UNIVERSIDAD RICARDO PALMA
COLLEGE OF ENGINEERING

PROFESSIONAL DEPARTMENT OF ELECTRONIC ENGINEERING

RESEARCH WORK
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RESEARCH WORK TO OBTAIN THE ACADEMIC DEGREE OF BACHELOR IN ELECTRONIC ENGINEERING

TITLE : IMPLEMENTATION OF A PROTOTYPE DERMATOSCOPE USING COMPUTER VISION ALGORITHMS AND FUZZY INFERENCE FOR THE PROBABLE DIAGNOSIS OF MELANOMAS.

LINE OF RESEARCH : DIGITAL PROCESSING, VISION AND ARTIFICIAL INTELLIGENCE ARTIFICIAL INTELLIGENCE

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INTRODUCTION

To ensure proper skin monitoring and control, early recognition of melanomas is important. To this end, with the help of technology and medicine as a whole, the options today for the recognition of these melanomas are increasing. This proposal deals firstly, with the photograph obtained of the possible melanoma going through an image processing process. Then, with the proposed methodology for feature extraction, which is based on fuzzy logic, we can obtain features such as symmetry, diameter and color composition of the image. Finally, all the algorithms used are integrated to receive a final percentage.

1. PROBLEM STATEMENT

1.1. Formulation and determination of the problem

According to the Peruvian Ministry of Health (MINSA), every year more than 69 thousand people are diagnosed with cancer, a disease that causes 34 thousand deaths in Peru [1]. Melanoma is a type of cancer that is visible to the naked eye and its basic indicators can be appreciated through an image [2]. Its diagnosis requires experienced physicians with access to specific technology (digital dermatoscope). However, there is an error in the rate of naked eye recognition of images [3]. False identification can severely affect patients, because they would undergo an unnecessary biopsy to confirm the suspicion. As described in [2] this process has a high cost due to the time it takes to perform and materials. However, the number of biopsies performed in relation to the number of melanomas diagnosed with this technique is low.

Therefore, there is a need for a method to obtain a diagnosis of melanomas to reduce costs and the error in the recognition rate at first sight.

In addition, it was found in [4] that patients with melanoma have an early survival rate within the first five years can reach 95%; while the late survival rate is only 15%.

That is why early detection is an important factor to increase the chance of survival in patients.

1.1.1. General Problem:

How to implement a prototype dermatoscope using computer vision algorithms and fuzzy inference, for the probable diagnosis of melanomas?

1.1.2. Specific Problems:

- How to develop a computational vision algorithm in Matlab software complemented with Toolbox Image Processing, for noise removal?

- How to develop a fuzzy inference algorithm in Matlab software, using the Mamdani model, that allows to grant a probable diagnosis of melanomas based on the ABCD rule?
- In what way to implement a prototype of a portable and intelligent dermatoscope, using a camera, with adequate lighting and applying the developed algorithms?

1.2. Importance and justification of the research work

According to [1], cancer is the leading cause of mortality by disease group in Peru. Melanoma is a skin cancer; its early detection is crucial in the treatment. For this reason, this research is justified because it contributes in a practical way with an alternative technology, to support the diagnosis through digital image analysis and vision algorithms and artificial intelligence. In addition, it will reduce the error in the recognition rate with the naked eye. Likewise, the results achieved with the development of this research will allow the proposed prototype to support the medical specialist, while he performs the diagnostic function.

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1.3. Objectives

1.3.1. General Objective:

Implement a prototype dermatoscope using computer vision algorithms and fuzzy inference for the probable diagnosis of melanomas.

1.3.2. Specific Objectives:

- Develop a computational vision algorithm in Matlab software complemented with the Toolbox Image Processing, for noise removal.
- Develop a fuzzy inference algorithm in Matlab software, using the Mamdani model, to provide a probable diagnosis of melanomas based on the ABCD rule.
- Implement a prototype of a portable and intelligent dermatoscope, using a camera, with adequate illumination and applying the developed algorithms.

2. THEORETICAL FRAMEWORK

2.1. Conceptual framework

<u>Melanoma:</u> Melanoma is a malignant tumor originating in melanocytes. It accounts for only 4% of all malignant skin tumors, but is responsible for approximately 80% of all skin cancer deaths. In recent decades, its incidence has increased considerably worldwide, and it has become a public health problem. Risk factors include genetic and environmental factors through ultraviolet radiation. On the other hand, certain rules have been implemented for clinical diagnosis, one of which is the ABCD rule, where A represents Asymmetry, meaning that one half is different from the other half. B represents Border, which can be differentiated in irregular, wavy or

mal definido. C representa el Color, en un melanoma pueden existir diversas tonalidades de color. Por último, D representa el diámetro, donde no se puede superar los 6 mm [5].

Fuzzy Logic: allows dealing with imprecise information, such as average height, low temperature or high strength, in terms of fuzzy sets. In addition, these are combined into rules to define actions, and as they also combine input variables to produce one or several output values [6].

International Commission on Illumination (CIE) 1976 L*a*b*: The CIE L*a*b* is a uniform 3D color space in which L* is the lightness-darkness (L* = 255, white; L* = 0, black), a* is the red-green (positive to negative) and b* is the yellow-blue (positive to negative) [7].

2.2. State of art

The state of the art of the present research allows us to identify the background of works related to the detection of melanomas.

In this regard, in [8] they performed lesion segmentation and identification of melanoma from dermoscopic images. They relied on two methods for segmentation, Otsu Threshold and morphological operations, used the ABCD rule for classification. The extracted characteristic values were used for the calculation of the total dermoscopy score (TDS), which is based on the ABCD rule, to find whether melanoma is present or absent. If the TDS score is lower than 4.75 it is non-melanoma, if it is higher than 5.45 it is melanoma and if it is between 4.75 and 5.45 it is a suspected case of skin lesion. There was a deficiency in the Otsu method, because it did not adequately detect some images. They concluded that the use of trained neural networks and the extraction of more features would provide a solution to this problem.

In [9] they proposed a mobile application for early detection of melanoma using image processing methods and pattern recognition algorithms using Android Studio software, Java programming language and OpenCV library. In pre-processing they used RGB images for conversion to gray images and Gaussian filter for noise reduction. On the other hand, in segmentation, the Otsu thresholding method and the Laplacian filter for segmented quality improvement. They concluded that their project is better in three parameters, accuracy, sensitivity and specificity by 95%, 98%, and 92.19% on average, respectively, compared with two other academic papers.

Additionally, in [10] they explain the problems that exist when detecting melanomas in dermoscopic images. Some of these can be the presence of hairs, illumination or many colors within an image. For this reason, first of all, they decided to perform a segmentation in order to be able to perform a proper analysis. The algorithm for the segmentation is based on the fuzzy classification of the pixels and then the thresholding of the histogram. To carry out the whole process, the work was divided into three modules. The first one consists of an extensibility mechanism for size homogenization. The second deals with the fuzzy classification of "lesion", "skin" and "other" type pixels, all by means of a supervised machine learning process, which generates the three corresponding probability images. Finally, the third module consists of thresholding-based segmentation. To obtain the corresponding results, the authors decided that this method will participate in the 2016 and 2017 ISBI challenges organized by ISIC. Where they obtained the first place in the 2017 challenge using the sensitivity metric as the main metric. So, for this improved version of the method, the authors tried to give more priority to sensitivity than to other metrics such as the Jaccard index, with the goal of making the method more robust when dealing with images from different sources.

In [11] they proposed a new approach for the removal of undesirable features in images used for the classification of melanoma skin lesions using unsupervised deep neural networks, specifically Generative Adversial Network (GAN) and CycleGAN networks. They qualitatively demonstrated that removing hair from the input images using the algorithm they developed significantly outperforms conventional methods; improving classification accuracy by 2%, 7%, 11% and 13% on ResNet-18, ResNet-152, EfficientNet-B3 and EfficientNet-B4 networks correspondingly. In addition, their method is robust to variations in hair density, thickness and length. They obtained the best result using their method in conjunction with the ResNet-152 network with an accuracy of 93.33%.

3. SOLUTION APPROACH

3.1. Description and characteristics of the solution or product to be obtained

The type of research is applied and technological. As for the research method, it is empirical and experimental.

3.2. Solution Methodology

Figure 1 shows the proposed methodology, which consists of three main stages. In addition, it has as input the image and as output the probable diagnosis.

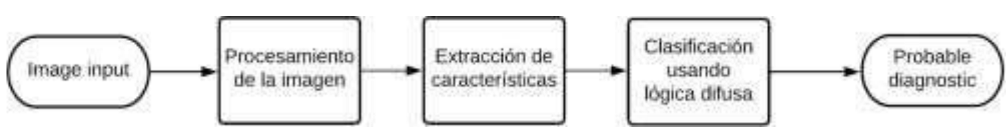

Fig. 1. General block diagram [Own elaboration].

The proposed methodology for segmenting the image, separating the background (the skin) from the area of interest (the mole). It is shown in the block diagram in Figure 2.

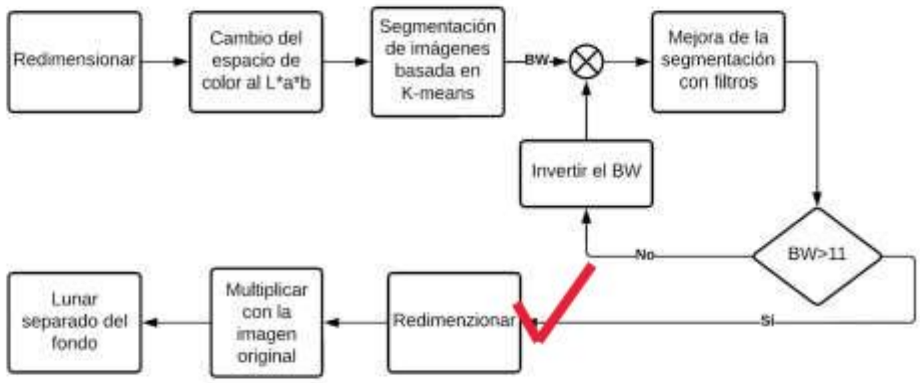

Fig. 2. Diagram of image processing [Own elaboration].

The first part is to resize the image. Where the size is reduced, preserving the ratio of height and width of the images. This is done in order to reduce processing time and improve efficiency.

Then, the color space is changed to L*a*b. This space gives more information about the different parts of the image. In the K-means based segmentation stage, a segmented binary mask of the image "BW" is obtained as output, which is enhanced with filters. The result enters a conditional block, in which the sum of all BW components must be greater than 11 and in case this condition is not met, the BW will be inverted to proceed with the same procedure of the segmentation enhancement. When the condition is passed, the image is resized to its original size. Subsequently, it is multiplied with the original image in order to obtain a final image, in which we can observe the mole separated from the background.

The proposed methodology for the extraction of features such as symmetry, diameter and color composition of the image. The symmetry and diameter of the mole are obtained by locating the center of gravity of the area of interest. The presence of red color is the component that helps to detect melanoma.

The proposed methodology for classification is based on fuzzy logic. It is shown in Figure 3.

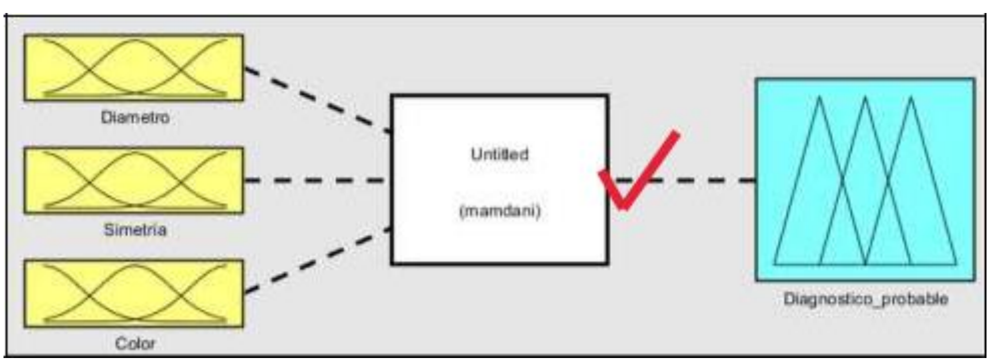

Fig. 3. Fuzzy logic Mamdani model [Own elaboration].

The fuzzy logic model has as inputs: the diameter, the symmetry and the color of the mole. These values are normalized from 0% to 100%. The output is the probable diagnosis.

3.3. Design of the solution or product

The developed image processing algorithm starts with the image segmentation process. It is shown in Figure 4 below.

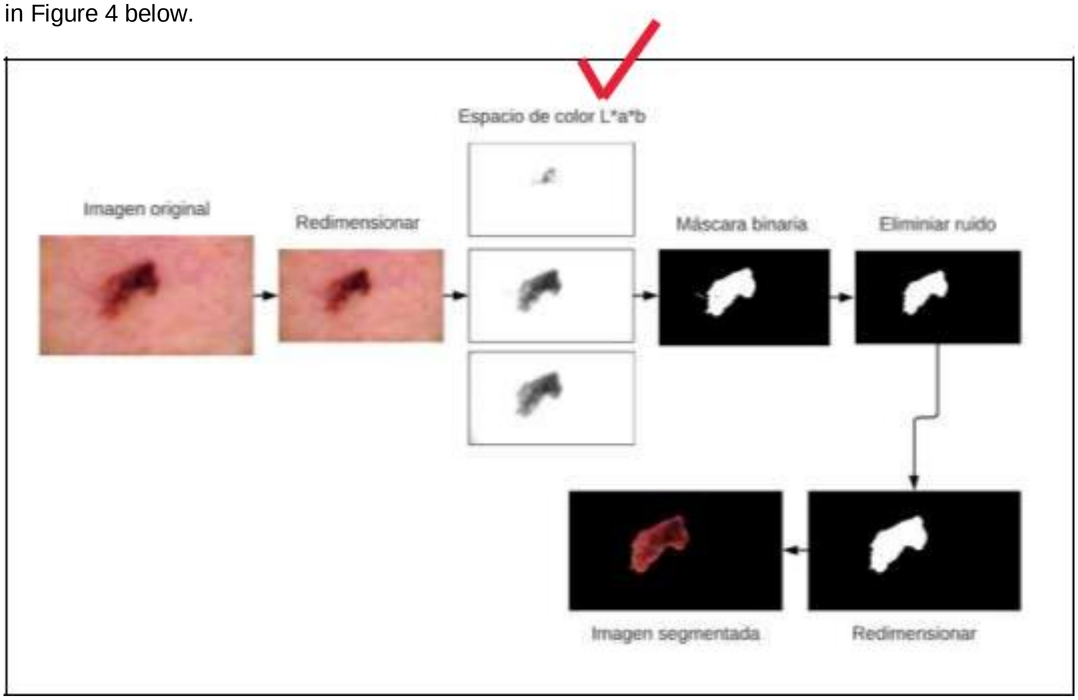

Fig. 4. Image segmentation process [Own elaboration].

The segmented image is the starting point for feature extraction. To obtain the mole symmetry percentage, the center of gravity of the mole is located, so it is necessary to work with a channel of the segmented image. This channel is binarized. From the center, the image is divided into four quadrants. The result is shown in figure 5.

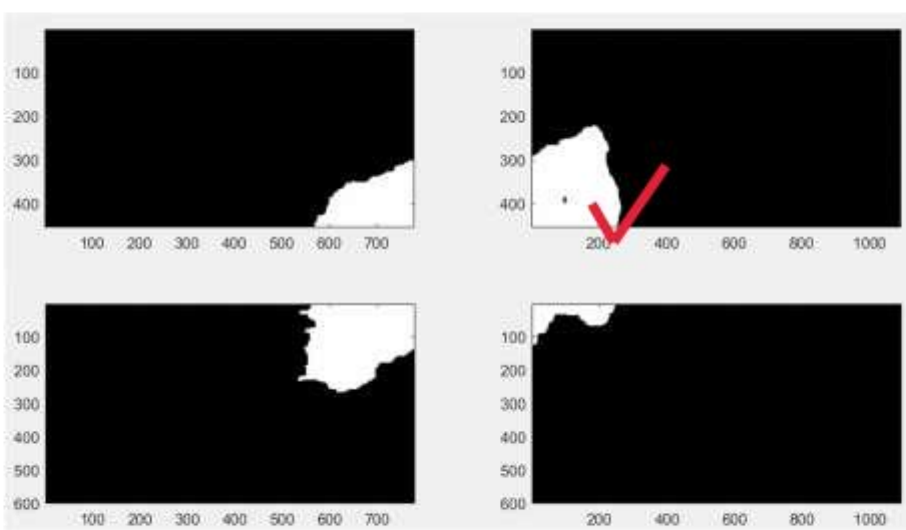

Fig. 5. Division of the image into quadrants [Own elaboration].

The mathematical process to obtain the percentage of symmetry is as follows:

All the components of each quadrant are added together:

$$C1 = \Sigma Cuadrante_1 \ ; \ C2 = \Sigma Cuadrante_2 \ ; \ C3 = \Sigma Cuadrante_3 \ ; \ C4 = \Sigma Cuadrante_4$$

An average of the above values is obtained:

$$P = \Sigma C_n / 4$$

The average is subtracted from the value of each quadrant, the absolute value is to avoid obtaining negative components:

$$\Delta_1 = |P - C1| \ ; \Delta_2 = |P - C2| \ ; \Delta_3 = |P - C3| \ ; \Delta_4 = |P - C4|$$

It continues with the calculation of how much represents, of the average:

$$A_n = \frac{\Delta_n}{P}$$

An average of the previous values is obtained, this represents the percentage of symmetry:

$$PF = \Sigma A_n / 4$$

Two examples are shown below:

Fig. 6. a) Melanoma Fig. 6. b) Mole

Fig. 6. Division of the image into quadrants [Own elaboration].

Figure 6 a) shows that symmetry was measured, obtaining a value of 53.171 %. This value is low, being in accordance with what was expected since the mole is asymmetric. In Fig. 6 b) 93.758 % was obtained, which is adequate because it is a symmetrical mole.

To obtain the diameters, it is only necessary to add the values of the binary mask in column form and in row form. The results are vectors, whose maximum values are the diameters.

From the diameters and the center of gravity of the mole, the image is cropped to focus only on the mole. The result is shown in figure 7.

Fig. 7. a) original image.

Fig. 7. b) Processing result.

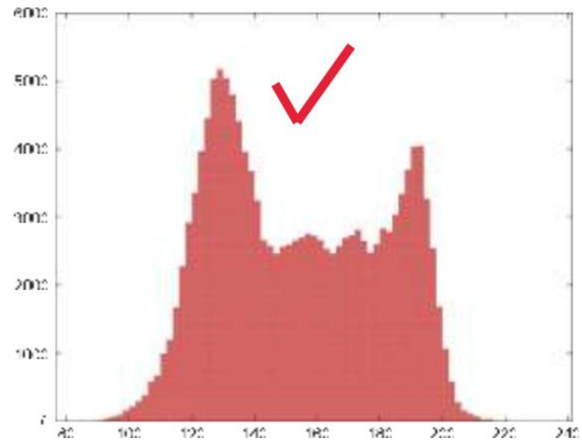

Fig. 7. c) Histogram.

Fig. 7. Approach to the mole [Own elaboration].

Figure 8 shows the 18 rules used for classification based on fuzzy logic.

1. If (Simetria is asimetrico) and (Diametro is mediano) and (Rojo is Bastante) then (Clasificacion is Melanoma) (1)
2. If (Simetria is asimetrico) and (Diametro is grande) and (Rojo is regular) then (Clasificacion is Melanoma) (1)
3. If (Simetria is asimetrico) and (Diametro is mediano) and (Rojo is regular) then (Clasificacion is Melanoma) (1)
4. If (Simetria is asimetrico) and (Diametro is mediano) and (Rojo is Poco) then (Clasificacion is No_Melanoma) (1)
5. If (Simetria is asimetrico) and (Diametro is grande) and (Rojo is regular) then (Clasificacion is Melanoma) (1)
6. If (Simetria is asimetrico) and (Diametro is grande) and (Rojo is Poco) then (Clasificacion is Melanoma) (0.5)
7. If (Simetria is asimetrico) and (Diametro is pequeño) and (Rojo is Bastante) then (Clasificacion is Melanoma) (1)
8. If (Simetria is asimetrico) and (Diametro is pequeño) and (Rojo is regular) then (Clasificacion is Melanoma) (0.5)
9. If (Simetria is asimetrico) and (Diametro is pequeño) and (Rojo is Poco) then (Clasificacion is No_Melanoma) (1)
10. If (Simetria is simetrico) and (Diametro is pequeño) and (Rojo is Poco) then (Clasificacion is No_Melanoma) (1)
11. If (Simetria is simetrico) and (Diametro is pequeño) and (Rojo is regular) then (Clasificacion is No_Melanoma) (1)
12. If (Simetria is simetrico) and (Diametro is pequeño) and (Rojo is Bastante) then (Clasificacion is Melanoma) (0.5)
13. If (Simetria is simetrico) and (Diametro is mediano) and (Rojo is Poco) then (Clasificacion is No_Melanoma) (0.5)
14. If (Simetria is simetrico) and (Diametro is mediano) and (Rojo is regular) then (Clasificacion is No_Melanoma) (0.5)
15. If (Simetria is simetrico) and (Diametro is mediano) and (Rojo is Bastante) then (Clasificacion is Melanoma) (0.5)
16. If (Simetria is simetrico) and (Diametro is grande) and (Rojo is Bastante) then (Clasificacion is Melanoma) (0.5)
17. If (Simetria is simetrico) and (Diametro is grande) and (Rojo is regular) then (Clasificacion is Melanoma) (0.3)
18. If (Simetria is simetrico) and (Diametro is grande) and (Rojo is Poco) then (Clasificacion is No_Melanoma) (1)

Fig. 8. Rules [Own elaboration].

Eighteen rules are used, since there are three inputs. The symmetry input has two states, asymmetric or symmetric. The diameter has three states; small, medium or large. Similarly, the red input has three states. This can be visualized in figure 9.

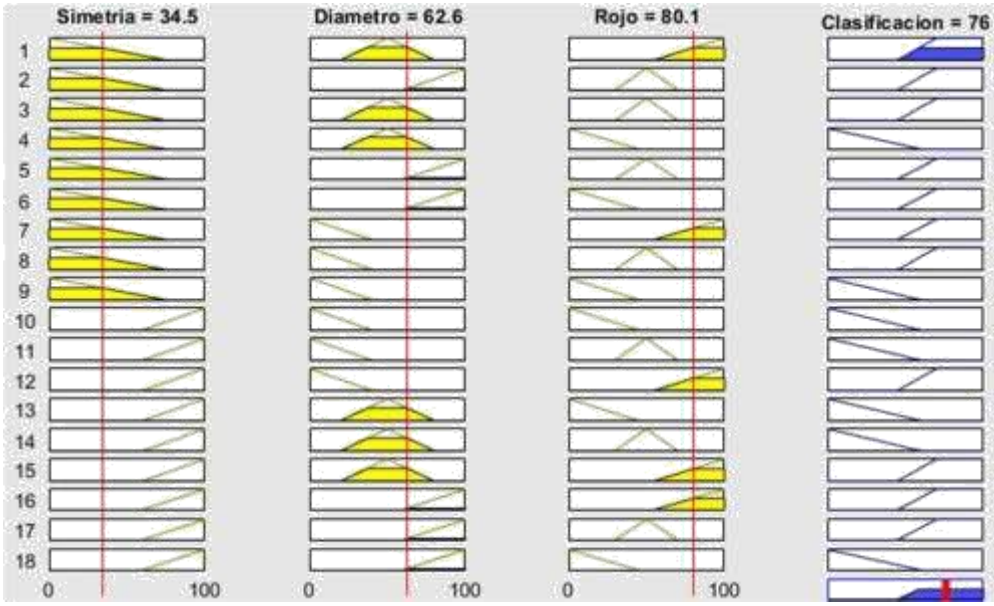

Fig. 9. Rules [Own elaboration].

4. TESTS AND RESULTS

The results obtained through the tests performed according to the proposed algorithm are shown below. Taking into account that for the tests we used photographs taken by ourselves and also acquired from the database.

In Table 1, we can observe a summary of the processed images, where we find the amount used, the amount of errors obtained and finally the error percentage.

Table 1. Summary of images processed by the proposed algorithm [Own elaboration].

	Cantidad	Error	Porcentaje
Melanoma	250	20	8,00%
No melanoma	250	31	12,40%
Total	500	51	10,20%

Fig. 10 shows a comparison between the error percentages obtained, where we clearly note that there is more error in the "non-melanoma" section. Putting the two sections together, both "melanoma" and "non-melanoma", we obtain an error percentage of 10.20%.

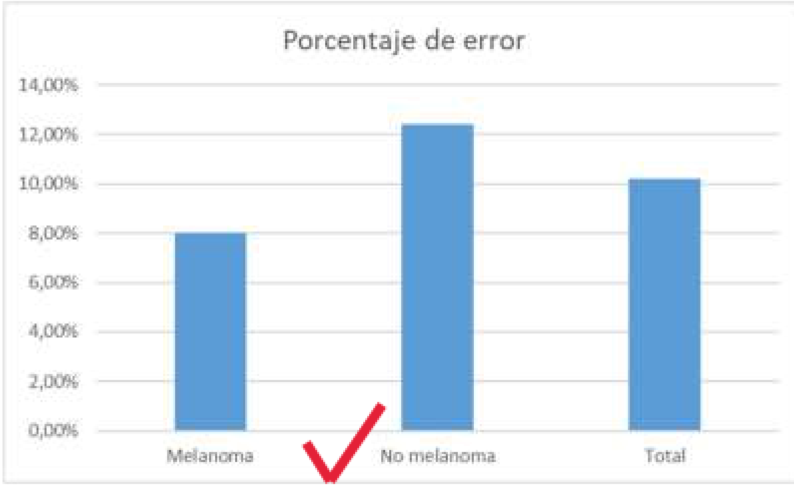

Fig. 10. Percentage of error in image processing [Own elaboration].

In Fig. 11, we observe the procedure for testing the operation of the classification based on fuzzy logic. In this first stage the data input is manual. The expected results were obtained, so we proceeded to integrate this stage to the algorithms already implemented.

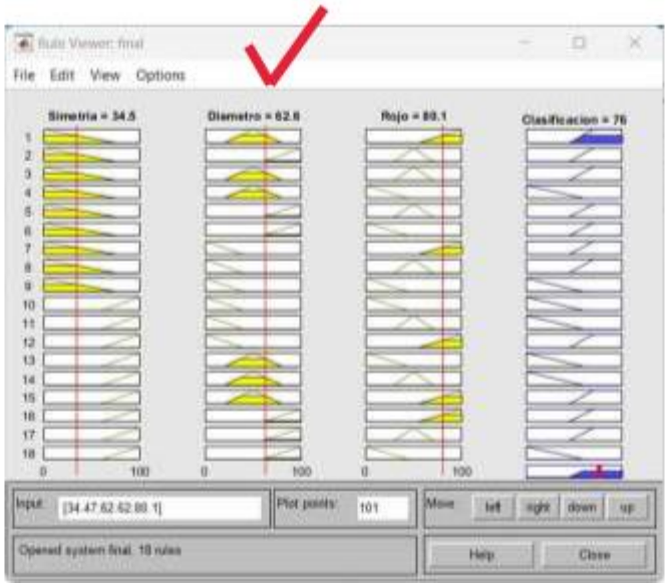

Fig. 11. Manual data entry [Prepared by the authors].

It was possible to integrate all the algorithms developed, thanks to the code shown in Fig. 12.

```
fis = readfis('final');
output = evalfis(fis,[promedio dir2 20]);
figure (2)
imshow(im)
title("Resultado " + output)
```

Fig. 12. Automatic data entry [Prepared by the authors].

Fig. 13 shows the final result. At the top is the result which is given as a percentage. If the percentage is close to 100%, it is getting closer to a possible melanoma.

Fig. 13. Division of the image into quadrants [Own elaboration].

5. CONCLUSIONS

The algorithm proved to be robust with respect to skin tone variations, having problems only with pink and very dark skin tones. It processes white and wheat tones correctly. An error rate of 10.20% was obtained, which does not represent such a high percentage. Out of a total of 500 images, 51 errors were found.

Among the limitations of the processing and feature extraction algorithm, it is found that due to the thick hair in the parts where the possible melanoma is located, it generated a failure due to the excess of presence in the photograph. On the other hand, the pink skin tone is not processed correctly.

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7. APPENDICES

APPENDIX 01: Matlab Programming

```
imagen = "ISIC_0052212.jpg"; % cambiar para ingresar la imagen deseada im
= imread('C:/Users/Control 10/Downloads/Mini database/Mini
database/Melanoma/' + imagen); % cambiar para ingresar la imagen deseada
[z,y,w] = size(im);
RGB2 = imresize(im, [480 NaN]);
X = rgb2lab(RGB2); %cambiando el espacio de color to CIE 1976 L*a*b*
L = imsegkmeans(single(X),2,'NormalizeInput',false,'NumAttempts',4); %
ksegmento más cercano
BW1=L==2;
BW2 = imfill(BW1, 4,'holes');
BW3 = imclearborder(BW2);
a = double(BW3);
ee = strel('arbitrary', ones(9));
a1 = imerode( a , ee );

a9 = imresize(a1, [z y]);

c3 = uint8( double(im) .* a9);

if sum(sum(sum(c3)))<=10
    BW2 = 1- BW1;
    BW3 = imfill(BW2, 8,'holes');
    a = double(BW3);
    ee = strel('arbitrary', ones(9));
    a1 = imerode( a , ee );
    a9 = imresize(a1, [z y]);
    c3 = uint8( double(im) .* a9);
end
figure (1)
imshow(c3)

%% Centro
cc3 = c3(:,:,1); %tomo un canal
cc4 = cc3>=40;   %binarizamos
L = bwlabel( cc4 );
[ m , n ] = find(L == 1 );
M = round( mean(m) );
N = round( mean(n) );

b1 = sum(sum(cc4(1:M,1:N )));
b2 = sum(sum(cc4(1:M,N+1:end )));
b3 = sum(sum(cc4(M+1:end,1:N )));
b4 = sum(sum(cc4(M+1:end,N+1:end )));

res = (b1+b2+b3+b4)/4;

f1 = abs(b1 - res);
f2 = abs(b2 - res);
f3 = abs(b3 - res);
f4 = abs(b4 - res);

promb1 = (f1*100/res);
```

```
promb2 = (f2*100/res);
promb3 = (f3*100/res);
promb4 = (f4*100/res);

promedio = 100-((promb1+promb2+promb3+promb4)/4);
disp('Porcentaje de simetria') disp(promedio)


figure (1)
imshow(c3)
title("Porcentaje de simetria " + promedio)
%% Diametro y Obtener el rojo
[z,y,w] = size(im);
m = sum(a9);
m1 = sum(pagetranspose(a9)); [M1,l] =
max(m,[],'all','linear'); [M2,l1] =
max(m1,[],'all','linear'); dir1 =
(M1*100/y); %ancho
dir2 = (M2*100/z); %alto
M3 = round( mean(M1/2) );
M4 = round( mean(M2/2) );
K = round( mean(M-M3));
K1 = round( mean(N-M4));
K2 = round( mean(M+M3));
K3 = round( mean(N+M4));
rojo = im(K:K2,K1:K3,:);
figure(2) imshow(rojo)

figure(3)
histr = histogram(rojo(:,:,1), 'FaceColor', [1 0 0], 'EdgeColor', 'none');

%% Integrando logica difusa
fis = readfis('final');
output = evalfis(fis,[promedio dir2 80]);
figure (4)
imshow(im)
title("Resultado " + output)
```