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Application of Image Processing Techniques for Characterization of Skin Cancer Lesions using Thermal Images

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Abstract

Objectives: Manifestation of thermal inconsistencies in skin lesions could be a potential pointer towards malignancy. In this work, an attempt was made to characterize skin cancer lesions through Thermography and Image processing. **Methods/ Analysis:** In this work, the Region Of Interest (ROI) was extracted from each of the thermal images of skin cancer lesions followed by their colour based clustering to characterize their thermal properties. Histograms and first order statistical parameters of both these image types were obtained and studied. **Findings:** With respect to the RGB model, for certain parameters, the content of red colour (considered to be indicative of warmer areas) was found in maximum percentage as compared to green and blue where blue colour (considered to be indicative of coolest areas) was at minimum. It was observed that the maximum values for red, green and blue ranged from 193 to 255, 110 to 255 and 39 to 255 respectively; minimum values of red in two cases was above 100 while minimum values for green were below 100. The values of blue were 0 or close to 0. The range of mean values was highest for red colour (137-190). Results hint towards certain characteristics in thermal images which can be potential indicators of malignancy of a lesion. **Novelty /Improvement:** These findings indicate the need to further experiment in this area with larger database for obtaining more robust results with diagnostic markers.

Keywords: Infrared Imaging, ImageJ, Image Processing, Skin Cancer Detection, Thermography

1. Introduction

Skin cancer is a serious skin disorder that is caused due to the uncontrolled growth of abnormal skin cells. This abnormal growth is a result of damaged DNA molecules present in the cells that go unrepaired. The damaged abnormal skin cells grow uncontrollably leading to formation of malignant tumours. Skin cancers are categorized into three major types – Basal Cell Carcinoma, Squamous Cell Carcinoma and Melanoma. Statistics indicates that there are more cases of skin cancer reported nowadays than other cases[1]. In US alone it is estimated that in 2015 there may be more than 90 thousand deaths accounting to melanoma[1]. There are no precise statistics for skin cancer cases in India, but SCC is more prevalent than BCC in dark skinned people and is also the more prevalent type in India[2].

Medical thermography uses specially designed thermographic cameras to derive diagnostic indications from infrared images (with large amount of detail) of the human body. It is used to determine areas of the body that have abnormal temperature values. In Figure 1, the right foot of the subject is cancer-affected and the cancerous lesion is easily identifiable when compared to the left foot. Research work in the area of cancer diagnostics indicates that cancer can be associated with thermal changes of an affected organ[3-5]. The engendering of larger amounts of heat and faster reheating of malignant tumours like melanoma

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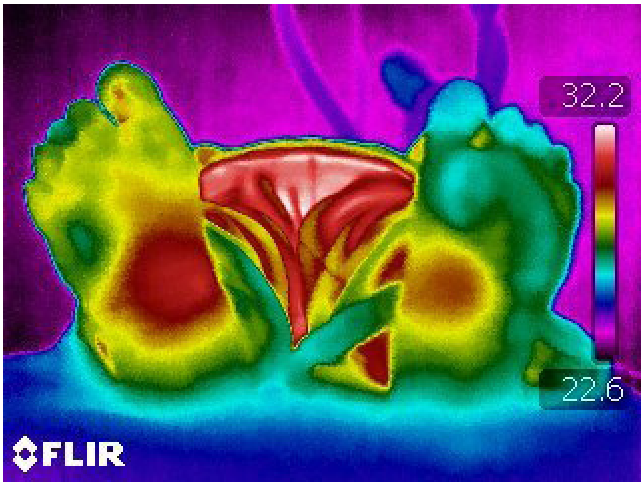

Figure 1. Skin cancer on the right foot captured using FLIR T400[4].

indicates signs for melanoma detection[6]. The verification of a lesion being malignant or non-malignant by equipment that are able to acquire and measure information that is not easily readable by human vision could improve the chances of survival and also the treatment costs[6].

Most accurate sensitivity of thermal emissions is shown by the rainbow palette for providing thermal differences[7]. Colour scales having red and yellow as indicators of increased temperature are frequently used[8-10]. Medical applications typically prefer the rainbow palette where the red symbolizes increased heat and blue as lower heat[6,11].

Biomedical Image Processing is a vast and rich field which has dramatically improved the diagnostic procedures and their results by leaps and bounds. Various Image processing methods can be investigated and applied over the thermal images to assess their role in correct diagnosis of diseases in their early stages.

Earlier, it was considered that Thermography is not considered accurate enough for early detection of cancer since there is not enough understanding about the relation of skin cancer tissue and skin temperature abnormality[12]. Research work and investigations for diagnosis of skin cancer using thermography are in infant stage and currently there isn't any standard acquisition and diagnostic protocol[6,12,13]. Pirtini Cetingul M et al.[14] suggested that there is need for further research of thermography to reassess and signify its role in early detection of skin cancer in view of the advent of newer and advanced computer technologies, and also concluded that early diagnosis of melanoma is possible with their computational models. Some of their[14] previous works[15-19] also assure of measured and early identification of melanoma with the application of thermal stimulation and recovery over the skin.

Thermal imaging provides visual interpretation of thermal properties of the affected skin area, and with suitable processing techniques, comparison and association of quantitative data with diseases of interest, can automate the detection of various skin cancer conditions[6]. This work is focused mainly on the aspect of studying malignant lesion that has already been identified over a thermal image of the subject in consideration and characterization of thermal properties on thermal images with a perspective of finding some useful insights and indicators of skin cancer.

Most of the studies and investigations in the area of skin cancer diagnostics using thermal imaging are promising. One of the earliest works by Buzug M T et al.[13] shows results that are better in identifying basal cell carcinoma as compared to dysplastic nevus using thermal imaging coupled with thermo-regulation. In a study by Santa Cruz G et al.[20] over two patients with nodular melanoma treated with BNCT (Boron Neutron Capture Therapy), it was observed that DIRI showcased higher sensitivity than Doppler ultrasound and was closer to CT in results. Pirtini Cetingul M et al.[14] used thermal imaging and cold stimulus for their investigations on skin cancer followed by image analysis using multi modal image analysis system. For further verifications they compared the results with the biopsy report. It was observed that cooling excitation was the key method to enhance temperature difference between lesion and surrounding healthy area and that the malignant lesion has higher metabolic activity and hence higher temperature than the surrounding healthy skin. Same results were obtained by Herman C et al.[21] in their study for skin cancer detection using thermal imaging and multi modal image analysis system. To observe the temperature profiles of healthy skin and BCC affected skin, Flores-Sahagun J et al.[22] proposed and experimented with the conjugated gradients method by considering the symmetric regions of the patient's body and concluded that the proposed method was useful for safe excision of the lesion. Shada et al. imaged 74 patients with 251 discernible lesions and studied them on the basis of their sizes. This was followed by confirmation using pathological reports. Their study resulted in malignant lesions with sizes greater than 15 mm being differentiated from the benign ones with outstanding sensitivity and specificity. Gonzalez F et al.[4] observed higher vascularity in BCC and SCC cases while vascularity remained constant in melanoma. But melanoma cases exhibited higher values of temperature which is indicative of higher metabolic heat production in the malignant lesion and indicates that melanoma diagnosis can be done through thermal profiling of suspicious lesions.

The aim of this work was to identify heat patterns from ROIs to interpret the presence of malignancy by studying and analyzing the prominence of red colour as compared to its counterparts which could be an indicator of thermal tendencies of cancerous lesions.

2. Materials and Methods

Currently, there is no standard public database of thermal images of skin cancer available (as per our knowledge). The investigations were performed on five thermal images of skin cancer that were provided by Gonzalez F[4]. For experimentation, ImageJ 1.48V was the preferred platform in comparison to MATLAB as it is open source and offers a suitable image processing environment along with the provision of plug-ins that can be downloaded and used for additional and advanced processing features as required by the user[24].

2.1 ROI Extraction

In case of thermal images depicted with the rainbow palette, presence of red colour indicates increased heat in that area and this region may be a candidate for malignancy. But this may not be the case always as certain regions of human body tend to be warmer than others in normal conditions too. In this scenario, the ROI extraction becomes a suitable approach for acquiring only that warmer region which is the prime focus for investigations.

As thermal images lack shape and precise limits, the task of extracting ROI limits from such images is difficult[25]. The manual or semi-automatic extraction of ROI is chosen by most authors due to the challenging task of developing completely automated systems[26]. Because of similar challenge, a manual approach was preferred for ROI extraction. As thresholding is one of the simplest methods for image segmentation, extracting the region of interest was done by implementing the iterative method which is the modified form of ISODATA[27] (Iterative Self-Organizing Data Analysis Technique Algorithm) for thresholding as part of image segmentation step to isolate the region that characterized the cancerous lesion. Figure 2 shows the steps of ROI extraction.

In the modified ISODATA, initial threshold is chosen for isolating the objects from the background in an image, followed by calculation of mean value that is below the threshold value or equal to it. The iterations are continued by finding the mean of two values and increasing the threshold, until it is larger than total mean as given in equation (I)[28].

Threshold = (average background + average objects) / 2 (I)

2.2 Split Channel

A composite colour image can be split into the Red, Green and Blue image components and each of the components can be studied individually. Red being the component of prime interest, split channel function was applied to obtain the three images of RGB channels separately as seen in Figure 3.

2.3 Histogram

Histogram is a useful function to understand color frequencies in an image. Shada et al.[23] studied melanoma thermal images by computing N, mean, standard deviation, and % for all demographic and clinical factors, as applicable[23]. Borchartt T et al.[26] computed statistical features like mean, standard deviation, variance, entropy,

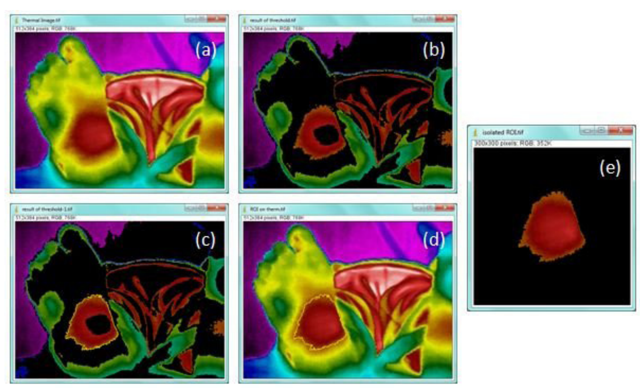

Figure 2. **(a)** Thermal image from which the lesion area (ROI) has to be extracted. **(b)** Resultant image after application of threshold function on the thermal image **(c)** Selection of ROI area from thresholded image indicated by yellow pixels at the lesion border **(d)** Yellow pixels from image(c) mapped onto the original thermal image **(e)** Extraction of ROI from the thermal image.

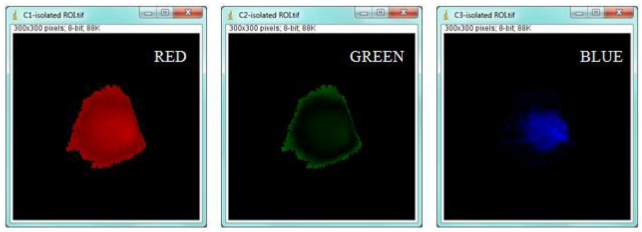

Figure 3. RGB channels of the extracted ROI.

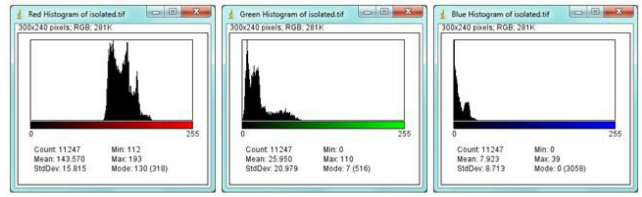

Figure 4. Histograms and related basic statistics of RGB channels (from figure 3).

skewness and kurtosis of breast thermograms while histogram based features were suggested by Wiecek B et al[29]. In this work, to study all three channels individually, the histograms were obtained for each of the three for analyzing their colour frequencies. For comparison purpose, some first order parameters (mean, standard deviation, min & max) were calculated from the histograms (figure 4).

2.4 Segmentation of Thermal Images

Image segmentation can be employed when there is need of partitioning an image into different regions by grouping pixels together that share same characteristics. So, clustering algorithms can be chosen for image segmentation as they are simpler and often preferred[30-32]. In case of this work, the aim is to identify regions within the lesion that emit higher heat content. A useful study would be to observe whether the region with highest heat overlaps the lesion centroid which may point towards the patterns of heat propagation in the lesion. Prior studies in the area of image segmentation suggest of k-means algorithm as one of the simplest and widely used algorithms[33,34]. The method attempts to identify k numbers of centroids from within the data set such that those centroids are the best representations of that data. The aim is to search for k number of clusters which reduce the mean squared quantization error[33]. In ImageJ, the k-means plug-in was employed for clustering the ROIs. Figure 5 shows the ROI and its clustered image. The clustered images were subjected to analysis after obtaining their histograms. The histograms of the clustered image (in Figure 5) are shown in Figure 6.

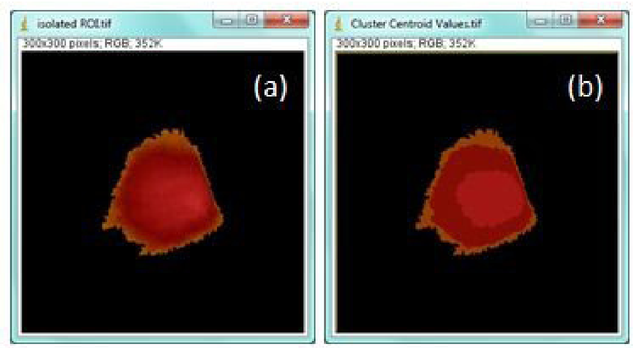

Figure 5. **(a)** ROI **(b)** resultant image after K-means clustering obtained after k-means clustering.

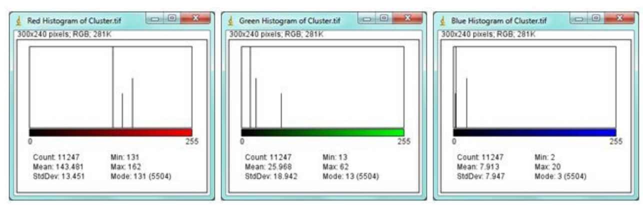

Figure 6. Histograms of RGB colours of the image obtained after k-means clustering.

3. Results and Discussion

The statistical parameters extracted from the histogram of the red, green and blue channels images indicated clear values of red component in increased amounts as compared to its counterparts. The Table 1 shows the first order parameters (mean, standard deviation, min and max) values of red, green and blue colour (from histograms of extracted ROI) in comparison to each other. The mean values of red, green and blue ranges from 137 to 190, 25 to 164 and 7 to 56 respectively, and are clearly indicative of red values being higher. Also, it was observed that the standard deviation values exhibited random patterns for all three colours and therefore they may not serve as effective features for classification using machine learning algorithms. The minimum values of red in two samples were higher than 100 and minimum values of green were not found to be higher than 100, while most of the values of blue were 0. This can be used as an indicative marker for identifying malignancy or may act as a threshold for

Table 1. First order parameters from histograms of extracted ROI

Sample	RED mean	GREEN mean	BLUE mean	RED Std Dev	GREEN Std Dev	BLUE Std Dev	RED min	GREEN min	BLUE min	RED max	GREEN max	BLUE max
1	149.707	64.042	8.972	27.079	53.393	11.01	0	0	0	247	217	93
2	143.57	25.95	7.923	15.815	20.979	8.713	112	0	0	193	110	39
3	137.102	163.078	27.127	76.549	41.152	56.441	0	14	0	253	244	242
4	161.671	149.196	11.906	41.028	35.223	12.043	39	55	0	228	224	57
5	189.103	56.153	55.959	31.105	60.287	60.102	132	5	7	255	255	255

Table 2. First order parameters from histograms of clustered images obtained using K-means Algorithm

Sample	RED mean	GREEN mean	BLUE mean	RED Std Dev	GREEN Std Dev	BLUE Std Dev	RED min	GREEN min	BLUE min	RED max	GREEN max	BLUE max
1	149.23	63.04	8.796	20.802	50.618	3.608	0	1	0	187	171	18
2	143.481	25.968	7.913	13.451	18.942	7.947	131	13	2	162	62	20
3	136.41	157.579	26.078	72.317	47.011	53.194	1	9	1	197	194	153
4	161.425	149.241	11.886	36.882	29.681	6.73	104	109	3	191	180	19
5	188.83	56.504	55.504	26.42	57.495	57.495	173	27	26	245	209	208

classification. The maximum values for red, green and blue ranged from 193 to 255, 110 to 255 and 39 to 255 respectively.

Similar pattern was observed from the histograms acquired of the clustered images (through k-means algorithm). The Table 2 shows the first order parameters (mean, standard deviation, min and max) values of red, green and blue colour (from histograms of clustered images) in comparison to each other.

With the availability of a larger dataset, attempts can be made for feature extraction based on colour intensities and simple classifications[35,36] can be done along with the implementation of feature selection algorithms[37] for selection of relevant features from thermal markers that are suitable for application of classification. A possible dimension for extension in this work could be study of the lesion size and growth from its identified border[38].

4. Conclusion and Future Work

Thermography is a promising technology that has the potential to provide advancements and safer procedures in medical diagnostics area with its non-invasive and harmless nature. Currently there is need for further research and establishment of standard and universal protocols for image acquisition and processing along with the design and development of CAD systems for completely automated diagnostic systems capable of precise and correct segmentation, processing and classification of regions of interests. The results obtained in this work hint towards the thermal features that could be distinct to a cancerous lesion and thereby become a marker for early identification of skin cancer.

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