Volume - 10 | Issue - 06 | June - 2021 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

SEGMENTATION OF THE VEINS OF THE DORSUM OF THE HAND IN INFRARED IMAGES

Radiology

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ABSTRACT

One of the great problems of computing is preserving the security, confidentiality, and integrity of the information. Biometric systems consist of identifying some physiological trait of an individual, focusing on information security aspects where the objective is the identification and authentication of individuals to give them access to certain information. The first stage of a biometric system consists of the segmentation of the area to be identified, which is why this work shows a methodology that allows obtaining the segmentation of the vascular network of the back of the hand in infrared images, furthermore, the methodology allows to determine the skeleton of the vascular network.

KEYWORDS

segmentation, image analysis, skeleton, biometry, vascular network

I. INTRODUCTION

Biometrics is the set of techniques for the automatic identification of individuals based on their physiological, behavioral, physical, chemical or distinctive features[1]. Although currently most security systems are based on textual keys entered by the user, due to the rise of computer systems in this area, several public and private organizations are migrating their security systems to biometric systems for identification and authentication. of individuals, as they are more reliable and easier to use[2]. There are several works that propose the development of biometric systems, some based on the iris [3, 4], others on the fingerprint [5, 6], others make use of hand geometry [7], or they use identification by voice [8], or the face [9] among others.

In each of these works, capturing the biometric trait is relatively simple since the trait to be captured can be obtained by means of a recording, such as the voice, or with a photograph, such as the face, the hand geometry and even the iris, although the latter uses a camera with specific characteristics.

On the other hand, there are biometric systems that by their nature require a more specialized device to capture images, such as biometric systems that identify and authenticate an individual through the geometry of the finger veins [10, 11], the forearm [12, 13], the palm of the hand [14, 15], or the back of the hand [16, 17] using infrared images.

The main advantages of biometric systems based on vein geometry using infrared images are that they are non-invasive, highly accurate, difficult to reproduce, non-intrusive, and distinctive and unique to each individual [18]. Infrared light with wavelengths between 740 nm to 940 nm can penetrate up to 5mm deep into the skin tissue and reach the deoxygenated hemoglobin, forming a dark contrast with the skin tissue [19] showing the veins as dark lines, biometric vein devices make use of these dark lines as the person's blood vessel pattern. A first advance for a biometric system based on the geometry of the veins is the discrimination of this pattern of blood vessels, this process is known as segmentation. Segmentation is the process in which an image is partitioned into spatially contiguous and homogeneous regions (segments) that form the basis for further analysis [20]. Segmentation algorithms are based on three fundamental criteria for grouping pixels: homogeneity within a segment, differentiation of contiguous segments, and homogeneity of shape [21]. Murat et al. [16] propose a biometric identification system based on methods of counting boxes of fractal dimension to infrared images of the back of the hand. The acquisition of the images was carried out by means of a black box illuminated with two infrared power LEDs of 850 nm wavelength, in addition they installed a Kodak 87C filter on the camera to avoid noise in the images obtained. The segmentation of the veins in the front part of the hand was carried out using gray scale algorithms, adaptive limited contrast, median filter, adaptive threshold and morphological aperture operations. Puneet et al [22] propose an authentication system that uses the vein pattern on the back of the hands. For the acquisition of the images, they make use of a black box to minimize environmental interference, inside this box the back of the hand is entered, which is illuminated with infrared light, the images are captured with an SLR camera. The segmentation is carried out in two stages, in one, they segment the back of the hand using algorithms such as conversion to gray scale, median filter, thresholding, morphological erosion operation, related components among others, in a second stage they used fusion of multi-algorithms such as convolution filters, multiplication by pixels, Canny algorithm for edge detection and subsequent morphological dilation operations, among others, to finally obtain the geometry of the veins on the back of the hands. Mustafa et al. [23] built a prototype for capturing the images, in which they used LEDs with a wavelength of 859 nm, two infrared LEDs of 1W power were focused on the target area (back of the hand) and mounted to the left and right of the camera connected to a Raspberry Pi with a flexible cable, also used a 5V 2.5-A power supply. For the segmentation of the geometry of the back of the hand, they used algorithms such as conversion to grayscale, contrast-limited adaptive histogram equalization (CLAHE), median filter, adaptive thresholding, binarization, and morphological operations. Inshirah et al [24] used a digital camera and an infrared filter to capture the images. When taking the image, the hand holds a handle and clenches the fist where the image is best defined. For the segmentation, they used normalization algorithms, histogram equalization, adaptive thresholding, median filter and low-pass Gaussian among others.

The purpose of this work is to propose a methodology that, through methods in the spatial domain, is capable of obtaining the vein pattern on the back of the hand and obtaining its skeleton.

II. MATERIALS AND METHODS

1. Theoretical framework

1.1 Digital Image

A digital image is a function $f: H \times W \rightarrow I$ where $H \times W \subseteq \mathbb{Z} \times \mathbb{Z}$. H and W represent the height and width of the image and I represents the intensity of light (brightness) at the point in space. Since a digital image is a function f(x, y) discretized in both spatial coordinates and brightness, it is often represented as a two-dimensional matrix $F_{ij} = (f_{ij})_{H \times W}$ where $f_{ij} = f(x_i, x_j)$. Image 1 shows the concept of a color H × W size digital image.

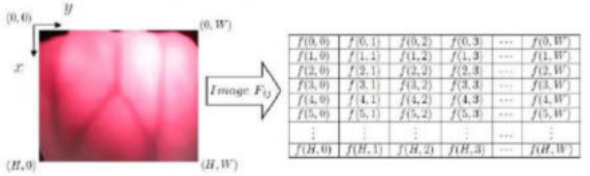


Fig.1: Digital image

1.2 Grayscale

A color model is a subspace coordinate system where each color is represented by a single point. One of the most used models is the RGB model. The RGB model decomposes an image into three components Red (R), Green (G) and Blue (B). A grayscale image can be obtained in different ways, one of which is the average of the three components (equation 1). A grayscale image is often graded on a scale of 256 levels numbered from 0 to 255, where 0 corresponds to a black pixel and 255 to a white pixel.

$$I(x,y) = (R(x,y) + G(x,y) + B(x,y))/3$$

Equation 1

1.3 Media Filter

It is a low pass filter whose purpose is to soften an image. The mean filter assigns to the central pixel the mean of all the pixels considered in the mask. If a 3 × 3 mask is considered, then the mean value will be given by:

$$M(x,y) = \left(\sum_{i=-1}^{1} \sum_{j=-1}^{1} f(x+i, y+j) \right) \Big/ 9$$

Equation 2

1.4 Weighted average filter

Like the middle filter, it is a low pass filter, where the central pixel is given greater weight to obtain a non-blurry image. Equation 3 shows the value obtained in the pixel (x, y) when applying the weighted average filter.

$$M(x,y) = \left(\sum_{i=-1}^{1} \sum_{j=-1}^{1} f(x+i, y+j) + f(x,y) \right) \Big/ 10$$

Equation 3

1.5 Median Filter

It is a non-linear local filter and has the characteristic that the value assigned to the pixel is a value present in the image, thus reducing the blurring effect in images caused by the application of filters such as the average. In a 3 × 3 mask centered on the pixel (x, y) the pixel values are ordered from smallest to largest. Let p_1, p_2..., p_9 be the corresponding values ordered from least to greatest. Then the median value that will correspond to the pixel (x, y) will be $M(x,y) = p_5$.

1.6 Histogram shift

Shifting a histogram can lighten or darken an image depending on whether the shift is left or right and maintains the relationship between the gray level values. The equation for the shift of a histogram is given by:

$$D(x,y) = f(x,y) + d$$

Equation 4

Where d is the value of the offset, d can take any value within the grayscale.

1.7 Thresholding using Niblack.

The Niblack thresholding method is a local type of method, these methods are tolerant to changes in lighting. Niblack proposes an algorithm that obtains local thresholds from a sliding mask w (x, y), to obtain the mean μ (x, y) and the variance σ (x, y). The threshold value T (x, y) is obtained by equation 5.

$$T(x,y) = \mu(x,y) + k \cdot \sigma(x,y)$$

Equation 5

Where k it is a factor that takes values of 0.2 for shiny objects and -0.2 for opaque objects.

1.8 Morphological dilation

Dilation is a morphological operator based on set theory whose objective is to grow or expand an object through a controlled process of adding points or elements through another object called a structuring element. In mathematical terms, if A is a binary image and B is a structuring element, then the dilation of A by B, denoted as A⊕B is given by:

$$A \oplus B = \{a + b | a \in A \ y \ b \epsilon B\}$$

Equation 6

1.9 Morphological Erosion

Like dilation, erosion is a morphological operator, the purpose of which is to eliminate elements of an object taking as a reference another object called a structuring element. In mathematical terms, if A is a set and B is a structuring element, then the erosion of A by B, denoted as A⊖B, is given by:

$$A \ominus B = \{x | x + b \in A \ para \ cada \ b \epsilon B\}$$

Equation 7

1.10 Relatad Components.

A connected component consists of grouping pixels from the same region by assigning them the same label. A pixel p is said to be connected by 8-connectivity to a pixel q, if p is one of its 8 neighbors adjacent to q. A path from a pixel p to a pixel q is a sequence of pixels $r_0, r_1, \ldots, r_k$ such that $r_0 = p, r_k = q$ and the pixel r_i is Connected by 8-pixel connectivity r_{i+1} foreach $0 \leq i \leq k$ A region S of an image is a connected component if for each pair of pixels p, q in S, there exists a path from p to q where each pixel that defines the path is in S.

1.11 Skeleton

Let S (A) be the skeleton of an image A. Zhang et al [25] present a method to extract the skeleton from a binary image by removing all points from the image outline except those points that belong to the skeleton. To preserve the connectivity of the skeleton, each iteration is divided into two subiterations. For the first subiteration, the outline of point p_1 is removed from the digital image if it satisfies the following conditions:

$$\left.\begin{array}{l} (a)\ 2 \leq B(p_1) \leq 6 \\ (b) \qquad A(p_1) = 1 \\ (c)\ p_2 \cdot p_4 \cdot p_6 = 0 \\ (d)\ p_4 \cdot p_6 \cdot p_8 = 0 \end{array}\right\}$$

Equation 8

Where $B(p_1)$ is the number of pixels neighboring p_1 that are different from zero, and A (p_1) is the number of patterns 01 in the ordered sequence of pixels $p_2, p_3 \ldots, p_9$ neighboring p_1.

In the second subiteration only the last two iterations (c) and (d) are changed, leaving as:

$$\left.\begin{array}{l} (c')p_2 \cdot p_4 \cdot p_8 = 0 \\ (d')p_2 \cdot p_6 \cdot p_8 = 0 \end{array}\right\}$$

Equation 9

2. Proposed methodology

The proposed methodology makes use of methods in the spatial domain. To do this, we start from the fact of considering infrared images of the back of the hand such as those shown in figure 2.

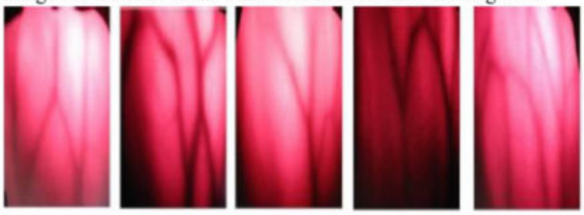


Fig. 2: Infrared images of the back of the hand.

The first step consists of applying a mean filter followed by a weighted mean filter, then transfer the image to grayscale, then a mean filter is applied to smooth the image and then a shift is applied in the histogram to clarify the image. picture. Figure 3 shows the result of sequentially applying these filters to an infrared image of the back of the hand.

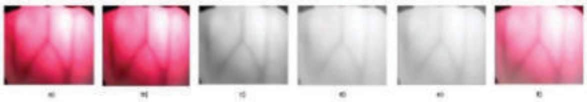
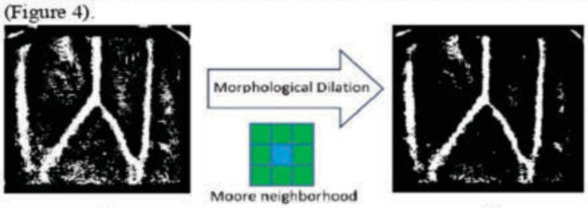


Fig. 3: Applying sequential filters to an infrared image of the back of the hand. In a) original image; b) after applying mean filter and weighted mean; in c) in grayscale; in d) mean filter; in e) histogram shift; and in f) color image after applying the filters.

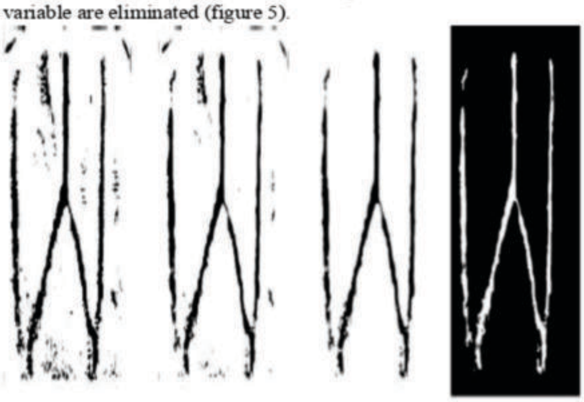
Subsequently, the image is binarized and for this, local thresholding is used using the Niblack method. A morphological dilation with a Moore neighborhood structuring element is applied to these images (Figure 4).



a) b)

Fig. 4: In a) Thresholding by Niblack, and in b) morphological dilation.

Subsequently, a negative filter of the image is applied to them using the equation Neg (x, y) = 255-f (x, y). Next, a median filter is applied, then the connected components are considered and all those connected components that have a few pixels less than a threshold variable are eliminated (figure 5).



a) b) c) d)

Fig. 5: In a) negative of the image, in b) median filter, in c) elimination of connected components, and in d) negative of the image.

The morphological closure applied to a set A by a structuring element B is defined as $A \cdot B = (A \oplus B) \ominus B$. That is, the morphological lock is equal to dilating the set A and then eroding it, all this process controlled by the structuring element B. Once the images were obtained as in figure 5 d), the morphological closure was applied, followed by a dilation and again a morphological closure. The last step of this methodology consists of finding the skeleton, and for this the technique of Zhang et al [25] was used. For this, the systems of equations exposed in (8) and (9) are considered. The application of the algorithm consists of the following: P1. Initially, the conditions of equation (8) are applied to each pixel in the image and those pixels that meet the condition are eliminated. P2. Equation (a) and (b) of (8) are considered in conjunction with equation (9) and all pixels that meet the conditions are eliminated. The steps are applied iteratively until there are no pixels left to remove. Finally, figure 6 shows the skeleton of an image of the back of the hand.

a) b) c) d)

Fig. 6: In a) morphological closure, in b) a dilation, in c) a morphological lock and in d) skeleton of the vascular network of the back of the hand.

III. Experiments and Results

For the acquisition of infrared images of the back of the hand, a vein locator with manual power regulator was used that uses infrared LEDs to transmit infrared light through the palm of the hand to the back. The size of the device is about 190 * 35 * 35mm, with voltage 5.0V-8.4V, with a working current of 0.98A-a and an illumination of 26000lux-27000lux [26]. The captured images were taken with a 7.2 Megapixel Canon PowerShot camera to which an infrared filter was placed, everything was carried out in a controlled environment inside a black box.

Fig. 7: Images of the back of the hand.

For the experimentation part, a total of 20 people were used. Each person contributed a total of 10 images of the right back of the hand. The proposed methodology was used using a mean convolution followed by weighted mean, gray scale through the average of the three RGB planes, mean, histogram shift with value d = 100, local Niblack thresholding, morphological dilation with structuring element equal to the Moore neighborhood, negative of the image, mean, elimination of connected components that had less than 400 pixels, negative of the image, lock, dilation and morphological lock through the structuring element Moore's neighborhood, and finally the skeleton through the algorithm shown in section 1.11. The proposed methodology was applied to each of the images obtaining results such as those shown in figure 8 where several images that make up the data set of infrared images of the back of the hand are shown and finally the skeleton of each one of them is shown.

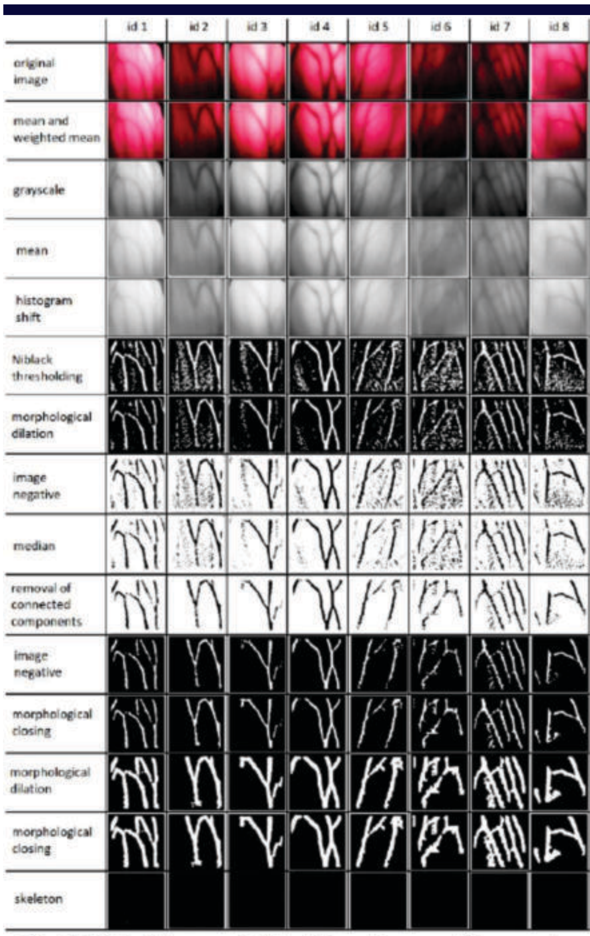


Fig. 8: Methodology applied to different images of the vascular network on the back of the hand.

IV. CONCLUSIONS

In this work, a methodology was presented that allows obtaining the skeleton of the vascular network of the back of the hand in infrared images. For the acquisition of the images, a device in the shape of a handle that radiates infrared lights was used and the images were captured by means of a 7.2 MP camera. Figure 8 shows the result of applying the methodology to various images of the data set. This work can be very useful for those works that identify and authenticate individuals by means of infrared images of the back of the hand.

ACKNOWLEDGEMENTS. The authors would like to thank the Instituto Politécnico Nacional (Secretaría Académica, COFAA, EDD, SIP and ESCOM) for their economical support to develop this work.

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