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Medical Image Processing of Thermal Images in Light of Applied Color Palettes

Shazia Shaikh, Nazneen Akhter, Ramesh Manza

Abstract: *The choice of colour palette in image processing of medical thermal images plays a crucial role and it essentially affects the interpretation and visualization of the thermal image. Even though it has remained a subject of criticism due to the difference of visualization as compared to the grayscale colour palette, the rainbow palette has been widely applied in medical image processing of thermal images. In this work, the rainbow colour palette and the grayscale colour palette were applied on the medical thermal images representing skin conditions and a comparative study was performed to assess their applicability and performance in the methodology applied. It is observed that both the palettes are suitable at different stages as part of methodology to study medical thermal images. Using the global thresholding techniques for foreground detection, the grayscale palette was found useful for image segmentation into background and foreground while the rainbow palette is effective when colour-based clustering is performed to segregate the object of interest into varying temperature zones.*

Keywords : Thermal image representation, false colour palette, pseudo colour palette, medical thermography, thermal image processing.

I. INTRODUCTION

The fundamental principle on which thermal cameras operate devoid them from detecting colours [1] because of the limitations of operating range under which they work which is different from visible light range. Such cameras record only the thermal information of the scene and therefore some processing is required to transform this thermal information into image form thereby aiding in visual interpretation. To simplify analysis and visualization of thermal images, they are represented through false colours for separating the thermal temperature differences [2]. Therefore, most of colour representation of thermal images includes a scale on either side of the image to indicate range of temperature in the image along with represented colours. False colours used in thermal image representation doesn't come with any fix or specific colour allotment to a particular temperature and the colours used are mere representation just to indicate varying temperature regions.

One of the most common representations of thermal information is in the form of grayscale image, usually used in night vision or security cameras [3]. It is considerably easier to use multi-colour representation of thermal information

when presented in image form, for detailed analysis of temperature variations like in medical diagnostics. In addition to grayscale, thermal information is represented using several other multi-colour palettes like iron, arctic, lava and rainbow to name a few [4]. Some of these also have various versions with varying the contrasts making the temperature differentiation vivid and apparent. In this paper, attempts were made to make detailed study of two colour palettes, namely rainbow and grayscale, to be used in thermal information representation. For medical diagnosis, a more vivid and high contrasting colour palette that could indicate the slightest temperature variation is considered to be more suitable. In our previous works [5-7], with the use of rainbow palette for pseudo colouring of thermal images, suitable image segmentation and edge detection techniques were identified that were useful for studying medical thermal images.

II. BACKGROUND

In image segmentation, a digital image is segregated into multiple regions based on some predefined approach for the purpose of deriving at some representation of the image data that is relevant to a specific aim such as image analysis in terms of edges or object identification, background elimination or foreground identification. The pixels of a segmented image share similar features (such as intensity or colour) with other pixels in the same segment. Image segmentation is a widely applied technique in bio-medical imaging for the purpose of extracting ROI (Region Of Interest) contours for lesion identification, tumour visualization, study of bones, tissue structures and other human organs. Image segmentation results in segmented regions or the contours defining objects in the image.

Segmentation algorithms based on thresholding are one of the most straightforward and persistently used techniques in digital image processing [8]. The result of thresholding is a binarized image that divides the image into two classes i.e. 1 and 0 each of which represents the foreground and the background regions respectively, and this is useful for the identification of objects of interest against their backgrounds. There are three types of thresholding techniques - local, global and adaptive thresholding. While the local thresholding method utilizes unique values of threshold for the segments of the original image, the global method works with one value of threshold that acts as a divider between the histograms of background and foreground of the image.

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For adaptive thresholding, a threshold value is calculated for each pixel of the image to be segmented. Global thresholding works by detecting the foreground from the background on basis of considering the histogram of the image to be bimodal and operating by comparing pixel values of image against a specified threshold value T based on which a pixel is either assigned to the foreground class or the background class [8]. If we consider $f(x,y)$ to be an image with two strongly differing groups of gray levels representing the background and the foreground, with a selected threshold T , then the segmented image $g(x,y)$ can be represented with the help of equation 1 and 2 as mentioned below.

$$g(x,y) = 1, \text{ if } \text{undefined}(x,y) > T \quad (1)$$

$$g(x,y) = 0, \text{ if } \text{undefined}(x,y) \leq T \quad (2)$$

Global thresholding methods give successful results of segmentation in images with foreground having smooth and uniform intensities against a background that is in contrast [9]. This peculiarity in images makes the contour extraction convenient and quick. Same results are challenging when the image is characterized by presence of noise or low contrasts between the foreground and the background. In light of the aforementioned, it is deduced that medical thermal images of body parts of interests that have a smooth and constant background qualify as suitable images on which global thresholding methods can help achieve optimum segmentation of body parts from their background. A thermal image is the temperature map of the captured target. In medical image processing, for a successful segregation of foreground and background of thermal image using global thresholding methods, a suitable background with uniform heat distribution can provide a constant colour with minor gradations and can help the body part being imaged to constitute a colour that is quite different from its background.

III. MATERIALS AND METHODS

Fig. 1 describes the methodology of the proposed work. The images used for this work have been acquired using an in-house designed and developed thermal image acquisition system using a thermal sensor of FLIR with an IR resolution of 80 x 60 pixels. The resolution of the final images used in performing the experimental work is 160 x 120 pixels. The thermal raw data acquired by the thermal sensor is converted to a temperature matrix where each pixel is representative of the measured temperature of the captured target. The images are 24-bit bitmap files of uncompressed type so that complete information is retained in its precise form. The dataset consists of pseudo coloured thermal images of body regions of 20 subjects with each thermal image represented in grayscale and rainbow palette, hence, the total number of images is 40. Subjects were identified from local hospitals having skin problems like allergic reactions and deep folliculitis. A relaxation time of ten minutes was given to the subject so that fluctuating body temperature values caused due to subject movement and random external sources of temperature are avoided. For the purpose of comparative study in terms of colour clusters generated, each thermal image was colour mapped using the grayscale palette and the

rainbow palette. The same methodology was applied on both versions of each image.

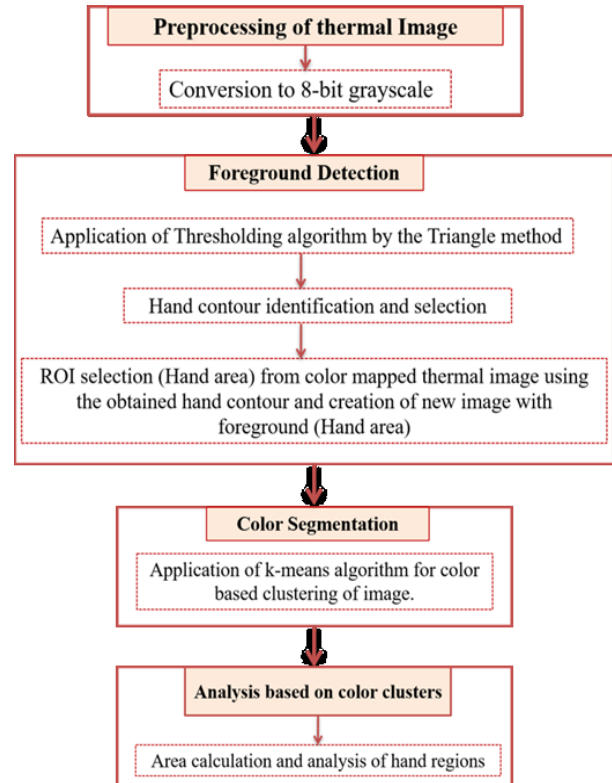


Fig 1: Steps of the methodology

1. Preprocessing and foreground detection of thermal images: In cases, where the complete image data are not needed, but only the background or foreground of the image is of interest, preprocessing step is required. In this work, the 24-bit colour coded thermal images were converted to 8-bit grayscale images before performing foreground detection as the global thresholding method that is applied on the images, requires 8-bit grayscale image as input (see fig. 2). It is vital to mention that the 8-bit grayscale version of image is required only for the purpose of foreground detection and that the processing steps/experimental works have been performed on the ROI i.e. extracted foreground from the original pseudo coloured thermal images. The 8-bit grayscale versions of rainbow palette thermal images are represented in the range of 256 grayscale colours and the images that have been colour mapped using the grayscale palette are different from the former as they are 24-bit RGB images.

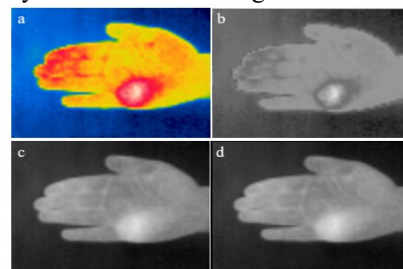


Fig 2: Thermal images before and after conversion to 8-bit grayscale.

(a) thermal image colour coded using rainbow palette, (b) thermal image in (a) after conversion to 8-bit grayscale image, (c) thermal image colour coded using grayscale colour palette, (d) thermal image in (c) after conversion to 8-bit grayscale image

Global thresholding method is a histogram-based approach that gives the output in binary form where the segmented region is in white colour and the background is in black colour. For foreground detection, the triangle method [10] of image thresholding was found to be most suitable as it creates an optimal binary image of background against foreground, which is helpful for obtaining a hand contour. The triangle algorithm is a global thresholding method that calculates side of the highest peak where the farthest point of data lies, using which the threshold is found. The binary image thus generated was used in selecting the hand contour as an ROI. The hand contour is mapped against the corresponding colour thermal image to extract the hand region and eliminate the background that is noisy and irrelevant. The new image thus formed, contains the segmented hand region i.e. the foreground, against a complete black background, the contours of which are required for colour-based clustering. The steps mentioned above are illustrated in fig. 3 and fig. 4 for thermal images colour mapped using rainbow palette and grayscale palette respectively.

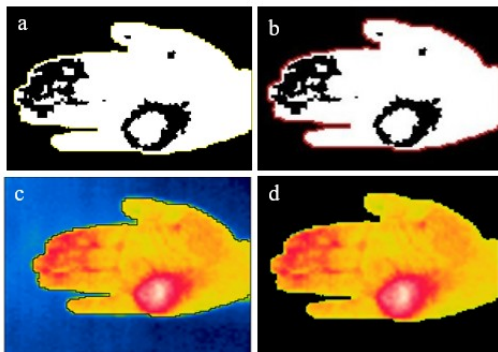


Fig 3: Process of foreground and background segmentation

(for rainbow colour mapped thermal image). (a) result of global thresholding, (b) ROI selection of hand region seen as a red outline, (c) selection of hand region from original colour thermal image, (d) new segmented image.

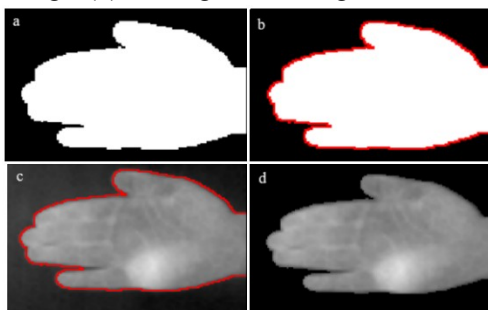


Fig 4: Process of foreground and background segmentation (for grayscale colour mapped thermal image). (a) result of global thresholding, (b) ROI selection of hand region seen as a red outline, (c) selection of hand region from original colour thermal image, (d) new segmented image.

2. Colour Clustering: Colour clustering is a form of

colour-based image analysis where an image is segmented into regions called as clusters. Using colour clustering, regions are extracted from the image that adhere to the uniformity rule based on spectrally derived features. Colour clustering and its analysis is a very popular approach to colour image analysis. One of the most applied colour segmentation techniques is k-means clustering in which k number of clusters are formed based on n number of observations, each of which is accommodated into the cluster which has the closest mean value. The algorithm converges once the cluster re-computation is terminated. In case of the colour-coded thermal images, colour is the most important parameter that is a means of temperature map analysis as each colour seen in the image is a representation of a unique temperature value. Colour segmentation, when applied to such images, can give the desired bifurcation of varying temperature zones where the highest or lowest temperature regions are of interest. The results after colour clustering the images using k-means algorithm [11] are shown in fig. 5.

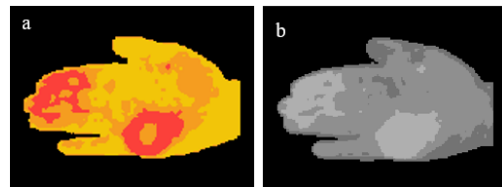


Fig 5: Results of colour clustering (using k-means method) on thermal images colour mapped with (a) rainbow palette (b) and grayscale palette

3. Statistical Analysis: It is of interest to analyze how much areas of the hand are thermally affected in case of presence of some abnormality. In terms of pixels, the total hand region, the total affected region and the highest temperature region inside the total affected region (fig. 6) were calculated for both- thermal images colour-mapped with the rainbow and grayscale palettes, serving as a means for comparative analysis (refer Table I).



Fig 6: Selection of ROI that represents the cluster with the highest temperature region on the hand

IV. RESULTS AND DISCUSSION

The results obtained through this work can be broadly divided into two categories, i.e. the performance of foreground detection techniques on the thermal images and the performance of colour-based clustering over the obtained ROIs, both, in light of the applied colour palettes. Luminance is the perceived brightness of a colour and is one important parameter that is responsible for the varying results obtained for the two palettes used.

When identifying the contour of a region for the purpose of background and foreground segregation, the amount of contrast between the two regions is the deciding factor, which relates to the luminance difference at the junction of the two regions. The foreground detection was performed using the triangle method of image segmentation which works on the 8-bit grayscale images. When compared for luminance difference, it can be observed that there is a sharp change of luminance between the hand region and the background for thermal image with grayscale colour palette (fig. 2 (c)) as compared to the thermal image with rainbow palette that is converted to grayscale (fig. 2 (b)). Hence, grayscale palette efficiently aided the process of foreground and background segmentation. With rainbow colour palette, extra pixels were included in the hand region and some pixels belonging to the hand region were included in background (fig. 3 (c)). This led to a non-smooth contour formation of hand region which seemed unnatural (fig. 3 (d)). For this reason, the rainbow color mapped images were not very effective for performing edge detection. Similar performance of pseudo colour palettes in identifying contours has been reported by [12]. The colours consecutively placed in the rainbow palette exhibit sharp changes in luminance. This is the reason that the regions of thermal images with varying temperatures tend to form defined clusters which is critical data when there is need to identify the most elevated and lowest temperature regions in the image. With rainbow palette, the most elevated temperature regions were identified through k-means colour clustering (fig. 5 (a)). On the contrary, the changes in luminance are very smooth and steadily transition from white to black in the grayscale colour map. For this reason, the varying temperature ranges in a thermal image do not tend to form well defined regions or clusters and therefore the results obtained after clustering grayscale color mapped thermal images are poorer as compared to the ones obtained in thermal images with rainbow palette (fig. 5 (b)).

Table I represents the areas calculated for the total hand region, total affected region and the region with most elevated region (in terms of temperature) for thermal images obtained using rainbow and grayscale palette of a subject. More reliable results for hand area (in pixels) calculation were obtained from the thermal images with gray scale palette but the same cannot be affirmed for the clusters formed inside the hand region obtained using this palette. *On the contrary, the images with rainbow palette performed better at clustering and the most elevated regions (temperature wise) were identified and were found more reliable.*

Table- I: Area calculation of hand regions for thermal images colour mapped using rainbow and grayscale

Palette	Subject ROI	Area in pixels
Rainbow	Total hand region	8192
	Total affected region	876
	Most Elevated region (in terms of temperature)	126
Grayscale	Total hand region	8343
	Total affected region	958
	Most Elevated region (in terms of temperature)	No cluster formation

V. CONCLUSION AND FUTURE SCOPE

This work was undertaken with the aim of studying the medical thermal images and the role of colour palettes over the results obtained after applying various image processing techniques. With a comparative study to assess two preferred colour palettes for thermal image visualization and interpretation in medical applications, it is observed that the greyscale palette outperforms the rainbow palette in providing suitable results of image segmentation where the foreground and background segregation is aimed, while the rainbow palette outperforms the grayscale palette for obtaining varying temperature regions within the object of interest through colour based clustering. Additionally, a system for medical study of human thermal images is proposed that can perform edge detection for identifying contours of body parts using grayscale palette initially, the mask of which can be used over the thermal images with rainbow palette, colour clustering of the segmented body part for bifurcating varying temperature regions followed by clinical correlations.

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