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Image Segmentation of Human Forearms in Infrared Image

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***Abstract*—Due to the possibility of detecting certain physiological conditions from thermal features of the skin surface acquired from infrared thermal imaging, the health conditions of a person can be revealed by analyzing the thermal signatures of his or her forearms regions in an infrared image. The assessment of hand's or arm's temperature distribution for clinical diagnosis or monitoring requires the confinement of region of interest (ROI) on the forearms regions. Hence, the purpose of this study is automatically to segment forearms regions in an infrared thermal image so that the clinicians can able to locate the interested regions and extract the skin temperature distributions with a high degree of reproducibility.**

I. INTRODUCTION

MEASURING, the local skin temperature is a useful method to diagnose the sign of a certain disease. With a better understanding of human physiology and the innovative advance in infrared imaging technology, a thermal imaging system is used for diagnosing especially peripheral vascular disorders, inflammatory disease, tumors, local metabolic disorders, and body temperature abnormalities[1]. Likewise, it is important to estimate the forearms skin temperature because it reveals not only the physiological properties of a certain disease such as Raynaud's syndrome, Thrombo Angitic Obstruction (TAO)[2], and diabetic foot[3] but also it can estimate even human mental-stress conditions[4].

The measurement of forearms temperature distribution for the clinical diagnosis or monitoring disease requires the confinement of regions of interest (ROI) across the forearms. The purpose of this study is to suggest an efficient image processing algorithm to extract forearms regions in infrared thermal image and consequently the clinicians can able to automatically locate the forearms area and to efficiently estimate its relevant temperature distributions. Firstly, digital infrared thermal image acquisition is applied on a subject's forearms and an adaptive image threshold algorithm is used with compromising the temperature distributions within a local window to extract the initial forearm region. This initial forearm region is refined by applying morphological filtering with geometrical correction and blob labeling. With evaluating 2nd moment features on the labeled forearm region, an orientation angle and the ratio of the major axis to the minor one is computed. Finally, a forearms region in infrared thermal image is obtained by computing the line profile of the forearm region along the major axis direction and estimating its inflexion points.

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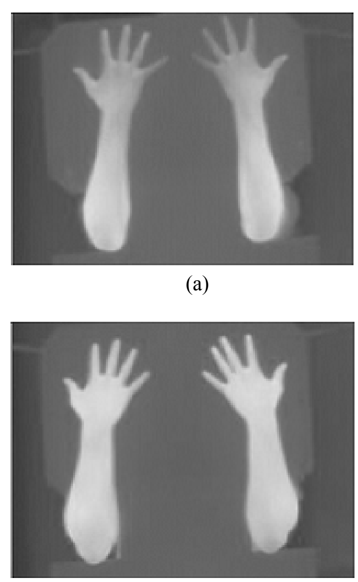
II. METHOD

Infrared camera scanning was done in a room with preserving the room temperature to obtain the thermal distributions on a subject's forearms. Each subject was adapted to the room temperature by allowing him or her to wait for more than 10 minutes. We used an IR camera (FLIR Therma CAM P20, 320 pixels x 240 pixels). Fig.1 shows the acquired sample infrared images with revealing the forearms of a subject.



(a)

(b)

Fig.1. Acquired infrared thermal images: (a) a subject 1 who has relatively low temperature distribution on the forearms (b) a subject 2 who has relatively high temperature distribution on the forearms.

We can extract forearm region candidates in infrared

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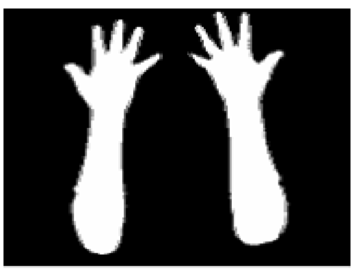
radiated image by utilizing the fact that the average human skin temperature ranges from 33°C to 34°C but the skin area covered with a cloth or hair has temperature value not exceeding over 25°C. Thus, we may extract the initial forearm regions in an infrared radiated image by restricting the temperature values between 25°C and 40°C. However, human skin temperature distribution can be different among the peoples and thermal signatures of a person's left forearm can be different from the right one. Fig. 2 and Fig. 3 show these facts when we use the identical temperature value to isolate the initial forearm regions in thermal images of two subjects, respectively.

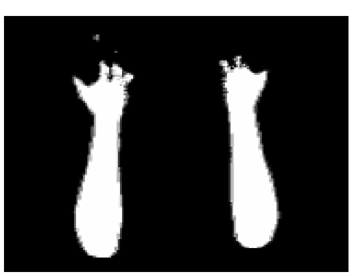
Notice that there exists thermal diffusion effect on the boundary between forearm area and non-forearm one. In this case, the thermal diffusion areas on the boundary can be considered as false skin temperature regions. We first extract this thermal diffusion information by local image threshold scheme with a 13 x 13 moving window. Fig. 4 depicts thermal diffusion information as a logical '1' pixel value.



(a)

(b)

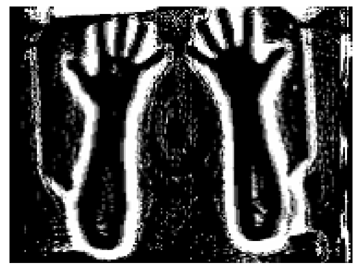
Fig.2. Forearm region candidates of (a) a subject 1 and (b) a subject 2, respectively with assuming the skin temperature value in the range of 25.5℃~ 37.5℃.



(a)

(b)

Fig.3. Forearm region candidates of (a) subject 1 and (b) subject 2, respectively with assuming the skin temperature value in the range of 29.5℃~ 37.5℃.



(a)

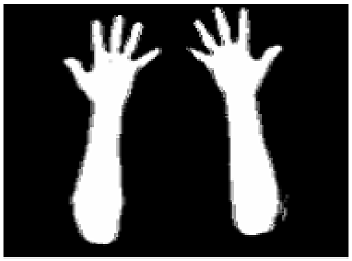
(b)

Fig.4. Thermal diffused areas of (a) a subject 1 and (b) a subject 2, respectively.

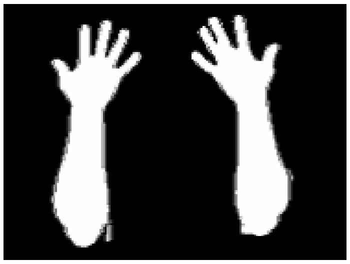
Thus, we can extract true forearm skin region with deleting the thermal diffused information and applying human skin temperature ranges from 29.5°C to 37.5°C as in (1).

$$f(x,y) = \begin{cases} '1' & if \quad 29.5°C \le g(x,y) \le 37.5°C \\ '1' & if \quad 25.5°C \le g(x,y) \le 37.5°C \quad AND \quad h(x,y) \ne 1 \\ '0' & else \end{cases} \quad (1)$$

Here '1' denotes a logical 1 image pixel and $g(x,y)$ denotes the acquired thermal image, $h(x,y)$ is an image containing thermal diffusion information, and $f(x,y)$ is a segmented forearm image. Fig. 5 shows the extracted true forearm skin regions after deleting thermal diffused regions existing on the skin boundary.



(a)



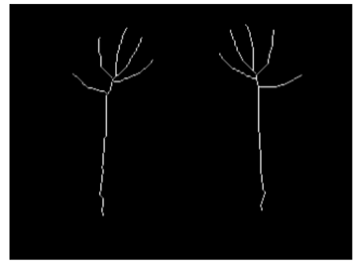
(b)

Fig.5. Segmented initial forearm regions of (a) a subject 1 and (b) a subject 2, respectively.

In order to delete the isolated spurious segment regions, Morphological processing [5] such as opening and closing operations are applied. Opening is the erosion followed by dilation and closing is a dilation followed by erosion. Dilation is an operation that grows objects in a binary image controlled by a shape and a size of structuring element. In contrast with dilation, erosion shrinks objects in a binary image also controlled by a structuring element. Thus, Morphological opening deletes an object smaller than a structuring element and closing tends to join narrow breaks or fills holes smaller than the structuring element. We adopt an opening followed by a closing on Fig. 5 (a) and (b), respectively. In this fashion, the facial candidate regions are refined by deleting the noisy objects that cannot be contained in the structuring element. To merge the refined regions and delete the spurious regions further, the summation operation in terms of '1' pixel counts is performed in a line profile along the horizontal and vertical direction, respectively. Each count is compared with the pre-defined threshold value and the pixels in the line profile are considered as forearm candidate region if the count exceeds the predefined threshold one. The refined forearm blobs are labeled by checking its 8-neighbor connectivity.

The procedure of identifying forearms area from the labeled forearm blob begins with deciding the position of the forearms in terms of 'forearms up' or 'forearms down'. This can be achieved by applying thinning algorithm and detecting the geometrical positions of fingertips in terms of 'up' or 'down' as shown in Fig. 6. After that, the features such as the orientation of the major axis of the boundary of labeled object and the ratio of the major axis to the minor one are estimated to decide orientation angle θ.

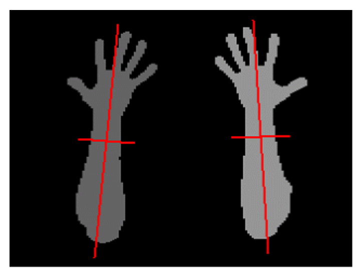
(a)



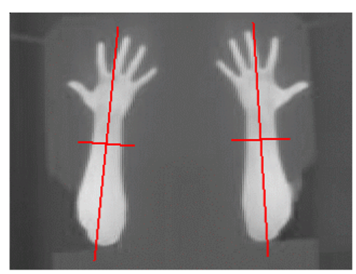
(b)

Fig.6. (a) The labeled forearm regions of a subject 1 and (b) its skeleton image to decide forearms position in terms of 'forearms up'.

The orientation θ and the ratio of the major axis to the minor one can be computed by evaluating a center point and 2^{nd} moment features [5]. Fig. 7 shows the labeled forearm region with superimposing the minor axis and the major one.



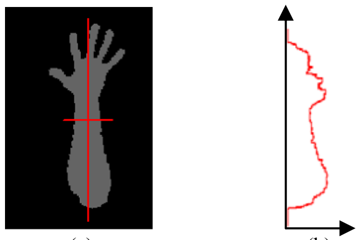
(a)



(b)

Fig.7. (a) The labeled forearm regions and (b) thermal image with superimposing the minor axis and the major one on the forearm regions.

Basically, human forearms are resolved by computing the line profile of the forearm region into the major axis direction, estimating its valley point and consequently identifying the position of wrist. To do this, the labeled forearm region must be rotated into the counter direction if the orientation angle θ is not zero. After that, the line profile is computed into the major axis and a local moving average window with compromising 10 neighborhood pixels is applied to smooth out the noisy line profile. Fig. 8 shows that the labeled forearm region that is rotated with θ degree in the counter direction with its line profile along the major axis.



(a) (b)

Fig.8. (a) The rotated labeled forearm region and (b) its line profile along the major axis.

The position of wrist to identify the boundary between hand and forearms is identified by detecting the valley point on the smoothed line profile as shown in Fig. 9.

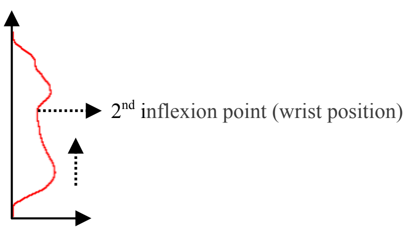


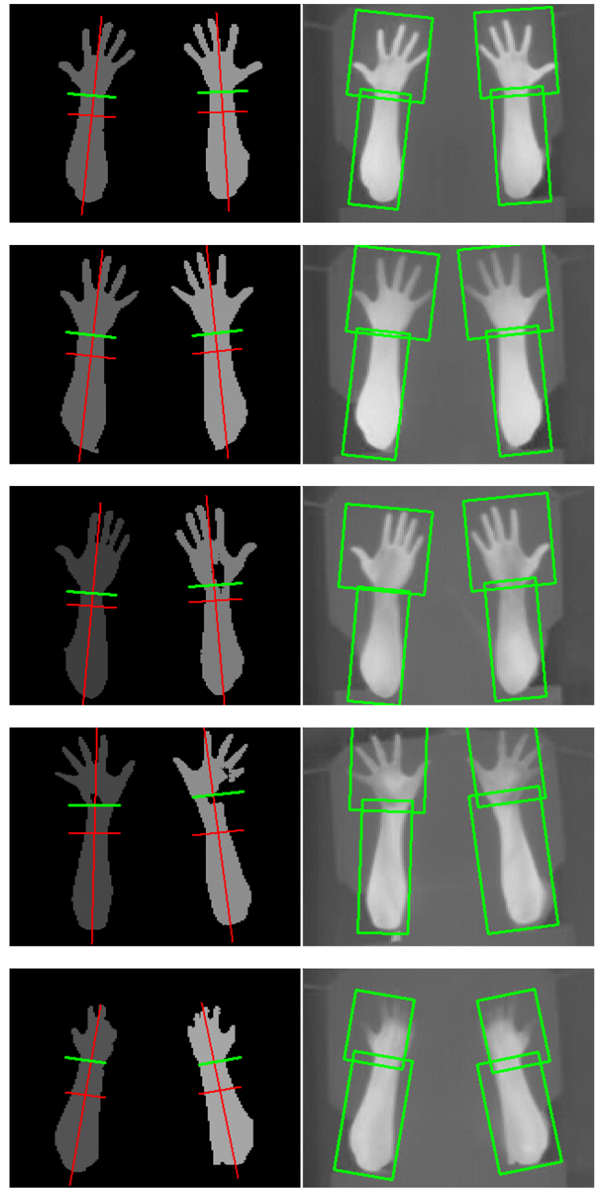
Fig.9. Identification of a wrist position in human forearms along thermal profile.

III. Results

Five healthy subjects (3 males and 2 females) who were the ages of 22 and 26 were scanned with IR camera (FLIR Therma CAM P20, 320 pixels x 240 pixels resolution) to get thermal information especially in their forearms. Each subject was adapted to the room temperature by allowing him or her to wait for more than 10 minutes before the thermal scanning had performed. Fig. 10 shows that the results of detecting forearms region for each subject

IV. Discussions

In this study, we presented new image processing algorithm to automatically extract human forearms region in infrared thermal images. The physiological conditions of a person can be revealed by analyzing the thermal features of forearms in an infrared image. Thus, we can able to locate the forearms region in thermal image with a high degree of reproducibility and we can efficiently estimate thermal features of human forearms.



(a) (b)

Fig.10. Identified arm and forearms region denoted with (a) a wrist position and (b) Minimum Boundary Rectangular (MBR).

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