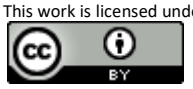
Available online at: https://ijact.in

Date of Submission	15/11/2018
Date of Acceptance	14/02/2019
Date of Publication	30/03/2019
Page numbers	3079-3087 (9 Pages)



ISSN:2320-0790

An International Journal of Advanced Computer Technology

EARLY IDENTIFICATION OF NON-MELANOMA CANCER AND ACTINAL KERATOSIS THROUGH ARTIFICIAL VISION

Jairo Eduardo Márquez Díaz Guanajuato
Cundinamarca University, Colombia.
jemarquez@ucundinamarca.edu.co

Abstract: This article shows the results about the development of a digital image processing system for the analysis of non-melanoma cancer and actinic keratosis, whose design starts from the implementation of morphological and filtering algorithms, among others, in which some characteristics are explored as the asymmetry, edges, color and diameter, typical of the spot or mole of this type of skin cancer. As a research methodology, we used mathematical modeling and simulation of algorithms that adjust to the requirements of the diagnosis, according to certain variables associated with the study image, which allow interpretation and inference by the specialist regarding them. In this sense, the ABCDE model of melanoma is taken as a parameter of analysis and study of a mole. Finally, the importance of implementing certain algorithms directly related to artificial vision is established, with a view to establishing a better functional software prospectus, which facilitates the decision making of the specialist regarding the type of melanoma and subsequent treatment to be followed.

*Keywords:*Actinic Keratosis, Binarization, Borders, Correlations, Image Processing, Non-melanoma, Segmentation, Thresholding

I. INTRODUCTION

Skin cancer is a disease that has been manifested progressively in the world population [1], which apart from charging thousands of lives per year, has generated an alarming increase in the costs of treatment and prevention for the same. In fact, it is one of the most common carcinogenic diseases with the greatest impact in contemporary society. That is why preventive medicine permanently seeks to implement new techniques and/or technologies that allow an early diagnosis of this disease [2], where operating costs are reduced, without sacrificing efficiency and quality in the service, which are key for a health system that demands greater attention to its patients.

Based on this problem, it require certain hospitals that treat this disease with the development of a computer program that allows an analysis in the context of clinical imaging, through the use and implementation of various mathematical algorithms integrated with the processing methods and image analysis through specialized software. It is based on the fact that the study images are spots or moles on the skin, whose pigmentation and morphology are characterized by their tonality and structure differentiated from the common spots of the skin. Therefore, to deepen the study of the objects that are part of the image, it is transformed to levels of gray and then binarized. With this transformation, it allows applying a set of mathematical algorithms, which provide relevant information about the form and structure of these objects in the desired scale, minimizing in the process and the excessive consumption of computational resources.

Regarding the treatment of the image, we resort to a series of phases, where each of them involves a set of mathematical algorithms that allow detecting the first

instance objects that have certain irregularities, which are key to determining if the spot or mole is malignant or benign the phases are summarized in figure 1.

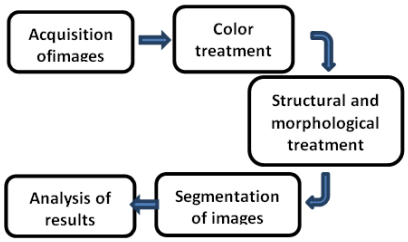


Figure 1: Phases for the treatment of images

The first phase involves the acquisition or capture of an image by means of a device, such as a digital camera or dermatoscope. In the next phase, once the image is stored in a repository, we proceed to make a color treatment, modifying it to a gray scale and then binarize it. In this phase we can apply other instructions such as selecting the region of the image to evaluate & centralize the study on it, in which certain algorithms are applied to highlight, extract and eliminate objects that are irrelevant. The grayscale or binary image is then submitted to other algorithms that allow the objects to be segmented to finally obtain a pattern that highlights the most relevant details and makes the decision making easier for the specialist.

The digital acquisition of the images is carried out by the specialist doctor, after registration of the patient's data in a clinical file, which will then be uploaded to the repository folder of the system. It then starts the application of the algorithms according to the exposed phases in Figure 1.

This acquisition is fundamental when performing the analysis for the extraction of characteristics of the objects of study. This is because, since the key lies in the quality or resolution that the image possesses as it is normally stored as a map of bits. Hence, if the registration of the objects that compose it is too granular or pixelated, it is going to be used in a complementary way. Restoration techniques, which implies an expense in terms of computational resources, which the current systems support it, but with the attenuating that the time required for this is limited in a consultation, especially when a prompt result is required.

II. METHODOLOGY

Before explaining the most representative algorithms used in the research paper, it is pertinent to explain the characteristics of the skin cancer which we analyzed in the paper.

The skin has the function of protecting the body from heat, sunlight, injuries and infections, as well as helping to control body temperature, storage of water and fat. The skin is composed of three layers: epidermis, dermis and subcutaneous tissue. The skin cancer begins in the epidermis (outer layer), which is composed of squamous cells, basal cells and melanocytes.

There are different types of skin cancer: from squamous cells and from basal or non-melanoma cells [3]. This last type responds to treatments quite well, as opposed to the first, which is more aggressive than most other types of skin cancer. The cancer called melanoma, [4, 5] if not diagnosed early, the probability that it invades other tissues and other parts of the body is very high [6]. When the state of evolution of this disease has been reached, the patient's life time is reduced, although there are aggressive treatments, the results in most cases are not promising. As an additional fact, the number of cases of melanoma increases every year, only 2% of all skin cancers are melanomas, which causes the majority of deaths from this type of disease. [7]

In the case of Colombia, there are 1488 new cases every year of melanoma, of which 328 die from this cause and for 2017, 4291 new cases was projected. [8] As noted, the increase in cases of this disease increases alarmingly each year, and the number of deaths also, making this type of cancer a chronic disease of high cost to health and the patient.

A. General information about skin cancer.

According to the detailed studies of the National Cancer Institute of the USA. UU [9], on skin cancer, is summarized in the following points:

- Skin cancer is a condition in which malignant (cancer) cells form in the tissues of the skin.
- There are different types of cancer that start on the skin.
- The skin when exposed to sunlight may increase the risk of presenting non-melanoma type cancer and actinic keratosis.
- Non melanoma skin cancer and actinic keratosis often appear as a change in hue.
- To detect and diagnose non-melanoma skin cancer and actinic keratosis, tests or procedures that examine the skin are used.
- Certain factors influence the prognosis (probability of recovery) and treatment options.

B. Non-melanoma skin cancer and actinic keratosis.

Non-melanoma [10] and actinic keratosis [11] are the types of cancer that usually appear as an abnormal change in skin pigmentation at certain localized points. For the case of non-melanoma, the most common signs are a wound that does not heal. Also, they usually manifest as white, yellow or brown spots that look like a scar. Another form of manifestation is skin elevations whose color is red

or reddish brown. In extreme cases, it may present as scaly, bleeding or scabby skin.

With actinic keratosis [12] as opposed to non-melanoma, it is manifested by a raised, flat and/or scaly rough area of the skin, in the form of a reddish, pink or brown patch.

C. Detection and diagnosis of non-melanoma and actinic keratosis.

There are several procedures for the detection of these two types of skin cancer:

- *Direct examination of the skin:* The skin is examined in situ, with the aim of detecting the presence of abnormal lumps or spots, either by its color, size, shape or texture. This examination depends on the expertise on the part of the specialist, since it is of observational type.

- *Skin biopsy:* A total or partial tissue is taken from the compromised region, for further pathological analysis in search of cancer cells. This study takes several days to issue a diagnosis. [13]

- *Dermatoscopy or epiluminescence:* It is a technique that uses a conventional optical device or with polarized light, which amplifies the image of the cutaneous region, eliminating in the process the refraction and reflection of light on the skin. [14] With this the specialist doctor, observes in detail the structure and morphology of the study area.

The detection procedures are analogical and do not imply the use of direct computer technologies for a preliminary study of the cancer.
Therefore, observing this need, a study and subsequent development of a computer program was carried out that allow an analysis of non-melanoma and actinic keratosis cancer images with the aim of examining their structural and morphological characteristics.

As a critical factor of the project, it was to take as reference the standard identification of the types of melanoma enunciated through self-examination in which the standard method ABCDE of melanoma is used. The patterns such as asymmetry, edge, color, diameter and evolution of the spot or mole are recorded, as shown in Figure 2. In this method it is required, since the type of morphology and pigmentation play a fundamental role when working with changes in the color of the study sample. Another aspect to consider are the series of external variables that can make the image present false positives. If the environment in which it was captured does not have good illumination, it is possible that an image with shines and changes of tonality that lead to an analysis and misinterpretation of the ABCDE method.

According to the ABCDE model, the asymmetry allows to establish if the mole is benign or malignant, drawing a line in half. If the mole presents unevenly and irregularly, it is malignant. Color characterizes the mole in the sense that if it is uniform, it is considered benign & if it is of different tonalities it is malignant. The Diameter, establishes the dimension of the mole, which if it is benign, must have a size smaller than 6 mm[15]. Evolution measures the changes that the mole can present at a certain time, which denotes that it is malignant.

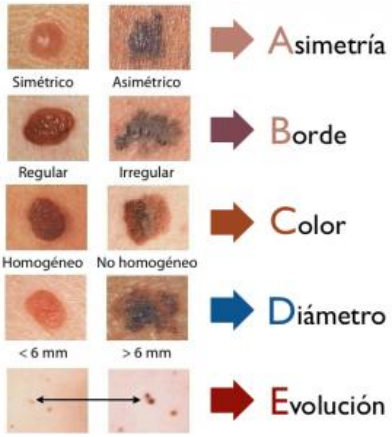


Figure 2: ABCDE for classification of Melanoma, in which the asymmetry of the spot, the shape of the edges, the tonality that it presents, the diameter it has and the stage of evolution to which it is found are evaluated. These parameters indicate to the specialist the type of clinical analysis to be performed and the subsequent treatment to be carried out, based on their knowledge and experience in this regard. Source image: calderonpolanco.com

The ABCDE classification is registered as a reference template in the software and as variables to carry out the study, both for the specialist and for the clinical support staff. It must be remembered that the image, when considered as an observational variable, it is subjected to parameters that the software cannot control and are associated with the human factors, such as: fatigue, disabling illness, medication, etc. influence in one way or another in the analysis. In technical terms, the variables to control are the variation of the light of the surroundings and form of registration of the study image, which must be focused specifically on the affected area.

Another aspect to be taken into account during capture of the image is that the skin of the patient should not have any type of cream or dirt, which at the level of optical physics, generates patterns of refraction and / or reflection irregularities over the study area, which leads to an erroneous analysis of the sample.

D. Analysis and image processing

The development of the research project focused on carrying out a study about the morphological and physical characteristics of the skin spots according to the ABCDE methodology, which allowed us to establish algorithms which would be ideal to carry out an analysis of the samples to be studied. This is obtained by maintaining the process, a comparative pattern with the original image, all managed through an application developed in Matlab.

The purpose of image processing is to improve the appearance and / or look for details that are not perceived by the naked eye of the objects that make up the studio image. This procedure is carried out in order to make the details of the objects more evident, and thus allow an accurate inspection of the most relevant characteristics of the sample, through the application of mathematical algorithms simulated in the computer.

E. Segmentation and binarization

One of the first steps in the processing of images, apart from the digitized capture, is to segment the objects that make up the image in order to differentiate the study region. In order to apply the segmentation algorithms, the the image must be in gray scale, in order to determine the limits of the study regions by creating thresholds, active contours and color and intensity analysis. With the discontinuity, a Laplacian model is applied that divides the image based on the abrupt changes that occur at the level of shades of gray, to then apply the detection algorithms of isolated points, lines and edges. These algorithms are related to the concept of thresholding, which involves methods such as entropy, histogram, clustering, local spatiality and similarity. In the case of the latter method, it is responsible for dividing the image looking for regions that have similar values, according to pre-defined criteria, such as the growth of the regions and the thresholding.

A parallel process to the segmentation, is to obtain the binary mask [16, 17], which consists basically of performing a matrix scan of the image by means of loops or recursion, in order to reduce the gray scale to values of 0 and 1 (logical image), where zero, indicates pixels of black color, and one indicates the pixels of white color. In the same context of analysis, we discuss about the pre-processing of the image, which consists of transforming it at the level of grays, which is fundamental for the subsequent algorithmic study, and then thresholding it, since what is pursued is the separation of the objects of the background of image I, so a threshold U is selected for any coordinate point (x, y), which meets the following condition:

$$I(x,y) > U \qquad (1)$$

Where the threshold *U* is a number that is between 0 and 255. Under this range of values, the image can be adjusted in order to establish specific aspects related to the resolution of objects of interest.

F. Thresholding of contours

With contour thresholding, it is sought to look for abrupt changes in the levels of gray present in the objects of the image, which turns out to be an indicative of the presence of edges in it. In general terms, you can see the thresholding method as an operation in which each pixel is evaluated with respect to a function U of the form:

$$U = U[x, y, p(x,y), I(x,y)] \qquad (2)$$

Where *I(x,y)* represents the gray level of a coordinate pixel *(x,y)* and *p(x,y)* that describes the local property of the pixel with respect to its neighbors or neighborhood, in which the image is taken in its entirety as a matrix of size *MxN*. Therefore, the thresholding results in another image *Im* defined under the following conditions:

$$Im(x,y) = \begin{cases} 1 & siI(x,y) > U \\ 0 & siI(x,y) \leq U \end{cases} \qquad (3)$$

From these conditions the following is inferred from *Im*: first it represents a pixel of coordinates *(x, y)* of the image, where the label 1, corresponds to the objects; and second, the label 0 that corresponds to the fund. In the thresholding phase, some aspects are considered regarding the treatment of the image, such as: Losses of connectivity between the pixels that are part of the edge of the image due to the inherent noise, due to the existence of edges and by noise filtering through the use of demanding algorithms. Each of these elements is relevant for a detailed analysis of the image, since the level of depth to which the study is made can only be done through the use of specialized software and a computer system provided for that purpose.

G. Algorithms for edge detection

Edge detection is an image processing technique that allows the search for boundaries that demarcate objects within the image. This is achieved through the use of approximations by first and second order derivatives, which detect discontinuities in the brightness of the objects. To do this, we proceeded to use edge detection techniques, which are based on the following algorithms: Roberts, Prewitt, Sobel and Canny. [18] These techniques, combined with other object counting algorithms [19], give a certain degree of reliability when carrying out a detailed study of the image through masks, which allow the gradient to be calculated.

The masks of the first algorithms are represented as follows:

- Roberts: only use two points for each mask as indicated, so it becomes ideal for when working with binary images.

-1	0
0	1

- Prewitt: calculates the gradient over the edges of the image, where each mask is different.

-1	-1	-1
0	0	0
1	1	1

-1	0	1
-1	0	1
-1	1	1

- Sobel: it is characterized because it allows eliminating part of the noise that the image carries, smoothing it and with it the false edges.

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

One of the most relevant algorithms in this study is Canny [20], which is developed in phases to detect edges using four filters for horizontal, vertical and diagonal directions. The first phase is to obtain the gradient before smoothing the image to avoid over detection of the edges. This smoothing is by means of a Gaussian filter function, represented mathematically as:

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (4)$$

The gradient of the image I (x, y) at a point (x, y), is described by a two-dimensional vector G, which has the form of:

$$|G| = \sqrt{G_x^2 + G_y^2} = |G_x| + |G_y| \qquad (5)$$

Where the gradient vector is represented by:

$$\nabla f(x,y) = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right] = [G_x, G_y] \qquad (6)$$

The direction between G_x and $G_y$is determined by the inverse function of the tangent:

$$\varphi(x,y) = tan^{-1}\left(\frac{G_y}{G_x}\right) \qquad (7)$$

The next phase of analysis consists of the non-maximum suppression of the gradients, in which it is sought to obtain edges of a dimension pixel. Therefore, a discrete set of addresses is taken for the analysis of 0, 45, 90 and 135 degrees. Then, we proceed to calculate the hysteresis of the threshold to the previous phase, eliminating maximum noise along with the other details not essential for the study of the image. Finally, the closing phase of the open contours of the image is applied.

As for the algorithms of Roberts, Prewitt and Sobel, they differ from each other by the masks used on the edges of the image, by their sensitivity to noise and vertical, horizontal and diagonal directions [16]. Thus, with the implementation of these algorithms in the system, it implies for the specialist to determine which are the most suitable for the study, providing a wide range of presentation of the objects of the image in terms of tones, morphology and more relevant expression. With these options given in the program, the specialist can select the algorithms that suit you according to the type of study you want to perform on the sample.

H. Presentation system

Before starting the process of analysis, the specialist doctor must register the details in the computer system with the purpose that posteriori can create the clinical record of the patient, entering the personal information to be registered in the database developed. We are using MySQL in this case. The system confirms the user and password in the database for the later entry of this to the program. Once this step is done, the doctor will be ready to record the patient's personal data in the subsequent consultations.

The next step is the collection and storage of the images of the patient's affected skin in the repository of the database. To do this, the original image is loaded from a digital camera or a dermatoscope. Once this step is done, the image is transformed to gray scale, to then apply the binarization or thresholding algorithms as desired. Then, we proceed to highlight the contour of the study image, as shown in Figure 3.

The next step is to eliminate pixels from the lunar contour and objects that differ in the sampling. In this process, we present the option of applying morphological algorithms [21] such as dilation, erosion, opening and closing on the binarized image [22], which allow us to clean and/or eliminate the contour and neighborhoods of the I image *(x, y)* of objects that are not very relevant to the study. It should be noted that the order of the morphological algorithms must be respected in order to obtain better results. Each morphology generates a structural element, which is a sub-image *I '(i, j).*

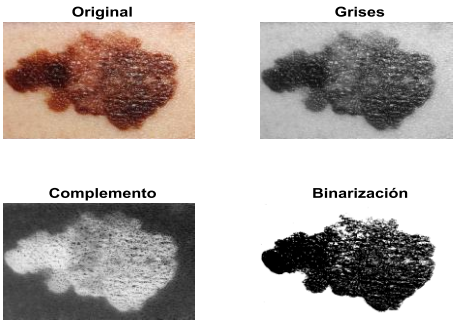


Figure 3: Binarization of the image, previous conversion to a gray level scale and complement of the image at gray level. This last process is carried out in order to establish the uniformity of the pixels in the relevant objects of the study image and establish whether or not a new information record is relevant.

Mathematically, the morphological structures E of I are designated by the operators ⊕ and ⊗, which define a set of

data according to the algorithm applied. For the case of the dilation process, it complies with the commutative and associative property, just as it is invariant to the transformation, which is also increasing, that is, the number of rows of the matrix I 'is equal to or greater than the matrix I. Then, the dilation is defined as the set:

$$I \oplus I' = \{d \in E^2 : x + b,\ for\ each\ x \in I\ y\ \ b \in I'\} \quad (8)$$

This set implies that:

$$(I \oplus I')(x, y) = \max_{\substack{0 \le i \le n-1 \\ 0 \le j \le n-1}} \{I(x - i.y - j) + I'(i, j)\} \quad (9)$$

That is to say, this algorithm allows adding pixels in the borders of the study image, in order to improve variations in the neighborhoods of the objects that compose it.

As for the process of erosion, it complies with the properties of not being commutative, it is invariant to transformations, and it is invertible (once applied it cannot be returned), it is dual and it is a growing transformation, among others:

$$I \otimes I' = \{d \in E^2 : d + b \in I, for\ each\ b \in I'\} \quad (10)$$

This set implies that:

$$(I \otimes I')(x, y) = \min_{\substack{0 \le i \le m-1 \\ 0 \le j \le n-1}} \{I(x + i.y + j) - I'(i, j)\} \quad (11)$$

That is to say, this algorithm allows removing pixels from the borders of the studio image, in order to soften the neighborhoods of the objects that compose it.

These models take values that are outside the binarized image, which assumes that their gray level is equal to zero, *I(x, y) = 0*. Furthermore, if an XOR function is applied to either of the two morphologies, they are obtained the contours of the image, which has remained as an option of use for the specialist.

For the case of opening and closing, these are combinations of erosion and expansion, which allow eliminating details of the image smaller than those of the structural element. The respective operations are:

$$I \circ I' = (I \otimes I') \oplus I' \quad (12)$$
$$I \cdot I' = (I \oplus I') \otimes I' \quad (13)$$

Both the opening and closing operations are idempotent, that is, they can be executed as many times as desired and the same result is obtained.

With the use of morphological algorithms, it allows eliminating any object not related to the study image, which decreases in a certain percentage the false positives of the skin, such as moles, spots and/or freckles near the study area, including imperfections of the skin like scars, or villi. Therefore, the step to follow for minimizing this problem is to add pixels to the outline of the objects present in the image in order to improve their border, as seen in Figure 4.

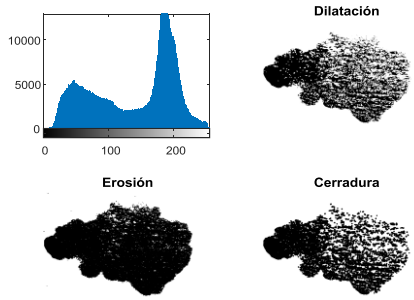


Figure 4

Once the histogram has been established, it allows observing the level of gray pixels and their distribution in the image, which in this case shows pale shadows in some regions. It is then necessary to apply the algorithm of dilation before binarization to establish its morphology. It removes the irrelevant details of the image i.e. reduces or refines the image, and finally applies the algorithm of the lock that softens the outline of the image on the outside. Another algorithm that eventually applies is the opening algorithm which smoothest the image inside.

Also, parallel to the previous process, a histogram of the studio image can be generated in order to establish the distribution of pixels in the gray levels. Similarly, with the histogram we can determine if the image is dark (shades off) or black background (shadows), the image has very clear regions (overexposure) or has no dark regions (pale shadows). It should be remembered that the histogram is a graphic representation of the relative frequencies according to the colors that make up the scene of an image. Haystacks and Cross [23] define the histogram as a discrete function, which represents the number of pixels in the image as a function of intensity levels, g, where the probability of occurrence P (g) of a given level g is define as:

$$P(g) = \frac{N(g)}{M} \quad (14)$$

Where P (g) is evaluated in the interval [0, 1], *N(g)* represents the number of pixels that is at an intensity level g and M represents the number of pixels in the image.

Within the statistical characteristic of a histogram that is evaluated in a gray scale image are: the mean, variance, asymmetry, energy and entropy. To this process we can add the equalization algorithm, which allows us to improve the resolution of the image, to later work with it from the beginning and apply the histogram again.

Continuing with the analysis, we define the degree of reflection and refraction of the study area in which the image is submitted to RGB masks in order to observe differences and coherences according to the ABCDE

model. In this same context, the counting of relevant objects of the image is performed as shown in Figure 5. It shows the area and geometry that one wish to study inside the sample is defined.

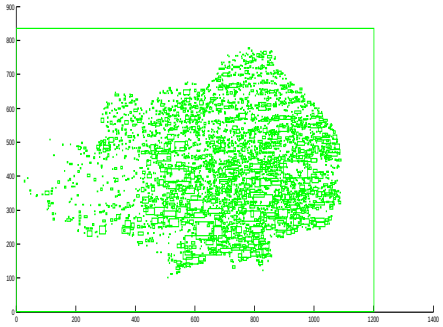


Figure 5: Counting of objects according to the number of pixels per predefined cell. This process is important when comparing the images with time. If there are minimal changes in the structure of the mole or spot, the count will be known immediately. Needless to say, this count is automatic.

A complementary option to the masks is to use the Mahalanobis algorithm [24], which allows determining the similarity between two multidimensional random variables through the measurement of the distance between distributions:

$$D^2 = (\mu_0 - \mu)^T S^{-1} (\mu_0 - \mu) \qquad (15)$$

Where μ_o, μ and S represent the means and variance respectively of a set of distributions calculated on the objects of the image.
The Euclidean distance, unlike the previous one, takes into account the correlation between the random variables. For the case of 2D images, the distance is calculated as follows.

$$d = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} \qquad (16)$$

That is, the Mahalanobis distance is calculated between two random variables that have the same probability distribution, which are related to a covariance matrix [25]. Hence the results in terms of the distribution of pixels are either in color or gray scale of an image turns out to be better than the Euclidean. This does not imply that the Euclidean metric is discarded as it is used to measure the diameter of objects, increase or reduce the size of the image and cut a part of it. Among other options, all of them leading to extract the most representative patterns of this, in order to facilitate the specialist, infer about the morphological characteristics and appearance of the spots for later comparison with the ABCDE model.

A help that is incorporated into the system, is the use of differentiation as a method to calculate the degree of separation between neighboring gray levels, edge detection and probability distribution of pixels (objects). To do this, the filtering algorithms [26] are applied, such as: Roberts, log, Poisson and Speckle. Each of these algorithms presents changes in the study image, which eventually are combined with others that the specialist deems necessary in order to clarify details and rule out false positives.

As a complement to what was previously developed, a series of image correlation algorithms are used, which allow the establishment of properties of certain study objects that may be relevant for clinical analysis, in terms of growth and patterns associated with the ABCDE model, & can be taken as a tool to support it. Also, with the correlation method, a comparison pattern is established between the original image and an image that has been recorded posteriori or a section of it, in order to establish if there are variations in a certain region of the spot, such as seen in figure 6.

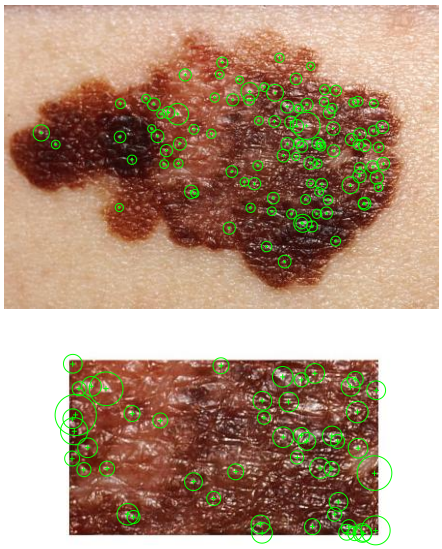


Figure 6: Method of pixel correlation of a color or gray scale image. This method is ideal when it is required to establish variations in saturation, tone and brightness of the objects in an image.

III. Discussion and Analysis of Results

The procedures is currently applied for the detection of skin cancer (in particular that of non-melanoma and actinic keratosis) from a computer system that acts as a support to the diagnosis of diseases especially when it requires the specialist to perform a detection in its first stages. In the obligatory bibliographic review for the development of the project, it is evident that there is very little material focused directly on the subject treated. There are investigations for the processing of skin cancer images in which dermatoscopic images are taken [27], applying techniques of morphological analysis, color manipulation, image segmentation and characterization [23, 28], even using neural networks, which they have proven to be good about selecting specific study regions, but not for non-melanoma and keratosis.

In contrast to the techniques mentioned, the proposed system combines various algorithms for edge analysis, filtering and color. This allows a detailed study on the morphology and structure of the spot or lunar. Special attention was paid to the detection of discontinuities, such as edges, lines and corners, where the canny algorithm was of particular interest, as well as that of sobel, Roberts and the prewit. We have taken these four algorithms as Alvarado [29] states that when applying image reconstruction considering combinations of phase and magnitude from different sources, they also show that the phase is the carrier of this information.

Combining several algorithms together allows a detailed study of specific regions of the sample, which is very important for further histological study. Also, within the analysis of the characteristics of the image, a combo of standard filters has been arranged, either to work with the morphology, such as the top-hat and the bottom-hat, as to improve the quality of the sample's enhancement, such as: the Gaussian, salt & pepper [30] and multiplicative, with various configurations to increase or decrease the noise level.

According to tests conducted in a controlled environment, an important element is the quality of the image, so the use of the dermatoscope is recommended. Although a series of photographic records was made with a conventional digital camera, even with images captured from a mobile device, the system proved to be flexible and functional when it came to processing the images. This experience proposes that if the patient, due to factors of access, transportation and costs, cannot travel to the health center, only with the capture of a good image through a smartphone, tablet or digital camera can be used directly for the diagnosis. In fact, with the advance that currently exists in terms of development platforms for mobile applications, part of the code developed for the desktop program can be extrapolated and implemented in a Smartphone, either in Matlab code (using the package of Matlab Mobile), or using other languages such as OpenCV [31], Java [32] and Python [33], among others.

The system developed is designed as a complement to the aforementioned diagnostic procedures, which will allow the specialist and/or pathologist to carry out a detailed and personalized study of the evolution of melanoma.

In the future, it is intended that the developed system be integrated with advanced artificial vision algorithms, combined with intelligent algorithms based on deep learning (deed learning) [34] and/or learning machines (machine learning) [35]. This will undoubtedly improve the performance, since these algorithms allow comparisons and/or correlations between objects in real time with what can be established if the treatments performed are working as expected or not. The correlations have proved their value in other contexts of clinical imaging and engineering in general.

IV. CONCLUSIONS

The study of clinical images has taken great relevance in recent years due to the exponential growth of computational power as well as the development of new applications that allow simulating high complexity mathematical algorithms quickly and efficiently. Thus, by using digital image processing for the early identification of cancer, the specialist can perform a detailed analysis of skin abnormalities such as non-melanoma and actinic keratosis in its early stages of evolution. One aspect to be taken into account of the program is that it can expand to other types of skin anomalies, knowing how to combine the various algorithms for image processing, whose visual manifestation can be identified quickly, based on the ABCDE classification of the melanoma.

By combining various image contour enhancement algorithms, segmentation, binarization, thresholding, Euclidean and Mahalanobis metrics, the ideal results are obtained for a visual study of the aforementioned melanomas, in addition to facilitating the field of observational research of this type of disease.

Although preliminary tests have been performed with standard neural networks, more research is required on the potential fusion of convolution neural networks with the developed system, as well as the incorporation of other artificial vision algorithms, such as: Viola Jones [36, 37] and the algorithm of AdaBoost [38] and an adaptive meta-algorithm of machine learning. This is to make the program more dynamic and assertive when identifying abnormal patterns in moles and/or skin spots. Therefore, identification of melanoma will be faster & making it easier for the medical specialist to make decisions in the early stages of the disease.

One aspect to mention that a neural network or artificial vision was not incorporated into the current software due to the fact that the system was created in principle to be implemented in a portable computer which allows its mobility if the specialist has to travel to hard-to-reach areas and carry out his on-site study.

V. REFERENCES

[1] Castañeda, P &Eljure J. (2016). El cáncer de piel, un problema actual. Rev. De la Facultad de Medicinade la UNAM, Vol. 59 No. 2, pp. 1-14.

[2] Weintraub, K. (2016). Las defensas contra el Cáncer. La estimulación del sistemainmunitarioestádandoresultadosprometedoresen la lucha contra el cáncer. Investigación y Ciencia, No. 477, pp. 19-27.

[3] American Cancer Society (2015). Cáncer de pieltipo melanoma., Enlíneaen: http://www.cancer.org/acs/groups/cid/documents/webcontent/002312-pdf.pdf

[4] Masloski, J. E., Piat E. G. L, Lujan S. A. M., De la Rosa J C. (2008). Melanoma. Revista de Posgrado de la VíaCátedra de Medicina, No 183, pp. 9-16.

[5] Casariego, Z. J., &Baudo, J. E. (2004). Trabajo de revisión: melanoma. Avancesenperiodoncia e implantología oral. Vol. 16, No. 3, pp. 157-177.

[6] Jordán, J. (2003). Apoptosis: muertecelularprogramada.ÁmbitoFarmacéutico. Vol. 22, No. 6, pp. 100-106.

[7] Instituto Nacional del Cáncer. (2015). Cáncer de piel (incluye el melanoma) para pacientesEnlíneaen: http://www.cancer.gov/espanol/tipos/piel

[8] Liga contra el Cáncerseccional de Bogotá. (2015). Cáncer de piel. Enlíneaen: http://www.ligacontraelcancer.com.co/cancer-de-piel/magnitud-del-problema/

[9] Instituto Nacional del Cáncer. (2015). Cáncer de piel: Tratamiento (PDQ®). Información general sobre el cáncer de piel. Puntos importantes. Enlíneaen: http://www.cancer.gov/espanol/tipos/piel/paciente/tratamiento-piel-pdq

[10] Lobos, B. P., Lobos S. A. (2011). Cáncer de piel no-melanoma. Medina Clínica. CONDES; Vol. 22, No. 6, pp. 737-748.

[11] New York Presbyterian Hospital, (2015). Cáncer de Piel. ¿Qué es la queratosisactínica? Enlíneaen: http://nyp.org/espanol/library/skin/actinic.html

[12] Godoy, D., Lova, M., & L. Martínez. (2014). Epidemiología de las queratosisactínicas. Queratosisactínica. Pautas y seguimiento. Consejo general de Colegios oficiales de Médicos de España. Madrid, España, pp. 21-25.

[13] Acosta, A. E. Fierro, E., Velásquez, V. E. Rueda, X. (2009). Melanoma: patogénesis, clínica e histopatología. Asoc Col Dermatol, Vol. 17, No. 2, pp. 87-108.

[14] Gómez, B. N., Rodríguez, C. R., Montoya, S. G., Roldán, M. R. & Ortega, C. B. (2015) ¿Quédermatoscopiodebousar? Dermatol Rev Mex, Vol. 59, pp. 62-66.

[15] Aguilar, D A., Asz, S. D, Fonte, A. V. & Dominguez, C. J. (2010). Melanoma cutáneoprimario. Actualización y énfasisen la importancia del dermatólogoen la detecciónemprana y sutratamientooportuno (Primera parte). DermatologíaCosmética, Médica y Quirúrgica. Vol. 8, pp. 203-209.

[16] Solomon, C., & Breckon, T. (2011). Fundamentals of Digital Image Processing. A Practical Approach with Examples in Matlab, Ed. Wiley-Blackwell. A John Wiley & Sons, Ltd., Publication, USA, pp. 197-233.

[17] Pajares, G. & De la Cruz, J. (2007). Visión por computador. Imágenesdigitales y aplicaciones. México D. F. México, Editorial Alfaomega, Rama.

[18] González, R. C., Woods, R. E. &Eddins, S. L. (2009). Digital Image processing using Matlab. Ed. Gatesmark Publishing. The United States of America, pp. 334-378.

[19] Sarria, P. M. & Castellanos, D. G. (2010). Entrenamientodiscriminativo por distancia de Mahalanobis para detección de voz de patologías de voz. Dyna, Año 77, No. 164, pp. 220-228.

[20] Canny, J. (1986). A Computational Approach to Edge Detection. IEEE Trans. Pattern Analysis and Machine Intelligence. Vol. 8, No. 6, pp. 679–698.

[21] Gonzalez, R. C. & Woods, R. E. (2002). Digital image processing, 2nd ed. Upper Saddle River, N.J.: Prentice Hall. Upper Saddle River, New Jersey, USA, pp. 519-560.

[22] Pratt, W. K. (2001). Digital image processing, Third Edition, Wiley & Sons, Inc, New York, USA, pp. 399-625.

[23] Pajares, M. G. & De la Cruz G. J. M (2008). Visión por computador: imágenesdigitales y aplicaciones. Ed. Alfaomega Ra-ma. 2da edición. Madrid – España, pp. 110-162.

[24] Arce, C. S., Castillo, E. W. & González, V. (2003). Algebra lineal. Universidad de Costa Rica. Escuela de Matemática, pp. 174-177.

[25] Moreira, Q. J., Valencia, D. V. & Chávez, B. P. (2015). Implementación de un algoritmo para la detección y conteo de célulasenimágenesmicroscópicas. Facultad de Ingeniería enElectricidad y Computación. Escuela Superior Politécnica del Litoral.

[26] Jiménez, A. R. (1998). Sistema de reconocimiento y localizaciónobjetoscuasi-esféricos por telemetríaláser,tesis (doctoradoenArquitectura de Computadores y Automática). Universidad Complutense de Madrid, Instituto de Automática Industrial (IAI). Consejo Superior de Investigacionescientíficas (CSIC) España, 317. Enlíneaen: http://biblioteca.ucm.es/tesis/19972000/X/1/X1032901.pdf

[27] Ocampo, B. C. (2011). HerramientaSoporte al Diagnóstico del Melanoma usandoImágenesDermatoscópicas. Tesis (maestríaeningeniería), Universidad Nacional de Colombia, Sede Manizales. Departamento de Ingeniería Eléctrica, Electrónica y Computación. Manizales, Colombia. Enlíneaen: http://www.bdigital.unal.edu.co/5735/1/7101024.2012.pdf

[28] Asunción, B. G. (2012). Reconocimientoautomático de melanomas mediantetécnicas de visión por ordenador y reconocimiento de patrones. Disertación de fin de carrera. Universidad Carlos III de Madrid. Departamento de estadística. España, 94. Enlíneaen: http://e-archivo.uc3m.es/bitstream/handle/10016/17028/RECONOCIMIENTO%20AUTOMATICO%20DE%20MELANOMAS%20MEDIANTE%20TECNICAS%20DE%20VISION%20POR%20ORDENADOR%20Y%20RECONOCIMIENTO.pdf?sequence=1

[29] Alvarado, M. J. (2012). Procesamiento y análisis de imágenesdigitales. Instituto Técnico de Costa Rica. Escuela de Ingeniería Electrónica. Recuperado de: http://www.ie.itcr.ac.cr/palvarado/PAID/paid.pdf

[30] Rosin, P. &Collomosse, J. Eds. (2013). Image and video base artistic stylisation. Cardiff, UK. Ed. Springer.

[31] Joshi, P., Millán, D., Godoy, V. &Laganiere, R. (2017). Build with OpenCV. Develop real-world applications in OpenCV with the latest in computer vision and image processing. United States, Ed. Packt.

[32] Pajares, G., De la Cruz, J., Molina, J., Cuadrado, J. & López A. (2003). Imágenesdigitales. Procesamientopráctico con java. Madrid – España Ed. Alfaomega Ra-ma.

[33] Munshi, R. (2018). Building Advanced OpenCV3 Projects with Python. Discover how to build advanced OpenCV3 projects with Python. United States. Ed. Packt.

[34] Müller, A. & Guido, S. (2016). Introduction to Machine Learning with Python. A Guide for Data Scientists. Sebastopol, United States. Ed. O'Really Media.

[35] Brink, H., Richards, J. &Fetherolf, M. (2017). Real-World Machine Learning. New York, United States. Ed. Manning Publications.

[36] Delgado, M. (2012). Extracciónautomática de carasenimágenescaptadas con móviles Android. (Tesis de pregrado). Universidad Politécnica de Cataluña (UPC). Cataluña, España. Enlíneaen: https://upcommons.upc.edu/bitstream/handle/2099.1/15485/78399.pdf

[37] Parra, E. (2015). Aceleración del algoritmo de Viola-Jones medianterejillas de procesamientomasivamenteparaleloen el plano focal. (Tesis de pregrado). Escuela Técnica Superior de Ingeniería. Sevilla, España. Enlíneaen: http://bibing.us.es/proyectos/abreproy/90325/fichero/TrabajoFinGrado.pdf

[38] Cantador, I. (2005). Aplicación de PerceptronesParalelos y AdaBoost a Problemas de Clasificación de Muestra Extrema. (Tesis de pregrado) Universidad Autónoma de Madrid. Escuela Politécnica Superior. Madrid, España.