Thermal Infrared Imaging for the Detection of Temperature Increase on the Head Surface Due to Motor Activity

Ana M. Guzman[1], Malek Adjouadi[1], Lu Wang[1], Armando Barreto[2], Naphtali Rishe[3]

[1]Center for Advanced Technology and Education
[2]Digital Signal Processing Laboratory
Department of Electrical & Computer Engineering
[3]School of Computing and Information Sciences
Florida International University, Miami FL 33174, USA
Emails: ana.guzman2@fiu.edu, adjouadi@fiu.edu, lwang001@fiu.edu, barretoa@fiu.edu, rishen@cs.fiu.edu

Abstract

This paper presents preliminary findings using thermal infrared imaging for the detection of temperature increase on the head surface of a human subject due to the performance of simple motor activities. When a person performs a motor task activity a particular area of the brain is activated due to neural activity which is the result of an increase of blood flow to the local vasculature. The experiment presented here consists of the statistical analysis of thermal infrared images captured using a mid-wave infrared camera from FLIR systems. A healthy, bald, male subject participated in this experiment, he was asked to perform finger tapping using his left hand while his right sagittal view was recorded. The subject was asked to perform finger tapping for 30 seconds and to rest for 30 seconds. The thermal infrared video was decomposed into individual frames and these were analyzed using the statistical one-tailed t-test. The preliminary results show that there is a temperature on the head surface in the area of the parietal lobe due to the performance of a motor activity.

1. Introduction

Motor task activities cause the activation of different areas of the human brain depending on the task being performed. Different imaging modalities exist for brain activity mapping. These modalities include positron emission tomography, event-related potentials, electro- and magneto encephalography, magnetic resonance imaging, and single-photon emission tomography. These non-invasive brain imaging modalities are used to explore the spatial and temporal organization of the neural systems supporting human behavior.

Thermal Infrared Imaging has many applications in different scientific, engineering, research, and medical areas. Different studies using thermal infrared imaging have been done to detect spontaneous emotional facial expressions [7], skin tumors [2], to recognize faces and facial expressions [5], frustration [4] and other emotions, as well as temperature increase on the ear and cheek after using a cellular phone [6]. The last study [6] is the closest related, statistically, to the experiment presented in this paper. In this paper we explore the idea of using thermal infrared imaging for the detection of temperature changes on the head surface of a human subject due to the performance of a motor activity. To the best of our knowledge no study has yet been done on this specific area of research.

2. Methods

2.1 Participant

For the purpose of this study the same subject was used for the entire experiment. The subject is a healthy, 25 years old male. The subject stayed in the laboratory room for 30 minutes before the recording session began in order to allow his body to adapt to the temperature in the room. Such a preliminary study is to include several other volunteers as the merit of the hardware-software integrated experiment is validated. It is of utmost importance to insure that the temperature accuracy of ± 2 °C and ± 2% of reading can be accomplished with the reliable setting of emissivity, temperature and humidity variables.

2.2 Equipment and software

The primary equipment used for this study is a thermal infrared camera (Merlin™ InSb MWIR Camera, FLIR Systems). The camera consists of a Stirling-cooled Indium Antimode (InSb) Focal Array Plane (FPA) built on an Indigo Systems ISC9705 Readout Integrated Circuit (ROIC) using indium bump technology. The FPA is a 320 × 256 matrix of detectors that are sensitive in the 1.0µm to 5.4µm range. The standard camera configuration incorporates a cold filter that restricts the camera's spectral response to the 3.0 µm – 5.0 µm band. The camera has a 25mm lens with a field of view of 22 × 16°.

The thermal sensitivity is 0.025 °C at 30 °C ambient temperature. The absolute temperature measured depends on different factors such as emissivity of the object, ambient temperature, and humidity. Relevant parameters can be changed in the software (ThermaCAM™ Researcher V2.8 SR-1) provided by FLIR Systems. The temperature accuracy is ± 2 °C and ± 2% of reading if all the variables (emissivity, temperature and humidity) are correctly set.

In the ThermaCAM™ software the following values were used for the video recording:

- Emissivity: 1.0;
- Distance: 1.5m
- Relative humidity: 50%;
- Temperature: 20 °C.

The effect on the absolute temperature was tested by choosing different values for these parameters on single images taken before and after the subject performed a few calisthenics exercises to elevate his body temperature. This single image recording session was done in a different day from the video recording session. When the temperature parameter was changed from 20 °C to 25 °C a change in the absolute temperature of about 0.025 °C or less was recorded, this change is equal to the sensitivity of the IR camera. Changing the relative humidity from 50% to 25% and the distance from 1.5m to 1.3m gave the same result. The emissivity value of human skin is 0.97, when this value was changed to 1.0 the absolute temperature changed by about 0.3 °C. However, the rise in the temperature from before and after performing a few calisthenics exercises did not change. Thus, a dependence on the emissivity or any other parameter setting in the camera was avoided.

2.3 Design of the experiment

The recording of the thermal infrared video sequence was done in a room with a mean room temperature of 23 °C. During the recording session the room lights were turned off to avoid the recording of any reflections, this was done as an extra precaution.

For the purpose of this experiment the subject needs to be baldheaded. The reason for this requirement is that we are interested on the surface temperatures of the parietal lobe which is associated with human motor activities, and hair interferes with the recording of skin surface temperatures. A suitable male subject volunteered for this experiment. The recording of the thermal infrared video sequence was done in one session. The recording lasted 1 min 30 s with a recording frame rate of 60 frames per second.

The subject was asked to sit on a chair for 30 minutes prior to the recording session; this was done with the purpose to adapt his body temperature to the temperature in the room.

The infrared camera was placed on a tripod. The lights in the room were turned off to avoid reflections on the subject's head that could influence the temperatures measured by the infrared camera. The subject sat on a stationary chair with a head rest to avoid any head movement. The camera was kept at the same position during the recording. The right sagittal view of the subject's head was recorded while the subject did 30 seconds of finger tapping using his left hand (ON activity) and 30 seconds at rest (OFF activity)

2.2 Statistical analysis

To test the hypothesis of increased surface temperature on the parietal lobe area caused by performing a motor activity a one-tailed t-test was applied to the region of interest shown in Figure1. The alpha value used for this experiment was 0.05. This alpha value is the probability of making a type I error (i.e. rejecting the null hypothesis H_0 when it is true) while testing the statistical hypothesis.

The testing procedure for this experiment is for a two-sample hypothesis. We have one sample group with ON activity and a second sample group with OFF activity. Their statistical means are represented by μ_{ON} and μ_{OFF}. The null hypothesis is $H_0 : \mu_{ON} = \mu_{OFF}$ and the alternate hypothesis is $H_1 : \mu_{ON} > \mu_{OFF}$. The criteria for rejection is given by $t_0 > t_{\alpha,n1+n2-2}$. The test statistic t_0 is given by (1):

$$t_0 = \frac{\overline{x_1} - \overline{x_2}}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad (1)$$

where $n_1 = 1800$ and $n_2 = 1800$ are the group sample sizes, in this case the sample sizes correspond to the number of individual video frames in each group sample.

The statistical analysis was performed using existing statistical functions in MATLAB and user defined scripts to select the region of interest in each individual frame.

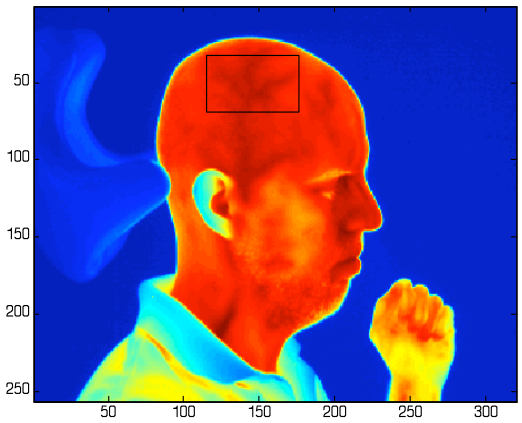

Figure 3. Single infrared video frame of subject performing finger tapping, black rectangular area is the region of interest (Parietal lobe) to be analyzed for temperature change during motor task activities.

3. Results

Preliminary results in this study show that there is a temperature change on the head surface in the area of the parietal lobe due to the performance of a motor activity.

In Figures 2 and 3 the mean temperature within the region of interest is shown. The image in Figure 4 shows a visual representation of the t-values obtained after applying a one-tail t-test to the data; the dark blue pixels represent the pixels that were found to not have significant change in temperature. As it can be seen from the color bar the pixels in dark blue have a t-value of zero, these pixels correspond to the pixels in which there was not a statistically significant change in temperature.

The dark red pixels correspond to t-values in which the temperature change is statistically significant.

4. Conclusions

The presented results show that there is a temperature change on the head surface in the parietal lobe area due to the performance of a motor task activity. Figure 4 shows a visual representation of the t-values obtained after applying a one-tailed t-test, further statistical analysis such as normalization based on statistical Z score will be performed in future work. The implementation of the Z score will take into consideration the temperature values at each pixel location in the selected region of interest in each individual frame. In future work multiple recording sessions will be done in order to offer a stronger validation of the preliminary results presented here.

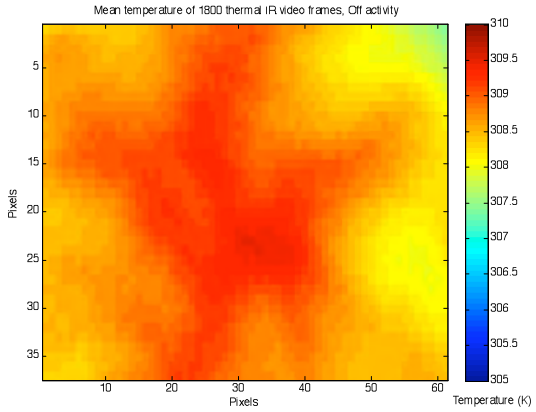

Figure 4. Visual representation of the mean temperatures during motors task activity, temperature is in Kelvin scale.

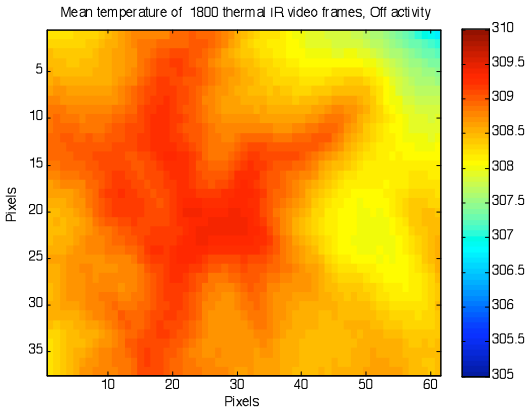

Figure 5. Visual representation of the mean temperatures at rest, temperature is in Kelvin scale.

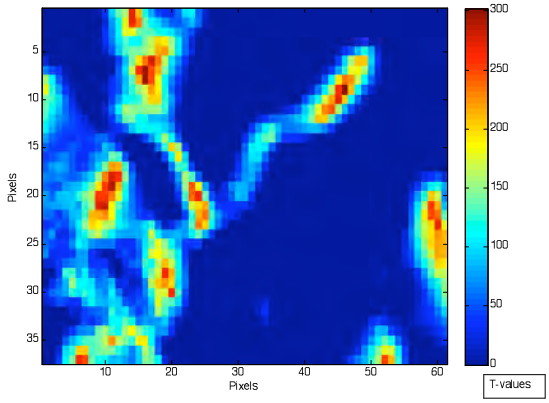

Figure 6. Visual representation of the t-values obtained after applying a one-tail t-test with an alpha=0.05 and degrees of freedom = 3598

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