Infrared thermography quantitative image processing

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Abstract. Infrared thermography is an imaging technique that has the ability to provide a map of temperature distribution of an object’s surface. It is considered for a wide range of applications in medicine as well as in non-destructive testing procedures. One of its promising medical applications is in orthopaedics and diseases of the musculoskeletal system where temperature distribution of the body’s surface can contribute to the diagnosis and follow up of certain disorders. Although the thermographic image can give a fairly good visual estimation of distribution homogeneity and temperature pattern differences between two symmetric body parts, it is important to extract a quantitative measurement characterising temperature. Certain approaches use temperature of enantiomorphic anatomical points, or parameters extracted from a Region of Interest (ROI). A number of indices have been developed by researchers to that end. In this study a quantitative approach in thermographic image processing is attempted based on extracting different indices for symmetric ROIs on thermograms of the lower back area of scoliotic patients. The indices are based on first order statistical parameters describing temperature distribution. Analysis and comparison of these indices result in evaluating the temperature distribution pattern of the back trunk expected in healthy, regarding spinal problems, subjects.

Keywords: Infrared thermography, Image processing, Scoliosis

1. Introduction

Thermal imaging has been used for the last 50 years as a non-invasive, non-contact and reproducible technique for assessing temperature distribution of objects with temperature greater than absolute zero. Its applications span a wide range in technology, industry and medicine. In medical applications thermal imaging provides an instantaneous temperature map of the body surface of the subject being analyzed, without any harmful effects either to the patients or to the medical staff involved. Modern thermal imaging cameras provide high speed and high resolution and their stability has improved dramatically. The human body emits radiation ranging from mid-infrared radiation to the microwave range. A wavelength in the range from 9 µm to 10 µm corresponds to the maximal intensity of the human body emission spectrum [1], [2]. Human skin is a grey body with an emissivity close to the perfect black body. As a result, the emissivity coefficient in the whole spectral range is constant and amounts to 0.98.

Skin is a complicated tissue and its temperature depends on physiological as well as anatomical factors, such as the presence of irregularities on the surface and the presence of different kind of subcutaneous tissue (fat tissue and muscular tissue) [3]. These factors can influence distribution of the
skin temperature of a specific body area, thus it is frequent to find a non-Gaussian thermal distribution inside a selected ROI.

Thermal images of the skin provide a very good qualitative visual estimation of temperature distribution but for all medical applications quantitative temperature information is also very important [4], [5]. Usually single pixel temperature values are not very informative and suitable for the estimation of temperature differences and distribution uniformity [6] - [8]. As a result in most cases ROIs of anatomical interest are selected on thermographic images and their statistical parameters are used as quantitative indices. The back side of the human trunk has a big surface area and its temperature distribution is believed to be influenced by spinal deformities such as scoliosis. As the expected temperature variations are generally low, establishing a thermographic protocol of acquisition and processing of thermographic images is crucial. The protocol should be based on healthy subjects as a control reference group.

2. Materials – Methods

2.1. Patient data

Six healthy subjects (weight $42 \pm 10$ kg, height $147 \pm 15$ cm, age $13 \pm 3$ years) were enrolled in the study which took place in the Tzaneio Prefecture General Hospital of Piraeus, at the Scoliosis Screening Clinic. All subjects were carefully instructed regarding the study and gave their informed consent to participation. The study was approved by the hospital ethics committee.

Images were acquired in line with the requirements of thermal imaging. In particular, they included: patient acclimatization in a room with a temperature of $24$ °C at least 15 minutes before the test, the removal of other heat sources (radiators, areas heated by the sun etc.) from the room, the removal of clothes from the imaging area and possible elements causing local pressure (e.g. belts, chains). The room temperature was kept constant at $24$ °C. The upper chest area and the neck region was exposed while subjects underwent thermographic analysis.

![Figure 1. The automatically generated ROIs (left) and the translated temperature values (right)](image)

2.2. Acquisition and processing of images

Images of the back side of the trunk were acquired with a FLIR T440 thermal camera, set at a distance of 1.5m. The camera made it possible to obtain images with a resolution $320 \times 240$ pixels, a temperature resolution of $0.1$ °C, 100 frames per second (operating frequency of $100$ Hz) and a wavelength range from $7.5 \mu$m to $13 \mu$m. The thermograms were saved as jpg format files to be further analysed and processed. Image pixel values were translated into temperature using reference points on the image temperature scale map. The point defining the midline as well as the top side of the ROIs to
be constructed were chosen manually. Sixteen ROIs were then automatically created at either side of the spine as shown in figure 1 and the corresponding temperature matrices obtained. First order statistics were calculated for each ROI (mean value, standard deviation, skewness and kurtosis). One sided t tests were used to test the statistical significance of differences between the findings at left and right, upper and lower, and inner and outer ROIs. Results were considered significantly different when \( p < 0.05 \).

3. Results

Mean values, standard deviation, skewness and kurtosis characterising the temperature matrices from the 16 ROIs were calculated. Regarding temperature distribution between left and right area of the back trunk, mean ROI values were not found statistically different. Significant difference is observed though between the upper and lower part of the trunk (with the upper side being characterised by a higher temperature in the range of 0.5°C to 2°C) (figure 2). Furthermore the outer ROIs of the same side of the trunk were exhibiting lower temperature values (0.2°C to 0.8°C), compared with the ROIs closer to the spine (figure 1).

Standard deviation of temperature values characterizes the homogeneity of temperature distribution. Comparing the ROIs on the left and right side, the right side presents significantly higher standard deviations. Statistically significant difference is also observed between the standard deviations of the upper and lower side, with higher values characterizing the lower side, while no statistically significant difference is observed on the values of standard deviation between the inner and outer ROIs. Generally, extracted skewness and kurtosis values indicate a fairly homogeneous distribution of temperature values in each ROI.
4. Discussion

Infrared thermography presents certain advantages as an imaging technique. Although the software provided by the manufacturers has built-in utilities, it has several limitations. Pixel temperature values are not always the best way to represent temperature differences and distributions on anatomical areas of interest. Selecting large ROIs and using mean and standard deviation values leads to a loss of information and corresponding degradation of spatial temperature resolution. In patients with faulty posture or spinal problems like scoliosis, there are indications that a temperature distribution deviating from that corresponding to normal subjects could be observed [9], [10]. Therefore, it is important to establish a method of quantitative temperature evaluation, which could describe the expected differences and establish the temperature distribution characteristics of healthy (in regard to spinal problems) subjects. Our preliminary study indicates, that the selected size of ROI results in generally normal distributions of temperature values in every ROI, whilst indicating a difference in temperature mean value and homogeneity in certain back trunk areas.

5. Conclusion

A preliminary study of healthy subjects regarding spinal problems to evaluate physiologic temperature distribution of the back trunk area, is presented. The outcomes indicate that the selected number of ROIs results in a fairly normal distribution in every ROI. Higher temperature was observed at the lower side of the back as well as the areas closer to the spine, whilst a higher inhomogeneity is observed in the lower and right side of the trunk. The proposed protocol will be applied to thermographically study more healthy and pathologic subjects, in an attempt to evaluate temperature distributions on scoliotic patients.

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