Characterization of thermographic images of skin cancer lesions using digital image processing

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Abstract. Skin cancer is the type of cancer with the highest incidence in the world. The alterations of temperature in the skin are organic indicators of the presence of several types of skin cancer, mainly squamous cell carcinomas and melanomas. In this work, thermographic images of lesions of this type were analyzed in order to find indicators of the presence of this neoplasm that allow the future development of a detection algorithm. The digital processing used consists of identification of areas of interest, color segmentation, quantitative discrimination according to color tonality and analysis by histograms. The results showed that lesions with skin cancer have values in the red component above 100 under the RGB color space on a scale of 0 to 255. Also, when segmenting, by the k-means algorithm, a thermography containing a melanoma, the area that contains the lesion has a higher average value in the red component with respect to the other areas. Taking these results into account, a non-invasive tool for prediagnosing skin cancer can be developed that reduces unnecessary clinical procedures and simplifies the diagnosis.

1. Introduction

Skin cancer is the uncontrolled growth of abnormal skin cells. This condition arises when the DNA damage of skin cells, caused mainly by ultraviolet radiation, triggers mutations or genetic defects that cause skin cells to multiply rapidly giving rise to malignant tumors [1]. During the last thirty years, skin cancer has had more affected people than all other types of cancers combined [2]. This type of cancer is classified as basal cell carcinoma, squamous cell carcinoma, melanoma, Merkel cell carcinoma, keratoacanthoma, among others [1].

Thermography is a non-invasive technique for measuring temperature in bodies through its representation in colors in images. This representation is given according to standardized color palettes. The acquisition of these images is done through cameras whose economic value depends mainly on the graphic and thermal resolutions. The temperature measurement ranges usually vary depending on the camera used to capture thermography, or they are selectable.

The usefulness of thermography for the diagnosis of diseases was demonstrated in 1963 [3,4]. Since then, thermography has been applied to diagnose diabetic neuropathy, vascular disorders, breast cancer, rheumatological diseases, diagnosis of dry eye syndrome, metastatic liver disease, intestinal
ischemia [3]. When an organ possesses a carcinogenic lesion new blood vessels are formed in the area through the process called angiogenesis [5]. Cancers of squamous cell carcinoma and melanoma skin exhibit this phenomenon, and therefore, due to increased blood supply, affected areas present higher temperatures compared to healthy tissues [5]. Other processes in cancerous lesions such as increased metabolic rate, inflammation, changes in blood vessel morphology, interstitial hypertension and altered response to homeostatic signals also generate a heat share [6,7]. This behavior was used in the present work to establish the presence of skin cancer

The use of thermography for the detection of skin cancer is recent. The differentiation between malignant and benign lesions through the use of thermographies has been demonstrated [8,9]. The thermal response of benign lesions, as opposed to malignant lesions, is similar to that of healthy skin tissue [10]. Consequently, the increased metabolic activity of a skin cancer lesion can be detected by thermographic imaging [11]. However, this behavior depends on the type of skin cancer: melanomas and squamous cell carcinomas exhibit this feature, while basal cell carcinomas have lower temperatures than healthy skin tissue [12]. The acquisition of thermographic images in areas suspected of skin cancer can be performed passively or actively. In the passive form, the thermography is taken without exposing the area to changes in temperature. However, some lesions cannot be detected by this technique, and it is therefore necessary to apply a thermal stimulus, generally cooling, which allows to enhance or improve its exposure [9,13]. The procedure consists of an initial cooling of the study area. This seeks to constrict the blood vessels, sending blood to internal organs. Then, the stimulus is removed and thermographs or videos of the thermal recovery process are taken: that is, as the body slowly sends blood to the area to gradually recover a temperature according to the conditions to which it is exposed. It is noteworthy that the process of acquiring thermographic images has a drastic influence on the processing of them. Currently, for skin cancers, the rainbow palette is configured in thermographic cameras [14,15,16,17], a measurement range is selected such that the upper temperatures close to the normal maximum body temperature are represented in shades of red [18,19].

In the field of digital processing of thermographic images of skin cancer lesions, the researchers have worked on the detection of edges, obtaining better results with the Canny-Deriche filter [20]. Through analysis by color segmentation, it has been shown that red component values in lesion images, after proper selection of the area of interest (ROI), are greater in comparison to their counterparts [14]. The red components show values higher than 100, the green ones are lower than that number, while the blue ones are 0 [14]. This characteristic was also taken into account when selecting the area of interest for each study lesion.

This research sought to characterize thermographic images of skin cancer lesions with the purpose of finding an indicator of the presence of this condition. Through this work, a non-invasive tool can be developed to detect skin cancer in order to reduce unnecessary clinical procedures and simplify the diagnosis of this type of neoplasm.

2. Materials and methods

This work was carried out on the MatLab platform and with images of lesions taken from other authors, due to the fact that thermographic cameras with adequate characteristics in terms of thermal graphical resolution have commercial prices in excess of twenty million colombian pesos. The study was conducted on 7 thermographic images of melanoma lesions and only one case of basal cell carcinoma. The maximum extension for the present article does not allow the exposure of all cases, due to this, we will expose only three cases. Of course, we are open to anyone who wants more information. The thermographic images to be examined were acquired under the rainbow palette and with the configuration of the range of temperature measurements so that the values above 37.5 ° C
were represented under the red color, given that the normal range of temperature of the human body is between 36.3º C and 37.5º C [21].

The characterization of skin cancer lesions using digital processing of thermographic images was carried out with the aim of identifying, through the thermal map, variations in the skin that will indicate the presence or absence of this condition. The figure 1 shows the proposed stages of characterization of thermographic images of skin cancer lesions. Taking into account that the red areas in the images indicate the presence of temperatures higher than the normal maximum of the human body, we selected these areas because they indicate the possible presence of skin cancer. Then, these images were examined by algorithms of selection of region of interest and K-means clustering. The results obtained from the implementation of the K-means algorithm were analyzed through the use of histograms. This stage consisted of the processes shown in figure 1.

3. Results and discussion

3.1. Extraction of the region of interest (ROI)
In this stage, thermographic images were preprocessed in image format. Given that many times elements that are not of interest or that can generate false positives are shown, the desired area was cut out in the image for the study. Figure 2a shows melanoma lesion. This image is property of Amber L. Shada, Lynn Dengel and Craig Slingluff [8]. This image shows the location of the skin cancer lesion by the study carried out by the authors. The manual selection was made as it is shows in figure 2b, and finally the original image is cut according to this selection, obtaining the image that appears in figure 2c.

Figure 1. Stages of characterization of thermographic images of skin cancer lesions.

Figure 2. Results: (a) Melanoma lesion, (b) Manual selection of an area, (c) Extraction of the region of interest, (d) Segmentation based on values of the red component, (e) Red component histogram, (f) Green component histogram, (g) Blue component histogram.
3.2. Segmentation based on values of the red component and histogram analysis

In view of the fact that lesions with skin cancer, due to the acquisition protocol, exhibit red colors in the thermographs [28,29], the image was segmented based on the existing values of red components in order to contrast the results of the authors Shazia Shaikh, Nazneen Akhter and Ramesh R. Manza. One of its conclusions is that the values of the red component in skin cancer lesions in this type of images, under the same acquisition protocol, are greater than 100 [14]. This characteristic was confirmed by the use of histograms in the segmentation: only the areas where the red component has values higher than 100 on a scale of 0 to 255 were taken and a new image is created. This image is shown in figure 2d and contains the carcinogenic lesion. Please, see the figures 2e, 2f and 2g to observe the R, G and B component histograms. The conclusion of these authors can be used as an indicator of the presence of skin cancer.

![Figure 3: Group 1 and its histograms. Values of the group 1 centroid, component a: 128, and component b: 128.](image)

![Figure 4: Group 2 and its histograms. Values of the group 2 centroid, component a: 163.9622, and component b: 197.7188.](image)

![Figure 5: Group 3 and its histograms. Values of the group 2 centroid, component a: 168.6863, and component b: 196.5698.](image)

![Figure 6: Group 4 and its histograms. Values of the group 2 centroid, component a: 158.6453, and component b: 199.1390.](image)

3.3. Segmentation of red color tones using K-means clustering and histogram analysis

Although the results of the previous stage indicate the presence of skin cancer, they do not accurately show the location of the lesion. Therefore, a segmentation of the tones of red color was carried out in order to establish discrimination parameters according to the values of the color components of the image. The image obtained in the segmentation based on values of the red component (See the figure...
2d) is taken as input to the K-means algorithm after changing its color space to CIE L*a*b. The objective is to divide the image into four according to the average of the values of its components a and b. At this stage of the process, one of the images obtained in the segmentation contains the skin cancer lesion. Figure 3, 4, 5 and 6 show the results obtained in this stage and the respective histograms for each obtained image in RGB color space. The figure 3 shows the selection of the black color area. This area obtained a count of total representation of each component in zero. The figure 3, 4, 5 and 6 show similar results in their histograms, but the figure 5 has a most uniform distribution in its red component histogram in comparison with the rest of the figures.

The use of the K-means algorithm generates centroids that express the average value of components a and b. Based on these, it is established that the lesions have a higher average value of component a (Positive values in this component indicate the representations of the red color). For the example we present, the values of the centroids of the four groups are shown in the captions of the figures 3, 4, 5 and 6, where it can be seen that the value of the component a of the centroid of group or cluster 3 is bigger than the other centroids. Also, note that group 3 contains the skin cancer lesion in the figures 5. This situation occurred in all the cases studied. Two additional cases are shown in the figures 7 and 8. This images are property respectively of the authors Cila Herman; and Amber L. Shada, Lynn Dengel, and Craig Slingluff [8,9]. This relation between the centroids and the skin cancer lesion can use like an indicator of this neoplasm.

![Figure 7](image1.png)

**Figure 7.** Case 2, (a) Original image with selection, (b) Group 1 with centroids, a= 128 and b=128, (c) Group 2 with centroids, a= 199.7899 and b=192.6630, (d) Group 3 with centroids, a= 165.7514 and b=202.0694, and (e) Group 3 with centroids, a= 185.1256 and b=198.1307.

![Figure 8](image2.png)

**Figure 8.** Case 3, (a) Original image with selection, (b) Group 1 with centroids, a= 128 and b=128, (c) Group 2 with centroids, a= 172.4175 and b=187.6311, (d) Group 3 with centroids, a= 179.9880 and b=185.1807, and (e) Group 3 with centroids, a= 191 and b=182.8043.

4. Conclusions

In this article we have shown that lesions with skin cancer have values in the red component above 100 under the RGB color space on a scale from 0 to 255. Also, when segmenting a thermography containing a melanoma, the area containing the lesion has a higher average value in the red component with respect to the other areas. Of course all these facts are valid for thermographic images of lesions acquired through the use of the rainbow palette and the appropriate selection of the range of temperature measurement. The characterization of thermographic images of squamous cell carcinomas is still necessary.
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