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Application of Newton's cooling model to interpret thermoregulation in the breast using dynamic infrared thermography

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Abstract

In this work was studied the thermoregulation process on skin breast using the dynamic infrared thermography (DIRT), there were captured sixty images on the chest region in a controlled closed space. The DIRT technique was used for getting an image each thirty seconds after cooling the breast with a conventional fan for 5 minutes. An algorithm implemented in Matlab permitted aligning, segmenting and verifying the Newton's cooling model in order to compute the thermal proportionality coefficient in both breasts through average temperature. A high coefficient Pearson's coefficient near to 0,96 was obtained in all cases.

1. Introduction

The great technological advances that are currently being presented, both in thermographic cameras and computer equipment, continue to reinforce the endless applications of infrared thermography (IRT), making it a valuable tool without side effects, for the study and identification of pathologies and processes at the cutaneous and subcutaneous level in animals and humans. [1]

Thermography is a non-invasive, low-cost, and non-ionizing technique, which allows visualisation of the functioning of the vascular, sensory, sympathetic nervous systems and inflammatory processes in the breast. These advantages make it possible to use it regardless of the age of the person and to identify anomalies up to 10 years earlier than the most commonly used technique, mammography. [2]

The IRT technique has an output a temperature value that is recorded in each pixel of the image, and many studies have suggested the need to improve the results of the thermal response of the skin, using the variant of dynamic infrared thermography DIRT to highlight and better identify the vascularization processes that occur in response to specific controlled stimuli, exposing the skin to thermal effects of heat and cold [3].

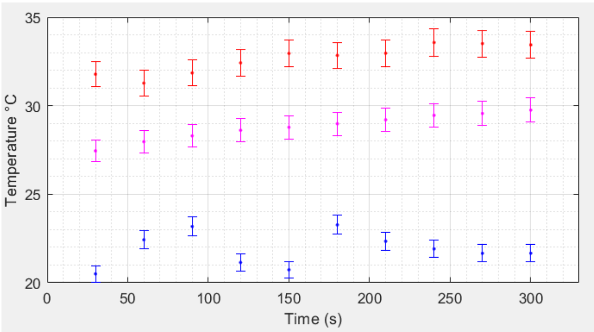
Conci et al, propose that DIRT dynamic thermography together with the use of image processing techniques and machine learning computational algorithms, provide an effective tool for screening subcutaneous tumours with accuracy greater than 95% [4].

2. Methodology

The capture of thermographic images was carried out on a sample of six women living in the city of Pereira, highlighting that none of them had any type of diagnosis of breast cancer, or breast malformation in their clinical history. The sample consisted of women between the ages of 20 and 60, in order not to consider possible variations in breast density with age. Air conditioning equipment and a dehumidifier were used to stabilise the temperature and relative humidity: background temperature of 20.8 ºC and relative humidity of 60%. The images were taken in a single study moment, which lasted 30 minutes per participant. When the patient enters the room, the patient's acclimatisation process begins for 5 minutes, and once it is finished, the lights are turned off and the participant is instructed to leave the chest area exposed, and then the acclimatisation process begins. cooling process. This cooling consisted of exposing the chest area to a conventional fan for 5 minutes. Once the 5 minutes of cooling were over, the thermographic images were recorded at intervals of 30 seconds, until a total time of 5 minutes elapsed. Therefore, 10 images per participant and a total of 60 images for the entire study were obtained.

Since the images from the Fluke Ti 300 thermal imager are in text file format (.txt), an algorithm was developed in Matlab that allowed the transformation of text files into two-dimensional images with numerical values, whose pixels represent the temperature value in the regions of interest of the pectoral area of the study participants. Once the set of thermographic images was obtained, they were packaged for subsequent alignment; since patients naturally perform involuntary breathing movements and movements of their limbs, due to minor discomfort that may arise during the test. This alignment is done through rigid linear transformations that use scaling, translation, and rotation methods, taking the first image of the set as the reference image since this image corresponds to the moment when the participant was in a state of greater muscle relaxation and minor movement. Regions of interest (ROI) were obtained using manual image segmentation techniques, and statistical descriptors defined as maximum temperature, minimum temperature, and average temperature were extracted from these ROIs. In the results, the GUM standards [5] were taken into account, and thus in the uncertainty values in the temperature, the technical characteristics of the measurement equipment were considered (resolution of 0.01°C and tolerance of 2% given by the manufacturer). Newton's cooling model was used to determine the thermal proportionality coefficient of breast tissue, with the criterion that in all results the correlation coefficients were always greater than 0.85.

3. Results



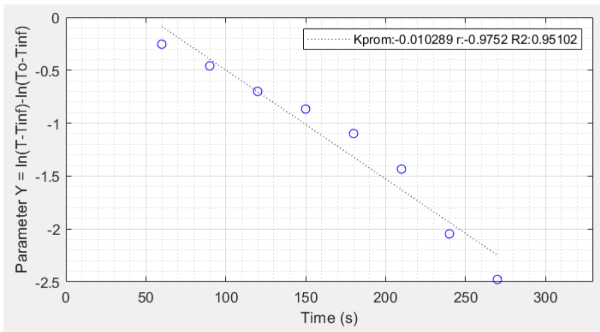


Fig. 1 *Fig. 2*

Fig. 1. Variation of the maximum, minimum, and average temperature extracted from the region of interest of the right breast, for participant No.1.
Fig. 2. Logarithmic scale of the average temperature of the region of interest of the right breast, of participant No. 1.

Fig. 1. shows the maximum (red), minimum (blue), and average (violet) temperatures with respect to the capture time of each image up to a total time of 300 seconds, extracted from the region of interest of the sinus right, for participant No.1. The variations of the maximum and minimum temperature show oscillations as time goes by, while the average temperature apparently shows an increasing and continuous behaviour.

Fig 2. shows the linearization of Newton's cooling model using the average temperature data recorded in Fig. 1., whose slope corresponds to the coefficient of thermal proportionality of the region of interest of the right sine, of the same participant, a value that corresponds to 0.010289 s^{-1}. A high degree of correlation is also observed between the data and the fit curve with a Pearson coefficient of 0.975 and an R2 value of 0.951.

4. Conclusion

The results with the participants of this study confirmed that for the sample of the six participants, both the left breast and the right breast satisfactorily complied with the characteristic thermoregulation process proposed in the Newton cooling model. For both breasts, a Pearson coefficient greater than 0.96 was obtained in all cases, and an average thermal coefficient of 0.010490 s-1 ± 0.002336 s-1 was found.

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