Infrared image acquisition system for vein pattern analysis

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ABSTRACT

The physical shape of the hand vascular distribution contains useful information that can be used for identifying and authenticating purposes; which provide a high level of security as a biometric. Furthermore, this pattern can be used widely in health field such as venography and venipuncture. In this paper, we analyze different IR imaging systems in order to obtain high visibility images of the hand vein pattern. The images are acquired in the range of 400 nm to 1300 nm, using infrared and thermal cameras. For the first image acquisition system, we use a CCD camera and a light source with peak emission in the 880 nm obtaining the images by reflection. A second system consists only of a ThermaCAM P65 camera acquiring the naturally emanating infrared light from the hand. A method of digital image analysis is implemented using Contrast Limited Adaptive Histogram Equalization (CLAHE) to remove noise. Subsequently, adaptive thresholding and mathematical morphology operations are implemented to get the vein pattern distribution.

Keywords: Pattern recognition, biometric, thermal imaging, infrared light, vein pattern.

1. INTRODUCTION

Nowadays, there exists a great interest in development of new and better biometric techniques with people recognition purposes. For companies and organizations around the world this has become a priority, due that impersonation and identity theft are frequently used to access confidential information[1,2].

The traditional security systems for identification, provide access to restricted areas or sensitive information through the use of electronic cards, keys, Personal Access Codes (PIN's), passwords, etc. However, the above methods of identification have a limited security and they are more susceptible to be forgotten, lost or stolen. Therefore, they are inefficient because can provide access to unauthorized personnel and the security system would be deceived[3,4,5,6].

Given this problem, to improve security and access control, the biometric systems have tried to minimize these disadvantages developing new ways of verifying the identity of a person based on the authentication process of new traits, making the new biometric method more practical, robust, reliable, comfortable (with special emphasis on non-invasive or non-contact techniques) and fast response time[7,8,9,10].

Some devices use physiological traits (body shape, hand geometry, iris, retina, vein pattern, palmprint, fingerprint) and behavioral features (keystroke, gait, facial thermography, voice, signature) as identification way. Such features are appropriate for biometric analysis, since they have a high degree of safety[11].

The biometric traits for a person have the advantage of that are unique and unalterable, therefore, they are more secure, accurate and reliable to the user. Some biometric systems are based on image analysis, which are used as keys or physiological biometric data for personal identification. For example, feature analysis of signature, fingerprint, iris and retina pattern, palm veins, hand dorsum veins and fingers, etc. In the Table 1 we presented an comparative analysis of some important biometric technologies actually in use in various devices for people recognition[12,13].

A biometric trait can not effectively respond to all requirements imposed for any application. In other words, don't exist an ideal biometric, but a combination of several biometric features for people identification

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Table 1. Comparative analysis of some important biometric technologies.

Biometric trait	Accuracy	Cost	Pattern size	Permanence over time	Security level
Face	Low	High	Big	Low	Low
Iris	High	High	Small	Medium	Medium
Fingerprint	Medium	Low	Small	Low	Low
Voice	Low	Medium	Small	Low	Low
Signature	Medium	Medium	Small	High	Medium
Vein pattern	High	Medium	Medium	High	High

is permissible, with this, the percentage of authentication increases making more secure the access to personal data or restricted areas[14,15,16].

Vein pattern recognition is a new and promising trait for identification or authentication purposes. This trait is more secure and highly accurate as recognition method due that the veins are hidden underneath skin and they are not visible to the naked eye, they are less susceptible to damage, contamination by external agents, etc. There are factors that determine which biometric feature is appropriate for a biometric application. These factors are: Universality, Uniqueness, Permanence, Measurable, Performance, Acceptability, Anti-Counterfeit[17,18].

The vein pattern satisfies all these factors since it's universal because all people have a vascular pattern, is unique, has permanence over time without changes, can be measured due that has high performance, it is acceptable since it's a non-invasive and non-contact biometric technique and is more difficult to forge and duplicate[2].

Infrared radiation can be divided into three sub spectra, near infrared (NIR), mid-infrared (MIR) and far infrared (FIR). Although the NIR and FIR technologies have been used to acquire images by researchers, these two methods work in different fields. The FIR or thermal images, working in passive mode detecting infrared radiation (heat) of human body and the NIR images need external IR light sources to be registered.

The IR radiation (700 - 900 nm) can penetrate under the skin and can be greatly absorbed by the deoxihemoglobin contained in the veins. The deoxihemoglobin is the principal absorbent of the IR in the blood, furthermore of the oxyhemoglobin and water. In anatomy the palm and hand dorsum can not be broken unless the person has suffered an accident[2].

In other cases, thermal images have been used for the purpose of acquiring images of the pattern of hand veins. Since the temperature of the veins is relatively high compared to the surrounding tissue, this allows highlight the pattern of veins in FIR images eliminating unwanted characteristics of the surface of the skin caused by visible light such as scars, wrinkles or hair. However, this kind of acquisition has some limiting factors such as temperature ranges, room temperature, among others.

In this paper we analyze the acquired images in near and far infrared. Furthermore, apart of security and identification purposes, some useful applications using vein pattern recognition includes flebography, venopunction, migration control, register votes, assist control, etc[2,17,18,19].

This paper is organized as follows: Section 2 are described the optical setups for image acquisition. In Section 3, we presented the hand vein preprocessing and segmentation of the region of interest. The results are summarized in Section 4. Finally, Section 5 shows the conclusions.

2. IMAGE ACQUISITION SYSTEM

In current literature, various system configurations for imaging the vascular pattern of the palm and back of the hand have been proposed. The acquisition method most commonly used is by reflection of infrared light incident on hand. In order to acquire NIR and FIR infrared images, two image acquisition systems was implemented. The first system consists of a multispectral *jAi* 2CCD camera *AD-080 GE*[20], a near infrared LED light source with emission peak about (880 nm), a base to position the hand and a computer for storage and preprocesing acquired images.

The second image acquisition system in far infrared is composed by a ThermaCAM P65 thermal camera of the FLIR Systems brand[21]. This camera has the following technical specifications: The spectral range is 7.5 - 13 μm, for temperature ranges above 500 and 1500 Celsius degrees; the spectral range is 10 - 11 μm, the image sizes are 320×240 and 640×480 pixels, the accuracy is $\pm 2C / \pm 3.6F$ or $\pm 2\%$ of reading.

Furthermore, this camera has manual and automatic focus mode. For digital image enhancement, use an adaptive digital noise reduction. In a similar way, the ThermaCAM P65 can acquire images in two channels (visible and far infrared). The optical setups for NIR and FIR image acquisition are shown in Figure 1.

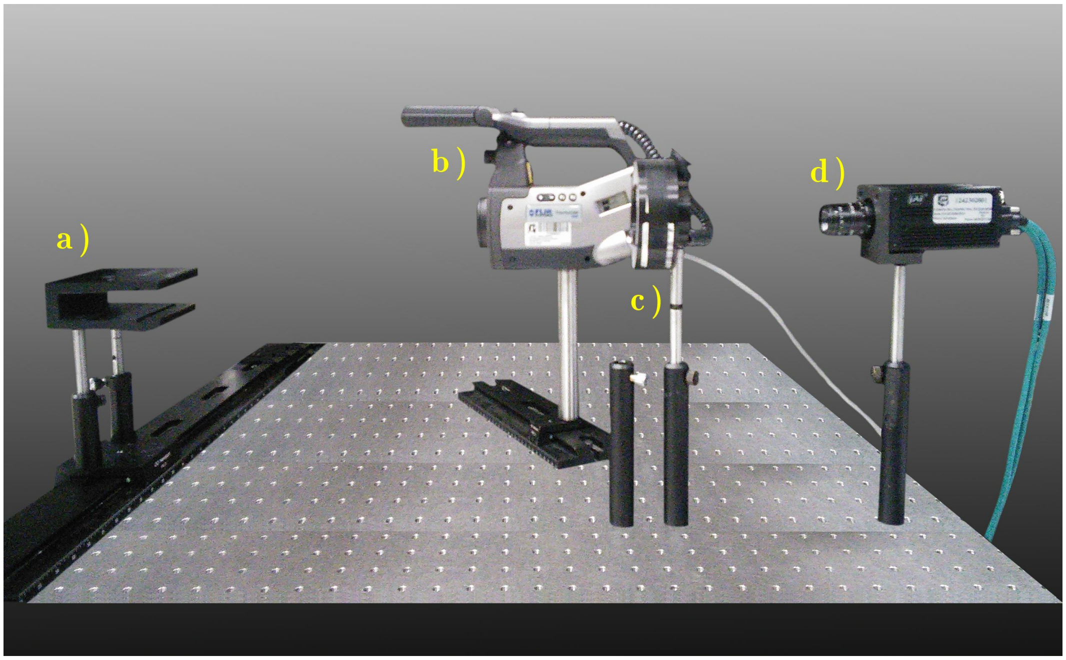

Figure 1. **Image acquisition systems for NIR and FIR images. a) Base to place the hand, b) ThermaCAM P65 camera, c) Infrared light source and d) Multispectral jAi 2CCD camera.**

The ThermaCAM P65 camera detects infrared radiation from the body and can produce images from the radiation emitted by the conversion of energy in the IR wavelength making it visible on the screen. This type of images are known as thermograms. The images can be acquired in dark environment regardless of whether it is day or night. In Figure 2a and 2b are presented images acquired in Visible and Near Infrared using a Multispectral *jAi* 2CCD camera. In 2c is shown a thermal image employing a FLIR Systems ThermaCAM P65 camera.

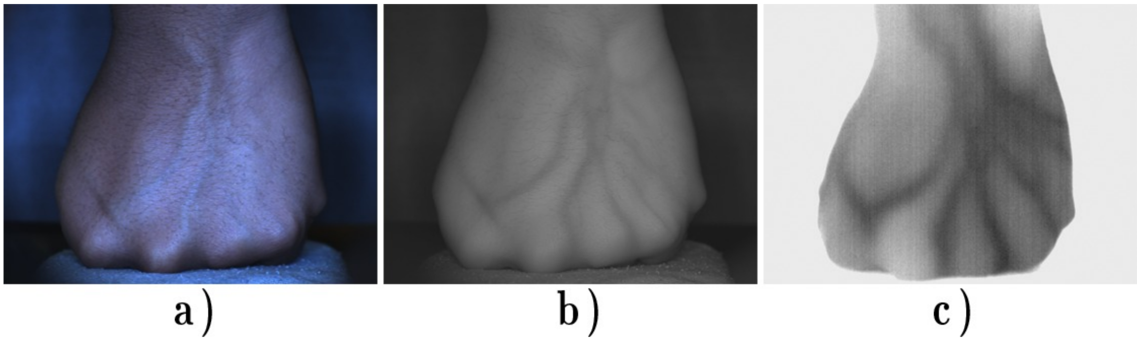

Figure 2. **a) Visible, b) Near Infrared and c) Thermal imaging.**

In Figure 3 the images of two different people were acquired using all palettes of the ThermaCAM are shown. In these images the vein pattern distribution of the hand dorsal is observed. However, in some images is not observed correctly the vascular pattern. The images captured with this type of camera, ignores certain characteristics such as hair, folds and scars on his hand. In the case of near infrared, the veins are distinguishable, but additional information is observable, which affects preprocessing stages.

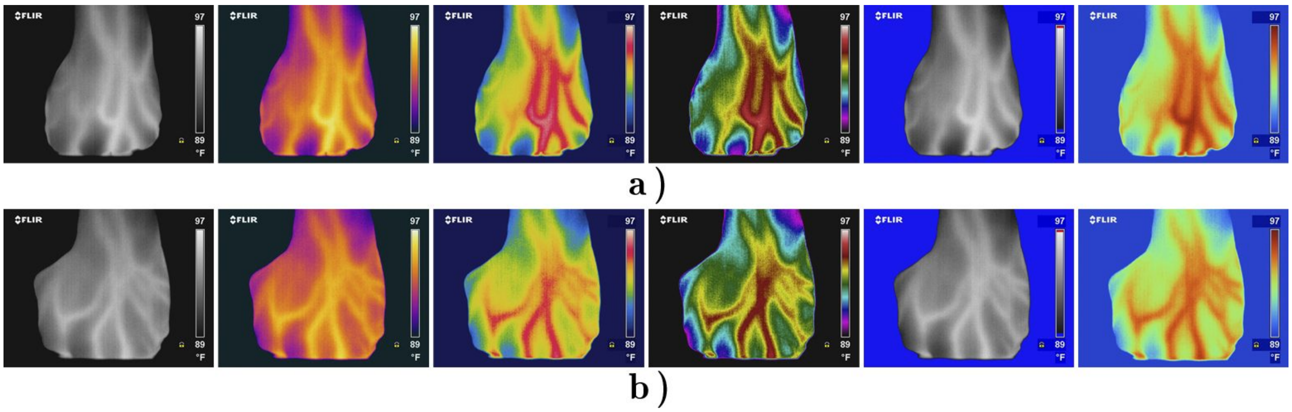

Figure 3. **Images acquired using different palettes of the Thermacam P65 for: a) subject 1 and b) subject 2.**

3. VEIN PATTERN SEGMENTATION AND ENHANCEMENT

Usually raw images are not useful for identification purposes because the quality is low, contain noise or artifacts caused by the acquisition environment. Other factors that influence the acquisition stage are generated by the hand characteristics, for example, pigmentation of the skin, the depth of the veins, environmental temperature, adipose tissue, scars, warts, abundant hair, etc. Therefore, during this stage, we eliminate unnecessary information, improve the contrast and the most important features of the structure of the vascular pattern are highlighted[22].

3.1 Hand vein ROI extraction

The first step before the preprocessing step is to determine a common area or region for all captured images. Generally this area is known as a region of interest (ROI). This preliminary step is important, allowing the analysis of a small region of the image where the greatest amount of discriminant information of the vein pattern distribution. With this, the computational cost decreases and increases efficiency in the biometric system in contrast if the whole image is used[23].

Often, some biometric devices use delimiters avoiding any movement of the hand keeping it in a fixed position during image capture, preventing rotation and translation of the hand. From the raw image, the process of ROI extraction is given by the following steps and is shown in Figure 4.

1. We calculate the centroid of the image by geometric moments.

$$\bar{x} = \frac{m_{1,0}}{m_{0,0}} \qquad \bar{y} = \frac{m_{0,1}}{m_{0,0}} \tag{1}$$

2. Obtained the coordinates $\bar{x}$ and $\bar{y}$ given by Equation 1, we calculate the distances $d1$ and $d2$, which are the width and length of the ROI. The ROI size is determined by the user and it depends of the spatial resolution during the acquisition process. In our case, the input or original images have a size of 1024×768 pixels for NIR images and 640×480 pixels for acquired images with ThermaCAM P65 camera.

3. From the centroid and the distances $d1$ and $d2$ we obtain the four points (E1, E2, E3 and E4) of the bounding box using the Equations 2. Therefore, the ROI is located between coordinates $(E1, E4)^2$.

$$
\begin{aligned}
E1 &= (\bar{x} - d1, \bar{y} + d2) \\
E2 &= (\bar{x} + d1, \bar{y} + d2) \\
E3 &= (\bar{x} - d1, \bar{y} - d2) \\
E4 &= (\bar{x} + d1, \bar{y} - d2)
\end{aligned} \tag{2}
$$

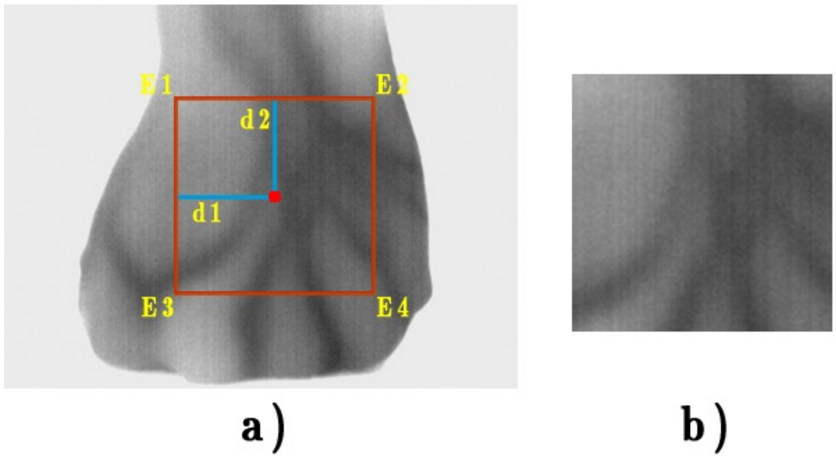

Figure 4. **a) Location of the points of the ROI in a thermal image, b) ROI extracted.**

3.2 Image enhancement

The main objective of this stage is to enhancement the contrast of the raw images and highlight relevant characteristics of the vascular pattern structure and remove unnecessary information such as noise, artifacts, and hand features as hair, scars, skinfolds etc[24,25]. In order to remove small artifacts or noise we apply techniques of digital image processing such as spatial filtering, Contrast Limited Adaptive Histogram Equalization and Unsharp masking with the objective of enhancement the vascular structure. This techniques are described below in this section.

The Contrast Limited Adaptive Histogram Equalization (CLAHE) and Unsharp masking are two techniques used are two techniques used in digital image processing because improves the details in the image. The CLAHE technique, uses the Adaptive Histogram Equalization for improving the contrast in the image. This method calculates various histograms, corresponding to different region in the image. Commonly is used to redistribute the brightness. However, the above technique increases the noise in homogeneous areas of the image. Therefore, the variant called CLAHE prevents this noise amplification, and the difference is the contrast limited. This characteristic makes this technique invariant to illumination changes[26,27,28,29].

Unsharp Masking is a technique useful to improve the sharpness in an image and typically is used to remove noise. The operation is given by

$$g(x, y) = f(x, y) + \alpha[f(x, y) - \bar{f}(x, y)] \tag{3}$$

where $f(x, y)$ is te original image, $f(x, y)$ is an average version of the original image, α is the sharpening effect factor and $g(x, y)$ is the enhanced image. The term "defocus" derives from the fact that the technique uses a blurred or unfocused image to create a mask of the original image.

In Figure 5 is presented the NIR and FIR images and their improve image using CLAHE and Unsharp Masking techniques. The binarization process is performed using an adaptive threshold, that is, local thresholding with global reduction. This method uses different thresholding values assigned to each pixel in the image, based in the analysis of grey levels of its neighbors[30].

The thresholds corresponding to the average grey values in a neighborhood of $n \times n$ size. The adaptive threshold is given by

$$g(x,y) = \left\{ \begin{array}{ll} 1 & if \quad f(x,y) \geq \delta(x,y) - T_g \\ 0 & otherwise \end{array} \right\} \tag{4}$$

where f(x,y) is the input image, $\delta(x,y)$ is an average version of the original image, T_g is a global threshold seed, the resulting image is given by $g(x,y)$.

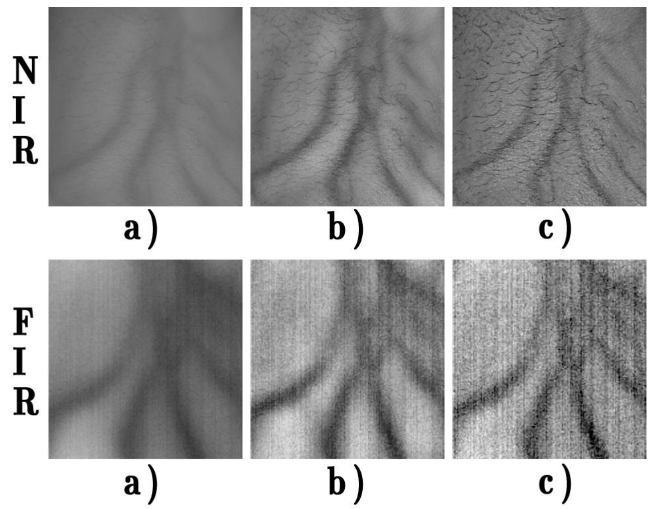

Figure 5. **a) Original image, b) Contrast Limited Adaptive Histogram Equalization and c) Unsharp masking.**

4. EXPERIMENTAL RESULTS

The results of process NIR and FIR images obtained with acquisition systems described in Section 2 are shown in Figures 6 y 7. As shown in Figure 7, although with thermal imaging the presence of veins are observed, The noise caused by artifacts that are still present until the final pattern is obtained, which gives false or unnecessary information of the correct position of the veins.

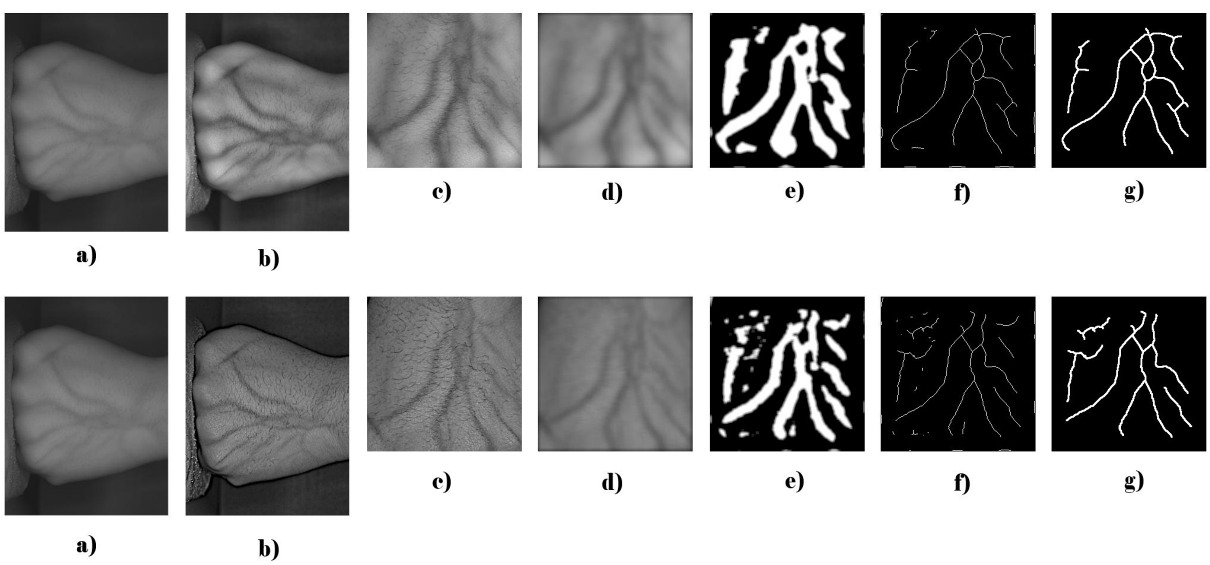

Figure 6. **Preprocessing using CLAHE and Unsharp Masking for NIR images.**

It also depends o the values assigned to the CLAHE or unsharp and binarization functions. Using the NIR acquisition system in NIR, the visualization of the veins is greater, compared to the acquired images in FIR, because some veins are not observed or are confused with the surrounding tissue. This may be caused by temperature changes and power penetration of IR in the skin.

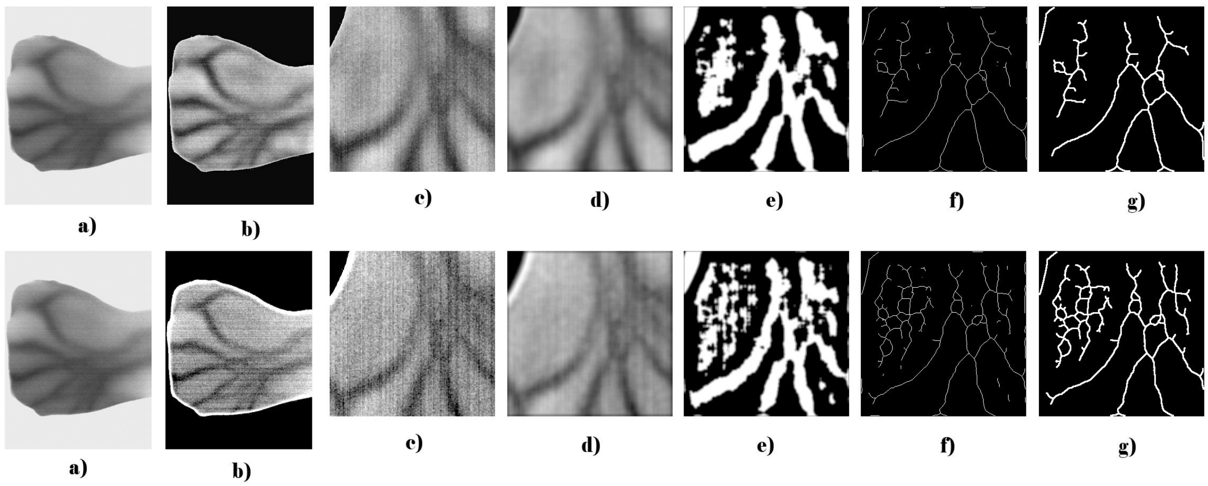

Figure 7. **Preprocessing using CLAHE and Unsharp Masking for FIR images.**

In Figures 6 and 7 is shown the preprocessing method in order to acquire the vein distribution. The process is achieved by a) NIR and FIR raw image, b) CLAHE and Unsharp Masking is applied in order to improve the contrast in raw images, c) ROI is located by geometrical moments, d) Spatial filtering is used to reduce noise and artifacts, e) an adaptive binarization algorithm is used to get vein distribution only. In the steps f) and g) we applied morphological operation such as Thinning and dilation to obtain the vein distribution and use the image g) to recognition purposes.

5. CONCLUSIONS

In this paper, NIR and FIR images were analyzed using a Multispectral jAi camera and a FLIR Systems ThermaCAM P65 camera. For NIR image acquisition a configuration by reflection was used and in the case of thermal images, the heat emitted by the human body is recorded by ThermaCAM P65 camera. The systems used by different researchers are focused on acquiring only images in the near infrared, Therefore, they are made using cheap materials and as light sources infrared LEDs approximately in 750, 850 and 940 nm. However these systems acquire images with low resolution.

The implementation of a FIR system is more expensive due to the type of sensor used, which is an Infrared Focal Plane Array. The images acquired with a multispectral jAi camera have a size of 1024×768 pixels compared to the thermal camera whose maximum size is 640×480 pixels. The factors such as environmental and body people can affect the acquisition of thermal images because these temperature changes can show or not relevant information about the vein pattern distribution. Therefore this type of images do not provide a stable image quality. During the image acquisition in near infrared and thermal, the temperature range sensed was 26 - 35 Celsius degrees.

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