Infrared investigation on the thermal field of the human face during the EEG session

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Abstract – **This paper presents a study on human skin surface warming during EEG. The case is with EEG with Emotiv® brain computer interface. For the experiment was used the connection between the optical radiation of the objects themselves and their temperature. The study was conducted under laboratory conditions during a session with a wireless 14 channel EEG system. The measurements were done simultaneously at many points by using an infrared camera. The conditions in the rooms and the condition of the patients were taken into account. The emissivity coefficients of the objects studied were also considered. In this work is presented only the thermography analysis.**

Keywords – **Infrared thermography, medical applications.**

I. Introduction

Technology evolves every day and we face new perspectives in the field of health - diagnostic and therapeutic. What is observed in the last few years, is the significant application of infrared imaging, usually in the field of diagnostics. However, the potential of this technology in contemporary medicine is still to be explored in further detail. The current paper is an attempt to broaden the view and deepen the understanding of some of the existing diagnoses through the analysis of data provided by a thermal camera [1-13]. The primary analysis (EEG) is parallel with the infrared measuring [14-16].

II. Current State of the Problem

Much research that is done now focuses on the measurement of one standard diagnostic procedure at a time. The study of the correlations between the fundamentally different physical nature of the random processes is relatively rare [17-20]. The study of EEG together with optical methods mainly is done in the near infrared spectrum called Functional Near-Infrared Spectroscopy (700-900nm) [19,20]. The study in the far infrared range (8-13um), based on the objects' own thermal radiation, is usually performed alone [2-4,13]. This is the reason to conduct this study.

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III. Experiments

The infrared pictures do not influence the main diagnostic procedure, so there are no special requirements on the part of doctors apart from the general requirements for hospital hygiene and rules. As the procedures that we use are non-invasive, they can be conducted outside the hospital [21,22].

The thermal camera used for data collection was FLIR E40, with thermal sensitivity of < 0.07°C and temperature range of (-20°C to 650°C) [23]. All examinations were performed in a sitting position in a quiet room at a constant room temperature of 20±0.5°C following an acclimatization period of 20 min keeping the hands free of any contact to the rest of the body or other objects [22]. For maximum accuracy, the camera was fixed on a stand and movement of the object was avoided. For the final analysis temperature values were determined and given in degrees Celsius (°C). Equally, the relative humidity showed stable values over time. All images were corrected using an emissivity factor of 0.98 for the human skin.

In this study, a series of images was made between certain intervals of time. The infrared pictures were taken at intervals of 20 sec. for 5 minutes.

During the experiment were taken 4 groups of pictures. The first one from the first group is shown in Fig. 1.

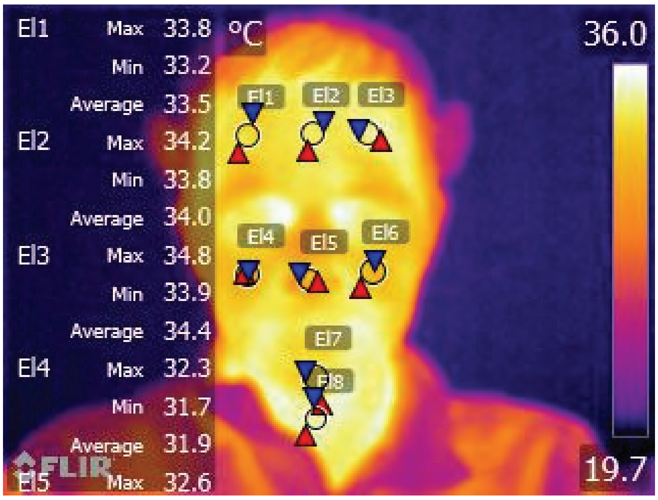

Fig.1.One of the infrared images taken during the experiment with areas of interest

They were organized and conducted in four states - relaxation, intense thinking, relaxation and intense thinking. For intensive thinking we used successive arithmetic operations - removal of a number between 5 and 10 from 200. The aim was to make difficult but not impossible calculations.

Eight ellipses of interest were selected: El1, El2, El3 – on the forehead; El4,El6 – in the area of the cheeks; El5 – on the tip of the nose; El7 – on the chin; El8 – on the neck; . We selected ellipses, not points, to eliminate probable human little movements and noises. For the areas where the human skin is observed, is selected a radiation coefficient 0.98 [21].

The processing was made with the original software of the camera - version FLIR Tools+ 5.3.1.

IV. Analysis

Figure 2 shows all the data obtained after the processing of data in areas El1 to El8. On the ordinate are combined numbers of the measurements of the four groups. The first picture is marked with 1 and the last one - with 60.

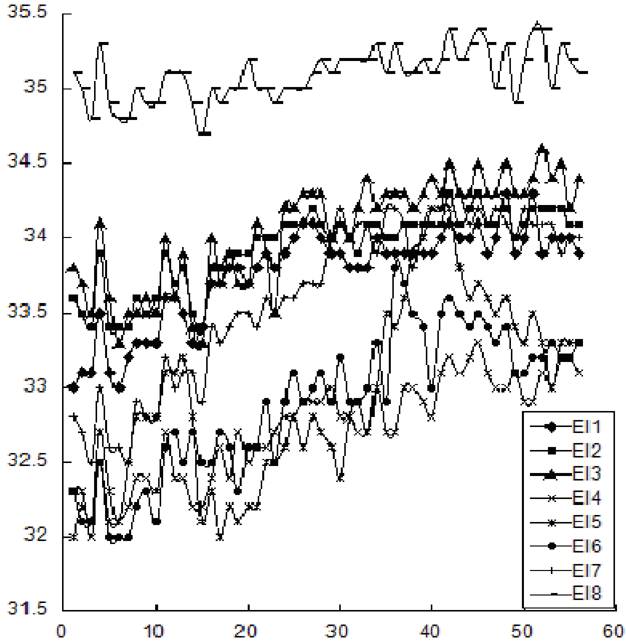

Fig.2.Results after averaging the data in the areas El1 to El2. On the x-axis is written the number of the measurement. It is a combination of four sets of measurements. The ordinate shows the temperature in degrees centigrade.

The results in Fig.2 are difficult to comment on. For this reason we made calculations for a variance [24] for each dataset. For a more detailed analysis we split each set into two equal parts. The results are shown in Fig.3, Fig.4, Fig.5 and Table 1.

After a careful study of the results of Fig.3, Fig.4, Fig.5, we noticed that the overall variance for the first two measurements (Series1 and Series2) is significantly greater than the second two measurements (Series3 and Series4). There is an exception for the results from area El5. With the so selected times between the pictures, there is a clear correlation between variance and mental load for the following areas of interest: El2 - the first half of the data shows that the increase in mental load increases the variance; E4, E6 - in the first and in the second half of the data it can be seen that with the increase in mental load, variance decreases; E5 - in the first and in the second half of the data as well as the overall processing can be seen that when there is a reduction of mental load, variance is significantly increased.

After these calculations, we decided to do some of the 28 combinations of correlation [24] between the 8 areas of interest. The results are shown in table 2.

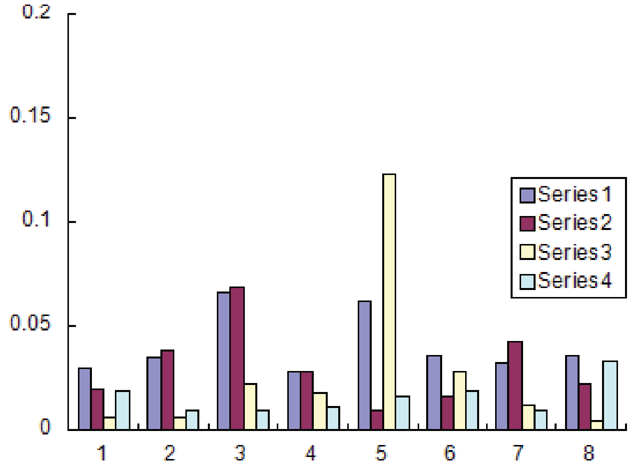

Fig.3. Results after calculating the variance based on the first half of the data set for fields of interest. The x-axis denotes the number of the respective region El1 to El8. The four groups of measurements are denoted as Series1 to Series4. The ordinate represents the values of calculated variance.

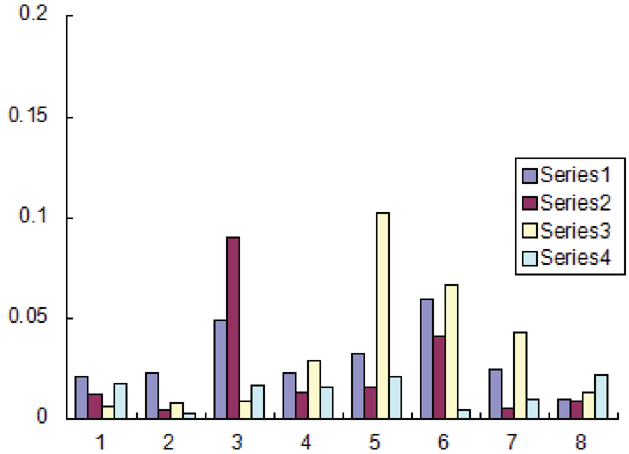

Fig.4. Results after calculating the variance based on the second half of the data set for fields of interest. The x-axis denotes the number of the respective region El1 to El8. The four groups of measurements are denoted as Series1 to Series4. The ordinate represents the values of calculated variance.

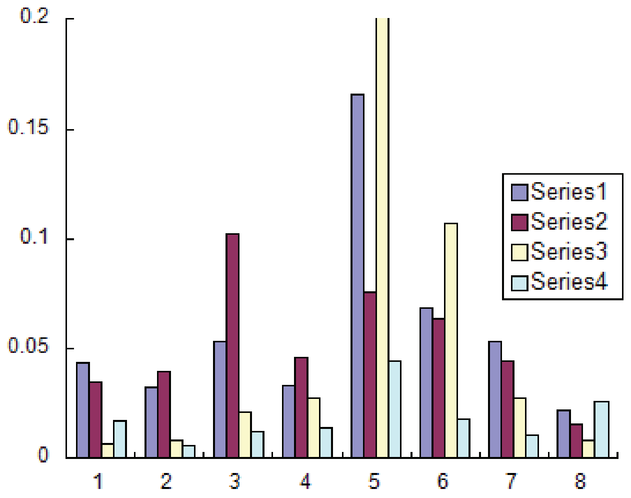

Fig.5. Results after calculating the dispersion based on the whole data set for fields of interest. The x-axis denotes the number of the respective region El1 to El8. The four groups of measurements are denoted as Series1 to Series4. The ordinate represents the values of calculated variance.

TABLE I
RESULTS AFTER CALCULATING THE DISPERSION BASED ON THE WHOLE DATA SET FOR FIELDS OF INTEREST (THE ROWS REPRESENT THE VALUES FOR EACH EXPERIMENT)

	El1	El2	El3	El4	El5	El6	El7	El8
1	0.04	0.03	0.05	0.03	0.17	0.07	0.05	0.02
2	0.03	0.04	0.10	0.05	0.08	0.06	0.04	0.02
3	0.01	0.01	0.02	0.03	0.42	0.11	0.03	0.01
4	0.02	0.01	0.01	0.01	0.04	0.02	0.01	0.03

TABLE II
CORRELATIONS BETWEEN RESULTS IN SOME SELECTED AREAS OF INTEREST

El1-El2	El1-El3	El2-El3	El2-El4	El2-El5	El2-El6
0.94	0.83	0.90	0.92	0.61	0.85
El2-El7	El2-El8	El5-El7	El5-El8	El5-El6	El5-El4
0.90	0.73	0.69	0.59	0.76	0.70

The results of the correlation analysis showed significantly poor correlation in combination with El.5 than other areas. It is possible to think in the direction that the information we gain from this area is sufficiently different from the other areas of interest.

V. CONCLUSION

The analyzed data provides another perspective on the myriad applications of thermal images for medical purposes. Such an analysis can be very useful in providing a new understanding of widely used technology in terms of safety and effectiveness in diagnostics. Since IR imaging is noninvasive and does not bear any risks, it can be used wherever it is useful and feasible. There is also great potential for diagnostic medicine to look for links between different points of temperature and completely different phenomena.

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