Title:
A Case Study Approach On 3D Customized Thermal Human Modelling For Visualized Health Data Interpretation And Ergonomic Design Application

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Keywords:
Thermal Imaging, 3D Body Scanning, 3D Customized Thermal Human Model, Visualized Health Data,3D Anthropometry, Ergonomic Design

DOI: 10.14733/cadconfP.2023.344-349

Introduction:

With the rapid development of infrared cameras and 3D body scanners, the capturing speed and accuracy of data based on three-dimensional space and thermal physiology of the human body have been greatly improved. The results of heat production and transfer of human body are presented on the body surface as skin temperature distribution. Unusual low or high surface temperature in the body are important physiological indicators that reflect the health conditions of the human body. The slight temperature changes owing to inflammations and tumors can be monitored in earlier stages by thermal imaging [1] [2]. Compared to other medical imaging equipments such as x-ray, ultrasound, CT and MRI, this non-contact and nondestructive tool previously indicate various diseases which has been widely applied in physical examination and auxiliary diagnosis of diseases [3] [4] [5].

3D body scanning system provides precise and true-to-scale cloud point data and accurate measurements of the human body which have been used in various ergonomic scenarios [6] [7]. Furthermore, the visualization and spatialization of anthropometric technique of 3D scanning coupled with infrared thermal images would make further contributions on body shape recognition and intimation of abnormal body parts. The potential relevancy between anthropometry, thermography and health data has great value to be further researched for healthy and sub-healthy people to attract awareness on prediction, prevention, and rehabilitation of diseases.

In this case study, utilizing 3D human model and infrared images, the developing of 3d customized thermal human model would combine geometrical and thermal physiological data to present a functional and visualized virtual body which would be a digital health platform acting as a personalized and sustainable health management tool and providing effective data for ergonomic design applications.

Experiments:

In this study, a stable experimental environment was the first condition to avoid uncertain indoor heat exchange between the subjects and the air. The Environmental parameters of the laboratory had been set as follows:

- Environment temperature: 24±1°C
- Relative humidity: 60±5%.
- Air velocity < 0.1m/s

Healthy people had been enrolled in the experiments by wearing only underwear for males or underwear and bra for females. Human Solution 3D Body Scanning System and FLIR infrared camera

had been respectively utilized to capture precise raw data of digital 3D human body and infrared images.

Data processing and analysis:
In this pilot study, one of the subjects with standard body had been adopted for demonstration in this paper, who was a 29-year-old, right-handed, professional tennis coach having a body mass index of 21.6 (BMI: Kg/m2). He was in good health and has no evident illness or pains. The 3D scanning system provided more than one hundred measurements and a set of point cloud data of him. This study was mainly based on his data to present the research methods and ideas.

3D model data processing
The Human Solution software can be used to optimize the raw data of 3D human body, such as filling tiny holes and smoothing the small holes. Geometrical 3D torso had been cut for in-depth analysis and modeling, as shown in Fig. 1 from front and back view.

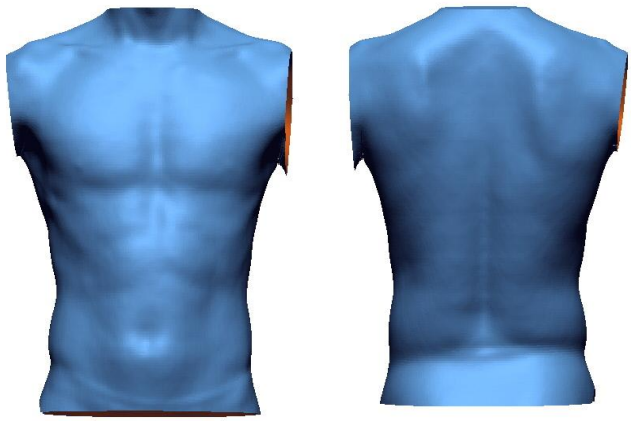

Fig. 1: 3D model: (a)Front of torso, (b) Back of torso.

Measurements data analysis
The traditional computer aided design technology in the fashion industry makes use of the measurements from 3D body scanning system for clothing manufacturing. In addition, the ergonomic researchers and designers work on them for human body shape, size and related standards and product development. Thinking from another perspective, differences in body size and body shape may probably reflect health information and potential risks. According to the length measurements of hands in Tab. 1, all the left lengths are longer than right lengths. In contrast, the girths of right upper arm, elbow, forearm and wrist are bigger than those of the left in Tab. 2. The upper arm diameter of the right hand is 10.8cm comparing to the left hand's 9.7cm.

Items	*Right*	*Left*
Arm length	59.3	63.1
Upper arm length	32.5	34
Forearm length	26.8	29.1
Arm length to neck	73.9	77.8
Arm length to neck back	80.9	84.6

Tab. 1: Length Measurements of hands.

Items	*Right*	*Left*
Upper arm girth	27.6	25.6
Elbow girth	25.3	24.1
Forearm girth	26.5	24.3
Wrist girth	15.6	15
Upper arm diameter	10.8	9.7

Tab. 2: Girth and diameter measurements of hands.

Spatial data analysis of 3D model
By observing the body shape of the subject from three-dimensional space, as shown in Fig. 2(a), the left upper back is quite different from the right, particularly in the scapular region. From the top view of the back, the bulge position and curve of the back are asymmetrical.

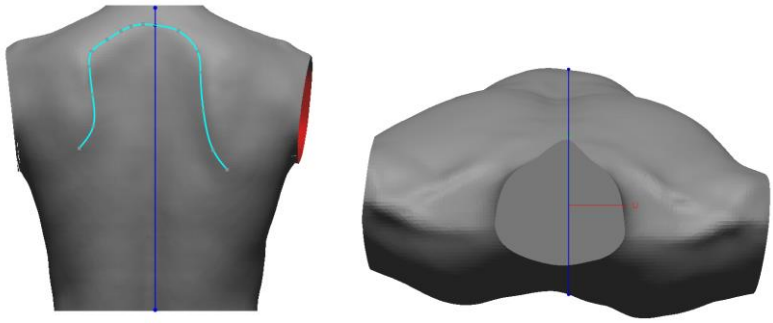

Fig. 2: 3D model: (a)Front view of the back, (b) Top view of the back.

Thermal images analysis of torso
2D Thermal images of the subject can be analyzed and presented by FLIR software system ResearchIR. From Fig. 3, the skin temperature of the right shoulder region is above that of the left. The location of the right deltoid muscle has the same condition. The left external obliques has bigger area of dark red which also means the higher skin temperature than the right. In addition, there is an abnormal high temperature area near lumbar spine indicating potential injuries.

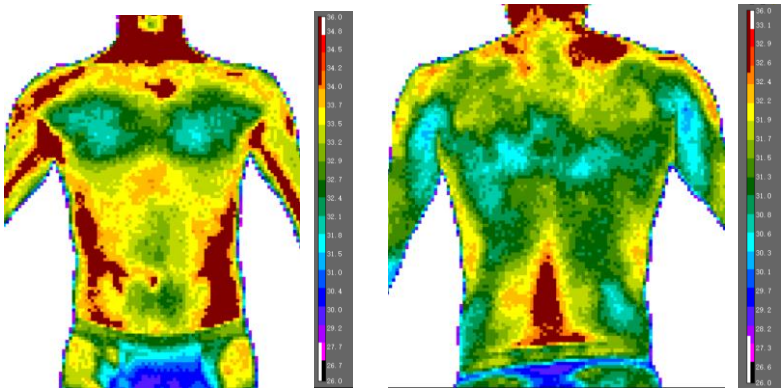

Fig. 3: Thermal images: (a)Front of torso, (b) Back of torso.

Thermal images analysis of hands
As shown in Fig. 4, the front region of deltoid and bicipital muscle of the right hand has a higher temperature area than the left hand. In Fig. 5, both the position of the whole back forearm has a greater temperature, and the right forearm seems more dark red areas.

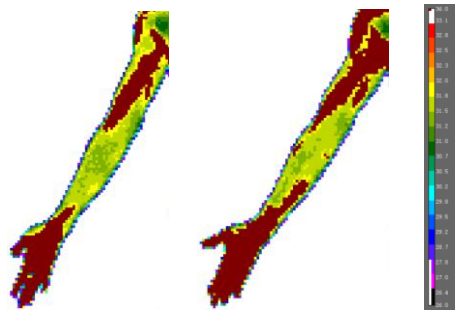

Fig. 4: Thermal images: (a) Front of left hand (mirror image), (b) Front of right hand.

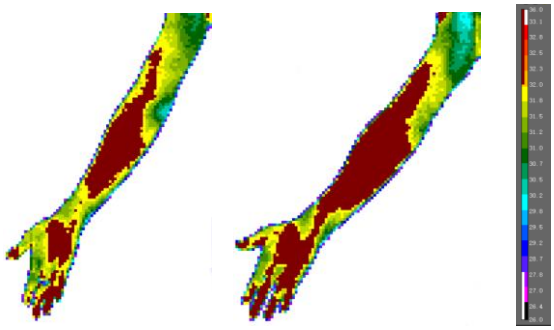

Fig. 5: Thermal images: (a) Back of left hand, (b) Back of right hand (mirror image).

3D Customized Thermal Human Model Design:
The human body is an integral system, and its inherent genetic characteristics and acquired behavior determine its physical and physiological performance [8]. Based on the previous data analysis, body measurements, spatial morphology and thermophysiology of the human body has probable mutual verification relationships. As the subject was a tennis coach, he had used the right hand for this movement for years. The related muscle group had higher frequency utilization than the left one which showing bigger girths related to right hand and diameter of right upper arm, higher skin temperature connecting to those positions of the muscles. From a biomechanical point of view, long-term pulling from the right hand potentially caused obvious morphological changes on the torso which would be at great risk of health [9] [10]. These data interpretation would be used to remind the health awareness and bring forward rehabilitative and protective product development.

3D Customized Thermal Human Modeling
A 3D customized thermal human model had been constructed in Geomagic Design X which presents a true two-dimensional skin temperature distribution on the three-dimensional digital human body, as

shown in Fig. 6. As all of the geometric and physiological data are obtained from the human body, this model helps to mirror the unique features of body shape, spatial dimensions and real time skin temperature distributions. This model provides a quantitative observation of asymmetry or abnormal shape of the human body which would indicate inappropriate postures, occupational injuries and poor habits leading to future possible diseases.

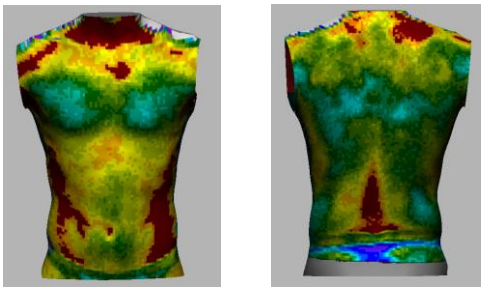

Fig. 6: 3d customized thermal human model:
(a) Front view, (b) Back view.

Conclusions:

Interdisciplinary research on 3D anthropometry and thermography has identified their potential relevancy relating to health. The virtual model carrying actual physical and physiological expressions of the human body can play a role of visualized 3D health platform for individuals, doctors and ergonomic product developers. Especially for healthy or sub-healthy people, this model helps to monitor body abnormalities and trends of potential disease for health and wellness. When developing wearable, functional and rehabilitative equipment, it provides accurate physiological and pathological digital data basis from visual dimensions which can be effectively input to 3D design process and adapted to rapid prototyping and manufacturing. The research had expanded the boundaries of the theoretical system and application of 3D thermal functional human modelling.

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