-shaped matching</td>
<td>4.25%</td>
</tr>
<tr>
<td>Line tracking</td>
<td>6.14%</td>
</tr>
<tr>
<td>Structural minutiae matching</td>
<td>9.50%</td>
</tr>
</tbody>
</table>

Table 1: The EER comparison with other methods
to use tools that aims to reduce or vectoring the data before carrying out classification, by techniques such as LBP (Local Binary Patterns), PCA (Principal Components Analysis) or technical ANOVA (Analysis of Variance) in future work. The index EER (Equal Error Rate) of our work was estimated at 3.15%.

REFERENCES


