Advanced BME Laboratory (AM5019)
Non-Invasive Imaging and Diagnostic Lab (NIID)
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EXPERIMENT:

Analysis of thermograms to identify the temperature gradients using image processing

AIM:

To analyze left-hand and right-hand thermograms using image processing post cold provocation.

OBJECTIVES:

i. To find the difference in IR camera measurements with respect to the temperature measured by a thermocouple.
ii. Segment different regions of the hand and find the time taken for the temperature to reach the normal body temperature post cold provocation.
iii. Understand the skin temperature redistribution after reestablishment of blood perfusion post cold provocation.

APPARATUS USED:

i. IR camera (Meditherm, Serial No-0200000812, infra-Rent LLC camera (Lakeland, FL))
ii. Velbon PH-368 Fluid Head Tripod
iii. Thermocouple connected to Fluke 287 RMS Multimeter
iv. Software used: MedHot Pro IR Version 2.0 (Record images); MATLAB (For analysis)
v. Water bath and iced water for cold provocation
vi. USB interface to computer to acquire images from the camera

Figure1: IR Camera

THEORY:

Infrared Thermography:

Infrared thermography uses infrared radiation emitted from an object to capture and create an image of an object. Thermographic cameras detect radiation in the long-infrared range (9,000– 14,000 nm) and produce images called thermograms. Since infrared radiation is emitted by all objects with a temperature above absolute zero according to the black body radiation law, thermography allows to visualize objects with or without visible illumination. The amount of radiation emitted by an object increases with temperature ($\propto T^4$), thus thermography allows to observe variations in temperature. When viewed through a thermal imaging camera, warm objects can be distinguished well against cooler backgrounds. Humans and warm-blooded animals are easily visible against the environment. As a result, thermography is particularly useful in military and surveillance. Thermography also has clinical applications allowing non-invasive monitoring of the body. It has been used for detection of allergy and inflammation, breast cancer screening, measuring subtle changes in skin temperature in real time, diagnosis of diabetic neuropathy and vascular disorder, fever screening and sports medicine.

Thermocouple:

A thermocouple is a simple and cost-effective temperature sensor used in a wide range of temperature measurement applications. It consists of two dissimilar electrical conductors forming an electrical junction. One junction is placed where the temperature is to be measured, and the other is kept at a constant lower temperature. The temperature difference causes the development of an electromotive force (Seebeck effect) that is approximately proportional to the difference between the temperatures of the two junctions. Thus, the instrument can be calibrated to measure temperature.

Seebeck effect: In an open-circuit, the gradient of voltage is directly proportional to the gradient in temperature, where S(T) (Seebeck coefficient) is the temperature dependent material property.

$$\nabla V = -S(T)\nabla T$$

Thermoregulation:

Thermoregulation is a physiological process of maintaining a constant core temperature in the human body and is crucial for normal functioning. The average person has a baseline temperature between 98°F (37°C) and 100°F (37.8°C). However, if the body it out of the extremes of body temperature, it can affect the body's ability to function. The hypothalamus senses fluctuations in body temperature and sends signals to mediate and return the temperature to normal. During positive (hot) or negative (cold) thermal stresses, thermoregulatory mechanisms cause vasodilation (increase in diameter of blood vessels) or vasoconstriction (reduction in diameter of blood vessels), respectively, which are achieved by a combination of neural mechanisms. Other mechanisms such as sweating, cools the skin as sweat evaporates which helps lower internal temperature. Hormonal control mechanisms mediated by the thyroid, for example, an increase in metabolism increases the amount of heat produced by the body.

PROCEDURE:

i. The subject was asked to dip the hand (palm and fingers) into cold water (at 8°C) for five minutes.

ii. After cold provocation the blood flow is reduced; the hand is completely numb and at a temperature lower than the normal body temperature.

iii. The temperature at the tip of a finger was measured using a thermocouple post the cold provocation at regular intervals of 1 minute until the hand reached a constant body temperature (~30 – 33 °C)

iv. Simultaneously, images of the dorsal surface of the hand were captured using the IR camera at regular intervals of 1 minute.

v. Procedure (i) – (iv) was repeated for both the left and right hand.

vi. The images were analyzed in MATLAB. The temperature at a particular region (Points 1-13: Figure 2) was calculated by taking the mean intensity of the pixels in the region and comparing it with the calibrated temperature value of the camera. The pixel positions were chosen manually for each frame since the position of the hand varied between frames.

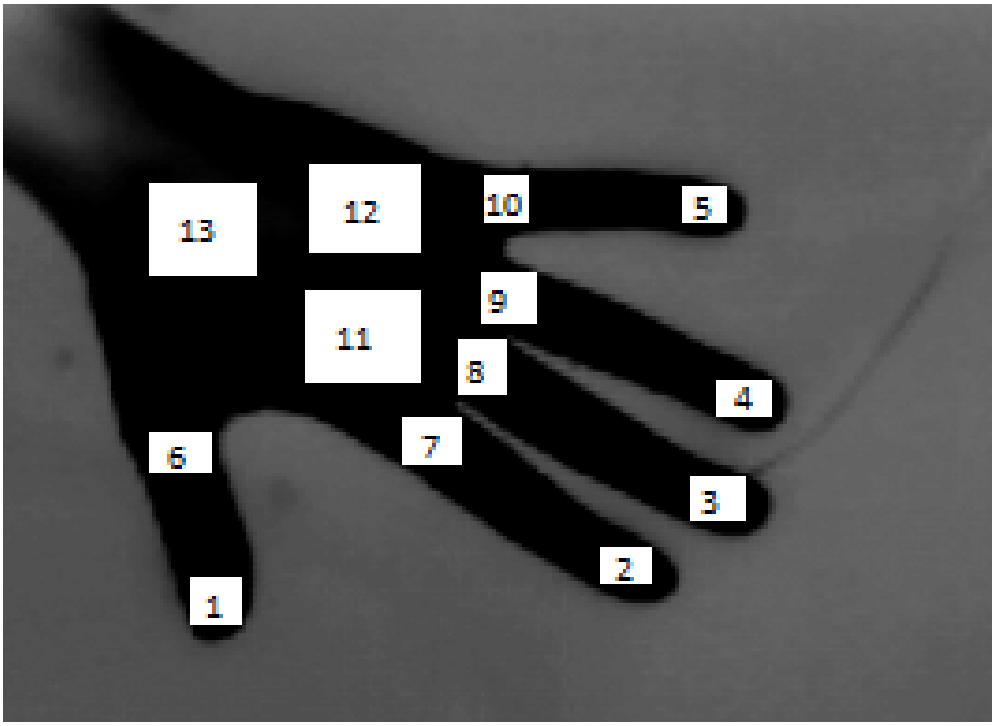

Figure 2: Temperature measured at 13 regions from thermograms

RESULTS & OBSERVATIONS:

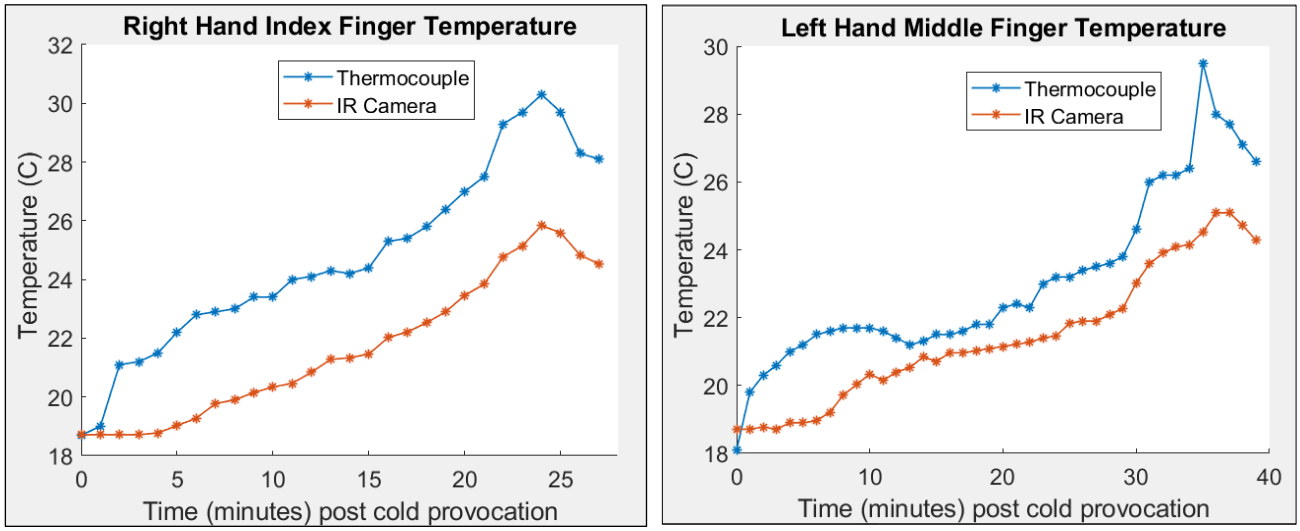

Figure 3: Temperature measured by the thermocouple vs IR camera

There are slight variations in the temperature measured between the thermocouple and IR camera. This could be due to the fact that the IR camera measures temperature on the dorsal surface of the hand whereas the thermocouple measured the temperature on the ventral surface. In addition, the accuracy of the IR camera depends on its calibration.

The temperature in the regions 1-13 can vary slightly depending on the exact pixels taken from the thermograms to calculate mean temperature in the region.

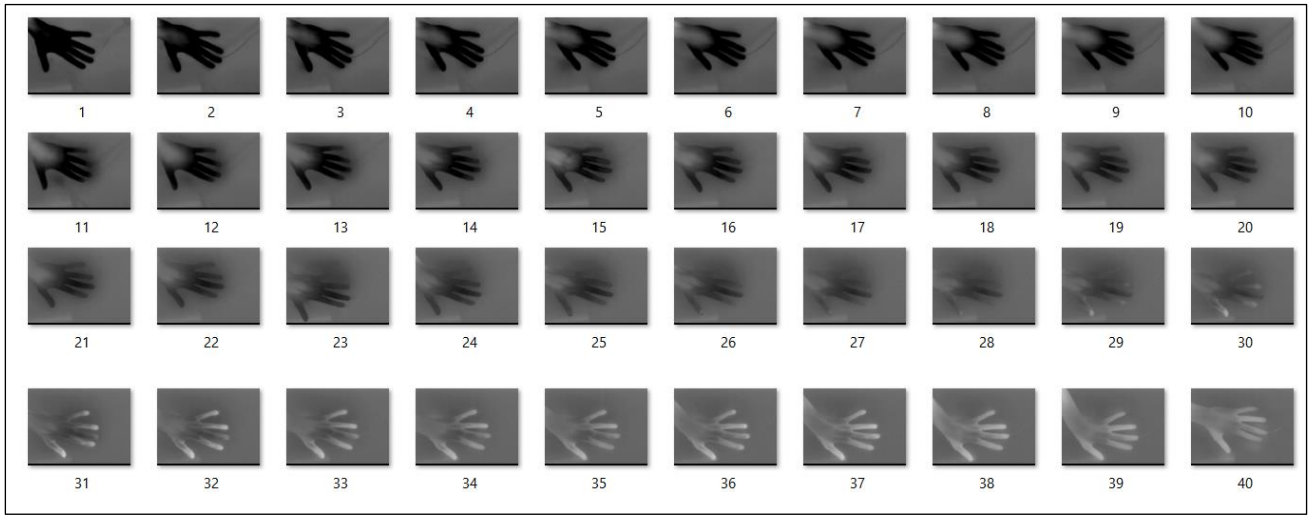

Figure 4: Thermograms of the left hand

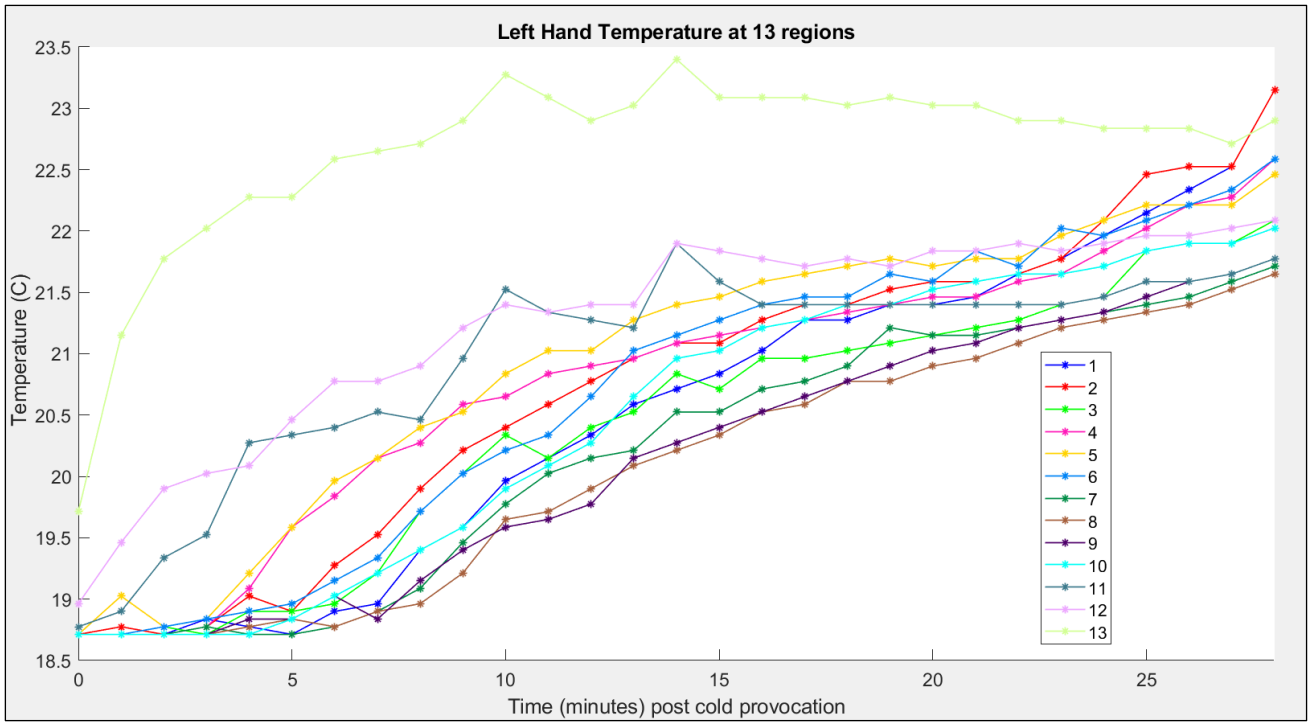

Figure 5: Left hand temperature at 13 regions

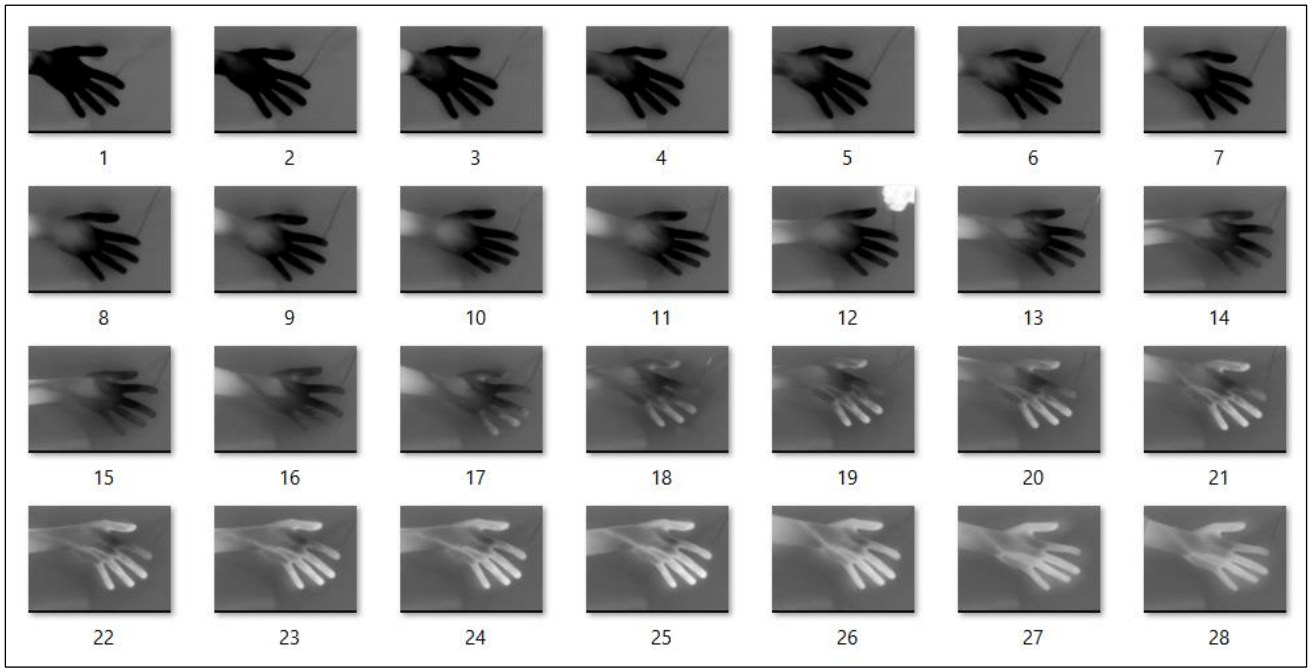

Figure 6: Thermograms of the right hand

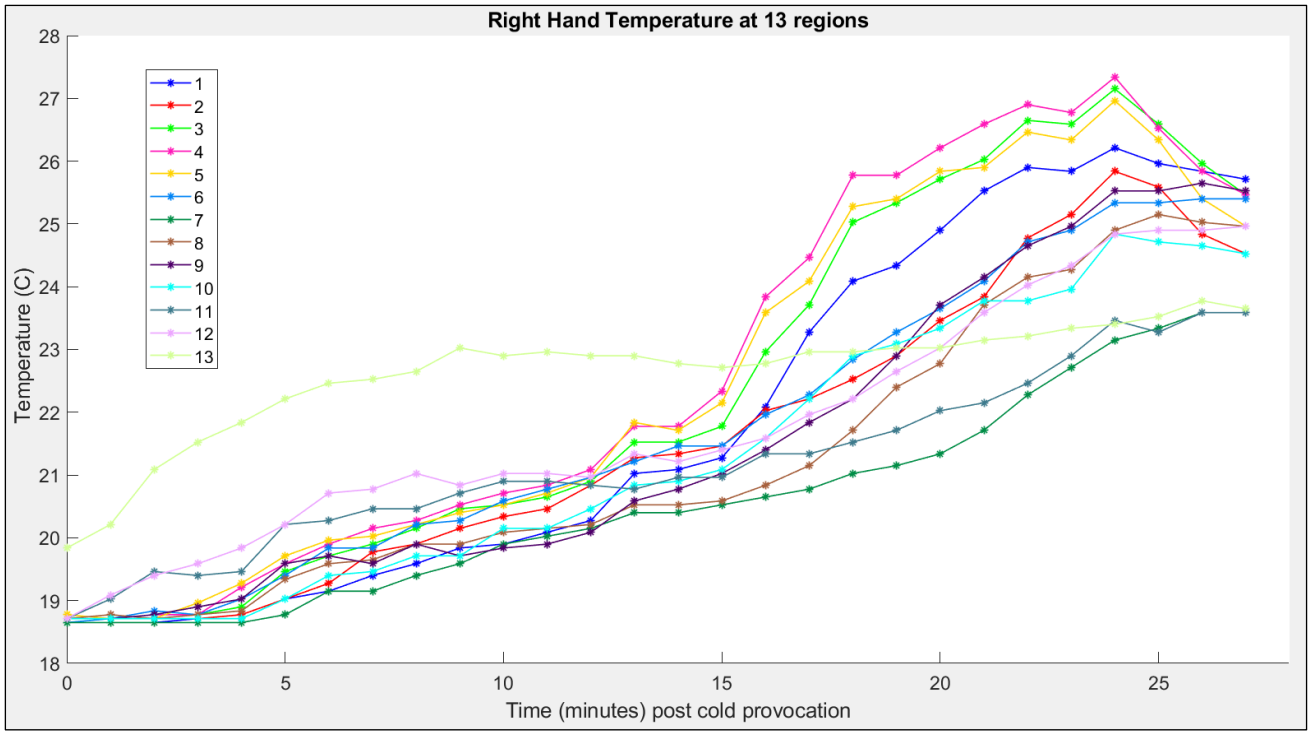

Figure 7: Right hand temperature at 13 regions

Key Observations from Right Hand Thermograms:

The palm region just below the wrist (Region 13) rewarmed first in the initial time period as blood rushes through the hand post cold provocation. Following this, Region 11 and Region 12 (Meta carpals) show slight increase in temperature up to 10 minutes.

As the blood flows through the fingers, the distal phalanges (Region 1-5) have the fastest rate of rewarming (as seen in Fig 7 these curves have the highest slope till ~23 minutes). The middle and proximal phalanges warm up at a rate lesser than the distal phalanges.

After ~23 minutes there is a decrease in temperature of the distal phalanges and steady increase in the temperature of the proximal phalanges until both regions reach approximately the same temperature.

CONCLUSIONS:

Left-hand and right-hand thermograms have been analyzed post cold provocation. The rewarming of different regions of the hand can be studied with IR thermography to understand thermoregulatory control in subjects.

CRITICAL REMARKS:

i. The accuracy of the IR camera depends on its calibration.
ii. The temperature in the regions 1-13 varies slightly depending on the exact pixels taken to calculate mean temperature in that region.
iii. The images have not been captured for the complete process of rewarming (>30C) due to lack of time.
iv. The readings were taken in an air-conditioned room at 22C which may have slowed down the process of re-warming vs an experiment performed at normal room temperature.