Proceedings of the 26th Annual International Conference of the IEEE EMBS
San Francisco, CA, USA • September 1-5, 2004

Standardization of Infrared Imaging

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Abstract—**To provide an atlas and database for the temperature distribution of the skin in normal human subjects aged from 10 years to 75 years. The technique used in digital infra red thermal imaging which has been in use since 1960. Despite, many different applications and published studies, a normal database is not available. It is particularly needed for forensic and hospital clinic use.**

Keywords— **Thermal image processing, infrared cameras, regions of interest**

I. Introduction

Temperature maps in so called normals with respect to the symmetry of temperature distribution on the body's surface were published in the eighties by several authors: i.e.: by Uematsu, Goodman, and restricted to temperature readings over joints by Ring and Engel. However, these papers did not mention any definition of health in their selection criteria nor did they meet the requirements for a representative sample for the population in a defined geographical area. Also anthropometrical features such as weight, height, body mass index and gender have not been considered. These shortcomings are addressed in this protocol.

The mean temperature of a defined region of the human body is used for the interpretation of medical thermograms. As the size of parts of the human body varies with body dimensions, the whole range anthropological variations must be investigated for the definition of normal values of surface temperatures. This protocol also addresses the issue of standardisation in order to achieve reproducible results. Environmental conditions, volunteer selection and preparation, standard views and image evaluation aspects are defined.

The aim of the study was to:

- determine the source of variables in a multicenter study to collect normal thermograms of human subjects,
- define the protocols needed to minimise or avoid these sources of variation,
- collect a database of images from normals in Poland and UK for on-line reference.

II. Volunteer Recruitment

To conduct representative study with regard to anthropological features, data of the local population are needed to select appropriate subjects for a representative sample. Subjects between 18 and 70 years should be recruited, an grouped into age classes, which are 18-30 years, 31-40 years, 41-50 years, 51-60 years and 61-70 years. Gender distribution should be equal (half male and half female). Each age class is subdivided into 3 sub groups according to the body mass index of volunteers: "underweight", "normal", "overweight" & "obese") according to the guidelines issued by US National Heart, Lung, and Blood Institute (NHLBI), in cooperation with the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK).

The person to be imaged should be protected from draughts, and allowed to come to equilibrium at about 23°C before an image is captured. This means that the infrared imaging laboratory must have a temperature controlled environment, a false ceiling through which air may filter, double glazed windows, a waiting area for the subjects and a cubicle where such clothing as may affect the readings can be removed and stored. The lighting in the laboratory is such that there is no output at wavelengths longer than 1micron. The temperature, humidity and air circulation are all controlled. The infrared camera or scanner should be allowed to come to equilibrium if it is cooled, and calibrated by including an isothermal surface in the image. It is particularly important that the focus and distance of the subject from the camera are standardized and recorded (27 standard views). Only thermographic equipment that can be calibrated for temperature measurement may be used.

III. Definition of the 27 Views and 87 Regions of Interest

A series of 27 standard views of the human body has been defined to cover areas that are likely to show significant temperature changes in the presence of physiological effects caused by disease. (Under normal circumstances, the temperature of the surface of the human body is symmetrical about the anatomical medial axis. Skin temperature close to the core of the body such as the truck and face is normally higher than that in the periphery such as the hands and feet. A knowledge of typical temperatures across the body is diagnostically important in cases where

0-7803-8439-3/04/$20.00©2004 IEEE

the temperature asymmetry is small and difficult to detect; this is the case, for example, with inflammatory rheumatic diseases where there is a bilateral involvement of the body.)

The normal range of temperatures representing 95% of all values in the designated area are needed as a reference. While normal temperatures of some areas of the body are available, a complete set of reference temperatures is lacking. The first step in measuring normal skin temperature distributions for use by clinicians in the diagnosis and monitoring of disease is to define regions of interest (ROIs) across the body.

The definition of 87 regions of interest (ROI) for temperature measurements must satisfy two criteria. Firstly, the ROI must capture as much information as possible from the body area of interest, and secondly, clinicians must be able to position the ROI with a high degree of reproducibility. Experimental results on reproducibility:

For each view, the distance of the subject from the camera is adjusted so that approximately the same number of pixels is covered. The view is defined in terms of the upper and lower edges of the subject and the orientation of the limbs. Several ROIs are defined for each view in terms of the shape of the area; anatomical features were used to locate the extremities of the shape. In some views, cross-sections are defined as lines whose end-points were pinpointed by anatomical features. Evaluation of Images The ROIs and cross-sections are drawn using CTHERM software which also enabled the mean temperature and standard deviations of the temperatures within the ROIs and along the cross-sections to be measured. Below is an example of an image of the upper back with four ROIs and their definitions. The minimum, maximum and mean temperatures are calculated for the ROI together with the standard deviation.

Number of ROIs: 4
ROI 1: left posterior shoulder joint (red)
Shape:circle
Outline of the circle is adjacent to the acromion and also to the posterior axillary fold
ROI 2: right anterior shoulder joint (blue)
Shape: Circle
Outline of the circle is adjacent to the acromion and also to the posterior axillary fold
ROI 3: half of the upper back (yellow)
Shape: rectangle
Lower edge: aligned with the left elbow **Right upper corner**: adjacent to the acromion **Left upper corner:** adjacent to the midline of the chest
ROI 4: half of the upper back (green)
Shape: rectangle
Lower edge: aligned with the right elbow **Right upper corner**: adjacent to the midline of the chest **Left upper corner:** adjacent to the acromion

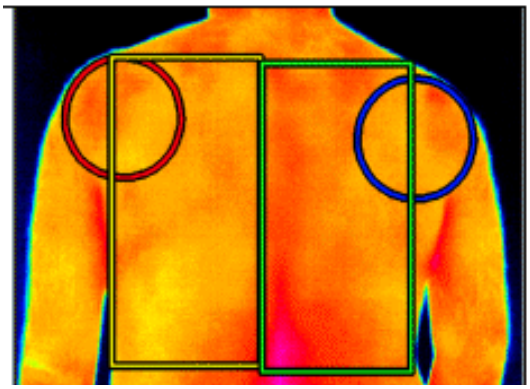

Fig. 1. Regions of interest on the upper back and shoulders

Standardization of patient position is essential, and in order to keep the subject in the same position, so-called masks are defined. Masks are created electronically and automatically appear in the correct order on the screen. They allow to adjust distance but not angle to make the body region fit the mask on screen. It is essential that standard views are defined by anatomical definition.

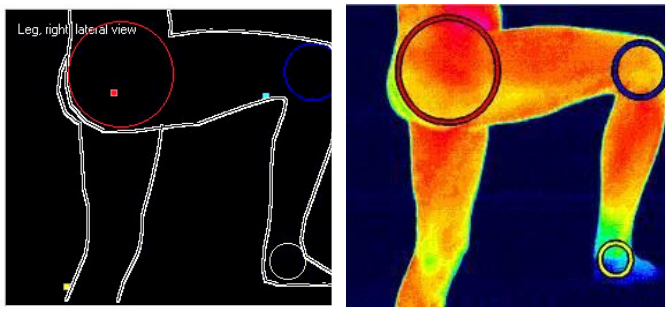

Fig. 2. Mask and ROIs for right leg in lateral view, ROI for medial knee, lateral hip and lateral ankle

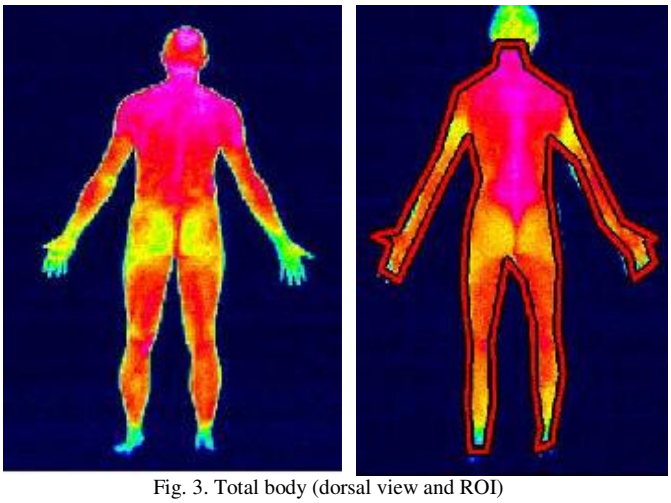

Fig. 3. Total body (dorsal view and ROI)

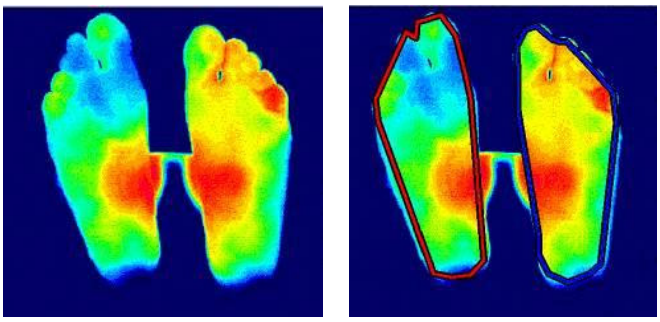

Fig. 4. Plantar Feet (dorsal view and ROI)

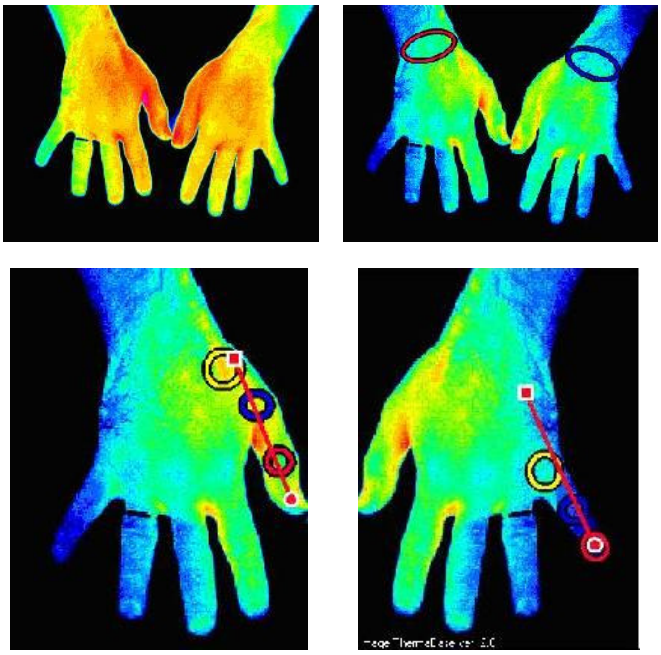

Fig. 5. Both Hands (dorsal view) , and ROI (wrist, right thumb, left little finger)

V. CONCLUSION

A protocol for capturing a series of images from the whole body of a healthy subject has been established. A total of 27 views of the body were specified and within these views, a total of 87 regions of interest (ROI) were defined. The repeatability of some standard views by different investigators and the inter- and intra-rater reliability of temperature readings from selected regions of interest has been investigated. The highest variation in positioning was found in the hands and feet. The face varied in a very narrow range. Individual dimensions of these body regions contribute to the variation of positioning. In the case of dorsal hands the distance between both little fingers may be longer than the distance from the wrist to the tip of the middle finger. Such a condition prevents the precise positioning in a defined manner. Similar conditions may occur in the views Upper Back, and Anterior Knees. According to the results of this investigation the rules for positioning and image capture of dorsal hands, upper back and anterior knees have been modified.

Inter-rater reliability coefficient alpha and ICC of the ROI "Lower Arm", and the hourglass shaped ROI at the anterior knee confirmed excellent repeatability of ROI placement. The influence of the angle of view on temperature readings from an identical object is also discussed. Reference values for the surface temperature of body regions based on images captured according to our protocol will reflect mainly the individual temperature variation.

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