

# Hand Veins Recognition System

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**Keywords:** Hand based Biometrics, Biometrics Recognition, Palm Veins, Hand Geometry, Palm Veins, Acquisition System, Palmprint, Web-cam.

**Abstract:** Accurate protection systems capable of replacing the traditional passwords and ID cards are essential, for commodity and for security reasons. A hand-vein pattern recognition system is just one of a vast group of biometrics techniques under research, in order to become the reference recognition system. This paper presents a hand vein biometric recognition system that uses the hand blood vessels pattern to identify an individual. All biometric systems have an immense application potential as they present advantages over the traditional identification systems. They are able to work with patterns that are very hard to duplicate, since they are different from person to person, and it is also impossible to lose or forget them, since the biometric characteristics are intrinsically attached to the human body. The developed approach was created with the intent of providing an effective protection system despite having been designed and implemented using inexpensive hardware, in comparison with the biometric recognition systems presently offered at a commercial level. The results show that a reliable system can be produced at a low cost and can be used standalone or in combination with other systems.

## 1 INTRODUCTION

Nowadays, we can access our personal data from almost everywhere. This is very convenient but entails increasing risks since the probability of phishing credentials increases with the number of users. More sophisticated protection systems are required to control possible harassments, like ID cards cloning, theft or compromised passwords.

When thinking about digital protection, one which immediately comes to mind is the use of passwords and smart cards, since they are used daily for almost everything. Despite being used very frequently, passwords and smart cards are a relatively insecure method of protection and access control.

The biometric systems experienced a significant growth in the recent years, both at research and commercial level, pushed by the need for innovative and improved ways to protect our personal information.

The field of biometrics recognition deals with the identification of a human by using its distinctive traits. They can be categorized in two major groups, behavioral and physiological.

The behavioral traits are related to the user

behavior and include the signature or gait. The physiological traits include personal characteristics like hand geometry, fingerprints, ear or face.

Biometric systems that analyze traits like the finger veins, fingerprint or iris, are nowadays mostly used as a form of recognition. Those systems are widely used to control the access to certain applications, private areas or even in forensic scenarios. The majority of the systems available provide real time automatic solutions which extract a human feature, then compute a template and compare it with the ones previously stored in a database to provide a matching decision.

## 2 DIFFERENT BIOMETRIC RECOGNITION SYSTEMS

There are several approaches that exploit the hand biometric characteristics to identify an individual.

Huan Zhang and Dwen (Zhang, 2010) on their hand vein recognition system achieved an EER of 1.82% with an AD-080CL camera that costs around 3000€.

Mauricio Ramalho (Ramalho, 2010) in his palmprint recognition system used an operating

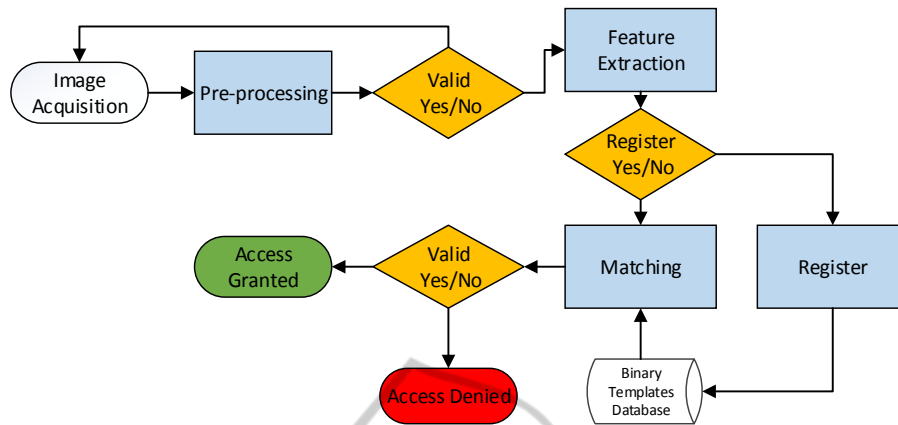


Figure 1: Developed system architecture.

point that achieves 9.5% for the False Reject Rate (FRR), 0.1% for False Accept Rate (FAR) and 3.29% for the Equal Error Rate (EER) using an expensive camera.

Nuno Moço (Moço, 2012) in his palmprint recognition system for cellphones used an operating point that achieved 9.87% of FRR and 0.03% of FAR with an EER of around 5%.

Table 1: Prices and cameras of different researchers.

Author	Camera	Cost(€)
João Neves	Logitech QuickCam Pro 9000	20
Huan Zhang	AD-080CL	3000
Maurício Ramalho	Olympus C-3020	400
Nuno Moço	HTC Desire	550

### 3 PROPOSED HAND VEIN RECOGNITION SYSTEM

The proposed biometric recognition system is unimodal and uses the hand vein pattern as the biometric trait. The architecture of the developed system is presented in Figure 1. It includes the following main modules: image acquisition, pre-processing, feature extraction, matching and decision.

The following paragraph gives a summarized description of the approaches taken.

To do the image acquisition in the developed

system a modified low cost camera is used. After the image acquisition the captured image is resized in order to reduce the required computational power, turning the pre-processing less demanding and consequently saving processing time. After resizing the acquired image, is preprocessed in order to reduce the amount of noise. The detection of the region of interest is obtained through some reference points in the hand contour. The feature extraction and template creation sections are based on the Orthogonal Line Ordinal Features (OLOF) (Sun, 2005) technique. The OLOF method turns the veins representation robust against illumination variations. It also makes the matching stage effortless since the dissimilarities between two palmprints can be measured through the differences in the binary bits from the two templates with a simple XOR operator, which can be computed almost instantly.

#### 3.1 Image Acquisition

Since the system performs recognition based on vein images, the illumination is obtained using 15 near IR leds (OSRAM – SFH4550), see Figure 2.

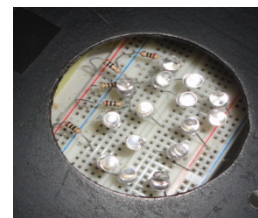


Figure 2: IR illumination.

The box is a cube with 26 cm side. The top of the box was painted black in order to reduce the interference instigated by the visible light coming from the exterior of the assembly, Figure 3.



Figure 3: Developed System.

In order to be able to capture the near infrared light, necessary for the vein acquisition, the low cost web-camera requires the removal of the infrared filter that is placed behind the lens, as illustrated in Figure 4. The main problem associated with the removal of the IR filter is that the auto-focus functionality of the web-camera becomes damaged, which turns the capture of good quality images at long distances impossible. This problem won't affect the image acquisitions of the developed system since they are captured from a small distance.



Figure 4: Square Infrared filter that needs to be removed in order for the webcam to capture infrared images.

As the camera needs to detect only infrared light, a visible filter has been applied. An old fashioned photographic revealed film was used for this purpose, as shown in Figure 5.



Figure 5: Photographic film used to filter out visible light.

After removing the IR filter in the back of the lens and assembling the visible light filter in front of it, the camera is ready to do the acquisition of near infrared images, Figure 6.



Figure 6: Modified web camera used to do hand veins acquisition.

### 3.2 Pre-processing

The pre-processing stage prepares the image for the feature extraction phase. This is obtained through several stages: image adjustment, filtering, segmentation, contour detection, key point's detection and region of interest extraction, as represented in the architecture illustrated in Figure 7.

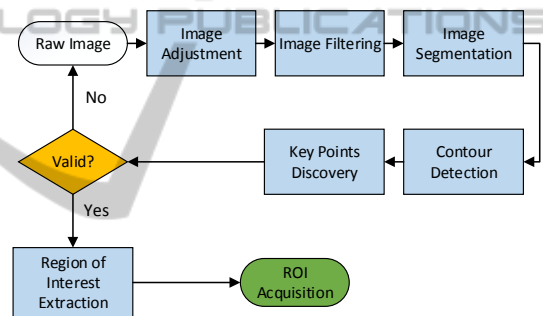


Figure 7: Developed pre-processing stages.

The first step of the pre-processing stage is image adjustment. During this step the raw image is resized from 240x320 to 192X256, in order to reduce the computational power required through the process. After resizing the raw image, the color space is converted from rgb to grayscale since the luminance information is enough for the image segmentation, see Figure 8.



Figure 8: Raw image and image after adjustment step.

The second step of the pre-processing chain is the

filtering, used to reduce the noise of the image and to smooth the areas with little variance. This is obtained using a Wiener filter, seen Figure 9.

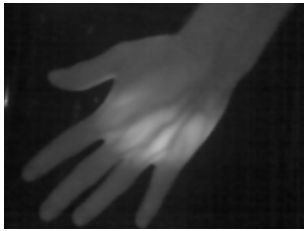


Figure 9: Image smoothed by a Wiener filter.

The third module performs image segmentation, where the image is segmented into foreground and background through a pre-defined threshold. Thresholding is a very fast way of identifying the hand using the contrast with the black background. After thresholding the image it is converted to binary. One example of a segmented image obtained is depicted in Figure 10.



Figure 10: Image segmented in foreground and background.

The segmented image is the input of the contour detection algorithm (Shapiro, 2000). This algorithm chooses a random starting point in the hand boundary and then searches for all the boundary pixels. The contour is essential for identifying the region of interest and the reference points. The hand contour can be seen in the Figure 11.

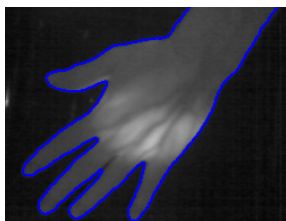


Figure 11: Hand contour.

The key point's acquisitions are obtained through the combination of two different techniques, the radial distance to a fixed point and the contour curvegram. Both methods identify the fingertips and

the valleys between the fingers.

The radial distance to a fixed point technique calculates the Euclidean distance between every contour pixel and a fixed point, which is the middle point of the region where the wrist crosses the image edge.

The contour curvegram analyzes the intensity of the curvature along the contour, and can be constructed by using a technique called difference-of-slopes (Konukoglu, 2006).

The two methods have their benefits and drawbacks, but together they create a stronger set of reference points. The radial distance to a fixed point is the first technique used in order to get an approximation of the final reference points. After obtaining the raw key points, the contour curvegram is used around the obtained locations. The final obtained positions are the final fingertip and finger-valley locations.

In order to obtain a good location of the fixed point, to be used in the radial distance method, an ellipse (Figure 12) with the same normalized second central moment as the hand region is drawn. Through the hand contour input, the ellipse's parameters like the major and minor axes, center position, end-points and lengths, orientation (given by the angle between the major and minor axes) are calculated.

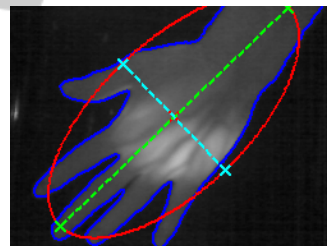


Figure 12: Ellipse with the same normalized second central moment as the hand region.

After obtaining the parameters that define the ellipse, it is necessary to find out in which side of the minor axis the wrist is located. This verification is obtained through the counting of the contour points that lie on each side of the axis. The wrist is located on the side with fewer points. Knowing the axis' side on which the wrist lies, the fixed point (Figure 13) in the wrist is defined as the intersection point between the major axis and the edge of the image.

The additional reference points, represented as yellow dots in the Figure 14, are necessary to extract the palm's region of interest. These additional reference points are determined by discovering, the thumb, index and pinkie fingers.



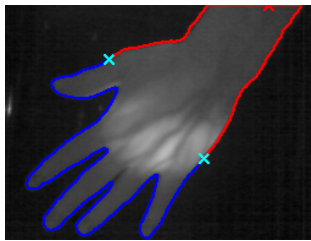


Figure 13: Fixed point marked as the half red cross.

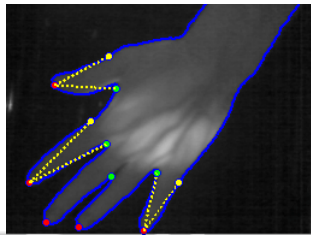


Figure 14: Hand reference points.

The final set of hand reference points, is composed by the five fingertips, the four finger valley and the three additional reference points.

After finding the reference points, the square that represents the ROI is obtained, Figure 15. The square position is defined through a line segment that is drawn between the index and the pinkie finger.

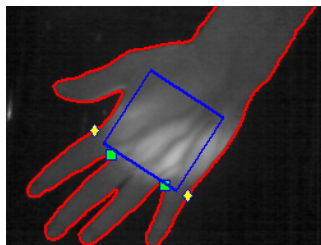


Figure 15: Region of interest acquisition.

Different hands will create squares with different sizes and orientations that will need to be normalized for matching purposes. In order to do the standardization the ROI is rotated to a vertical position and resized to a standard dimension. The standard ROI dimension chosen is 128x128 due to the results that will be presented in the performance evaluation section. Decreasing the dimensions would reduce the computational effort but would also reduce the detail of the image.

After the rotating step the image is binarized and filtered and then a thinning method is applied in order to thin and repair the vein line. The ROI treatment step can be seen in the Figure 16.

After being thinned the standardized ROI is



Figure 16: ROI treatment steps.

converted into a vector consisting in luminance values.

Through the reference points illustrated on Figure 17, the value of 35 hand geometry characteristics will be calculated in order to provide the geometrical information of the hand. The characteristics used are the finger widths (20), perimeters (5) and lengths (10). After acquiring the 35 hand geometry characteristics, a mean of the 35 values is calculated. This mean summarizes the geometrical information of the hand, so each user in the database will have one mean associated. At the identification stage, the mean of the recently acquired template under identification will be compared with the remaining geometrical information (means) of the previously acquired data in the database. Instead of comparing templates randomly, the most probable will be compared first.

The most probable users will be the ones that have similar hand geometry. If the vein pattern under identification does not fit the one from the user with the most similar geometry, the algorithm searches the next most similar and so on, until finding the one with the same vein pattern. The delay obtained by calculating the hand geometry characteristics is almost irrelevant, due to the simple calculations required.

The geometry similarity is not crucial for a positive matching, but helps sorting the most probable hands.

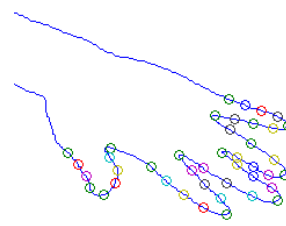


Figure 17: Reference points used to calculate the hand geometry characteristics values.

### 3.3 Feature Extraction

The feature extraction module will output the biometric template, which will be used in the matching stage. The feature extraction technique used in the developed system is the Orthogonal Line Ordinal Features (OLOF)0.

The one-dimension vector obtained in the pre-processing module will be the input of the OLOF method that will generate a one bit feature code that is going to be the template stored in the database.

The OLOF approach uses a 2D Gaussian filter to acquire the weighted average intensity of a line-like region, equation(1) (Sun,2005).

$$f(x, y, \theta) = e^{-\left(\frac{(x-x_0)\cos(\theta)+(y-y_0)\sin(\theta)}{\delta_x}\right)^2 - \left(\frac{-(x-x_0)\sin(\theta)+(y-y_0)\cos(\theta)}{\delta_y}\right)^2} \quad (1)$$

In equation (1),  $\theta$  symbolizes the orientation of the 2D Gaussian filter,  $\delta_x$  the filter's horizontal scale and  $\delta_y$  the filter's vertical scale.

Equation (2) represents the orthogonal line ordinal filter, designed to compare two orthogonal line-like palmprint image orientations for the same region (Sun, 2005).

$$OF(\theta) = f(x, y, \theta) - f\left(x, y, \theta + \frac{\pi}{2}\right) \quad (2)$$

The filtering of the ROI is accomplished using three orthogonal line ordinal filters through three different orientations ( $\theta$ ), in this case: OF (0), OF ( $\frac{\pi}{6}$ ) and OF ( $\frac{\pi}{3}$ ). The filter parameters used were  $\delta_x = 9$  and  $\delta_y = 3$ . The filter is centered at  $(x_0, y_0) = (17,17)0$ .

The output of the feature extraction phase using the OLOF extraction method are three bit ordinal codes based on the sign of the filtering results from equation(2), (Figure 18).



Figure 18: OLOF output in three directions,  $\theta = \frac{\pi}{6}$ ,  $\theta = \frac{\pi}{3}$  and  $\theta = 0$ .

### 3.4 Matching System

A successful or unsuccessful recognition of an individual is based on the calculation of the bitwise Hamming distances of the recently acquired template and all the others in the database. The Hamming distance between two vectors is the number of coefficients in which the corresponding symbols differ. If two vectors are exactly equal the Hamming distance will be zero. To calculate the Hamming distance a bitwise XOR operator is used. The validation or refusal of the matching is defined by a predefined threshold.

## 4 EXPERIMENTAL RESULTS

The experimental results of the developed biometric system are evaluated by the Receiver Operation Characteristic (ROC) curve which plots the FAR against the Genuine Accept Rate (GAR) (or 1-FRR) and by the Equal Error Rate (EER), which is defined as the error rate when the FAR and the FRR are equal.

A recognition attempt might have the results presented in Table 2.

Table 2: Possible recognition attempts results.

Type of user	Match	Non-Match
Genuine	Correct Accept	False Reject
Impostor	False Accept	Correct Reject

### 4.1 Test Conditions

In order to test the performance of the developed system, the first step was to create a hand palm vein database containing 30 registered people. For each person, five different acquisitions from each hand were performed. For the testing purposes each hand is considered as a different user. 30 registered people represent 300 different templates.

### 4.2 Performance Evaluation

The system performance was tested using the database mentioned above, using a ROI size of 128x128 and the features were extracted with the OLOF technique.

The obtained ROC curve is shown in the Figure .The ROC curve is near the perfect point (0,100) which shows the good matching performance of the system.

The ROC curve and the table show that GAR is near 85% when the FAR is 0%.

For applications like opening doors for non-high secure areas values of FAR above 0% can be used despite the slope suggesting that there is no benefit on using an operating point that has a GAR above 85%.

For ATM machine operations the FAR must be around 0% so values of GAR around the 85% or inferior are mandatory.

An alternative way of evaluating the performance of a biometric system is through the EER. A low EER means that is possible to get both

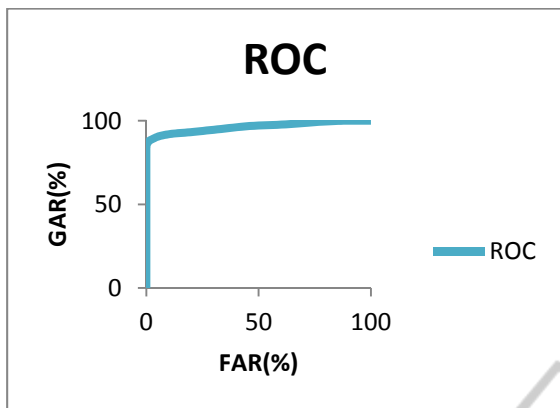


Figure 19: Receiver Operation Characteristic curve for a ROI with 128x128 pixels.

low values of FRR and of FAR and thus the lower the EER, the better the performance is. Despite being a good reference point, the EER might not be the ideal operating point for a given system. The system might require a lower FRR or FAR for special application conditions. A system that requires high security conditions like the ATM machine will require a really low FAR which will possibly imply a higher FRR.

Figure 20 shows the FAR and FRR curves produced as functions of the threshold. The figure shows that when the threshold value increases the FRR decreases and the FAR increases. The figure also shows that if the threshold is lower than 40% the FAR is near zero. Through the figure it is perceptible that the EER of the developed system is near 9% and the associated threshold is about 45%.

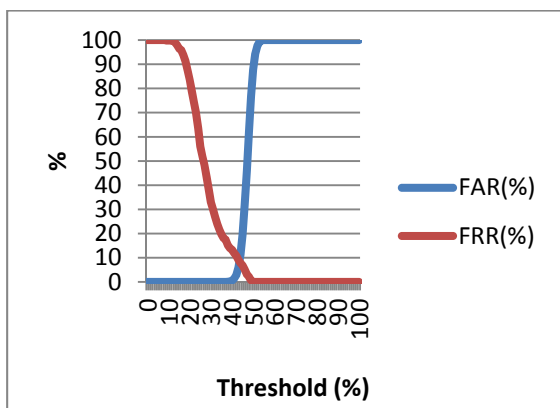


Figure 20: FAR and FRR at different operating thresholds.

In order to test which ROI size should be used, three ROC curves were created. The three sizes tested were, 32x32, 64x64 and 128x128 pixels. The obtained result is depicted in the Figure 21.

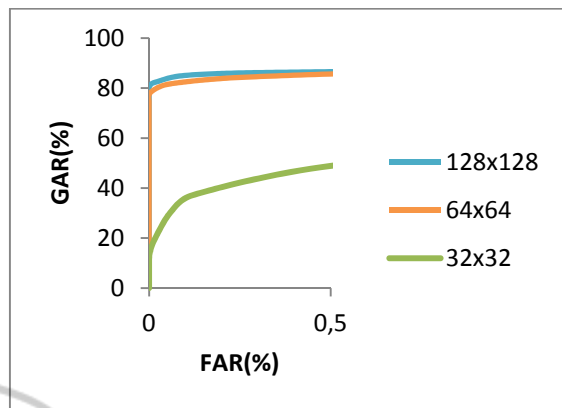


Figure 21: ROC curve for different ROI dimensions.

From the Figure 21 is obvious that the ROI size of 128x128 pixels and 64x64 obtain the best results in terms of matching. The ROI size of 32x32 pixels clearly underperforms both in the ROC curve as well in the EER (see Figure 22).

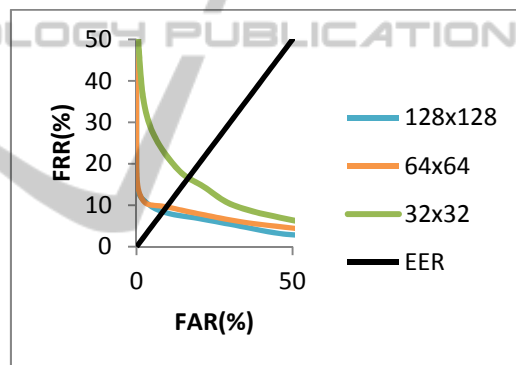


Figure 22: FRR (%) against FAR (%) to obtain EER for different ROI dimensions.

The ROI size chosen was 128x128 pixels due to the better matching performance.

### 4.3 Operating Point

The operating point used depends on the application. It must be chosen taking into account the system recognition performance and his security. The developed system can be used on several applications, like ATM machine operations, opening doors or even to unlock a computer. The operating points obtained with the developed system are present in the Table 3.

Table 3: Values of FAR and FRR for different operating points.

Threshold(%)	FAR(%)	FRR(%)
35	0.000	19.667
35.5	0.002	18.833
36	0.009	18.167
36.5	0.011	18.000
37	0.020	17.500
37,5	0.038	16.167
38	0.072	15.167
38.5	0.113	14.667
39	0.199	14.000
39,5	0.337	13.833
40	0.508	13.333

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## 5 CONCLUSIONS

This paper presents a unimodal biometric recognition system that used the hand vein patterns to do the identification of an individual. It was developed in Matlab and implemented to work on a Windows operation system.

The developed system has proved to have several operating points that can be used in different scenarios. In addition it has the advantage of being a low-cost, requiring an investment around 50€, and is simple to assemble.

The EER of the developed system is near 9%, The ROI dimension used is 128x128 pixels due to the best matching results during the tests. The OLOF templates dimensions used is 32x32.

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