Title:
3D Thermal Human Model (T_i-model) Design for Female Individuals of the Physiological Functional Clothing Approaches

Authors:
Huang Chao, chao@szu.edu.cn, Shenzhen University
Ameersing Luximon, Ameersing.luximon@polyu.edu.hk, The Hong Kong Polytechnic University
Kwok-Wing Yeung, kwyeung@cita.org.hk, Clothing Industry Training Authority

Keywords:
3D Thermal human model, human modeling, 3D body scanning, functional human model, functional clothing design, T_i-model

DOI: 10.14733/cadconfP.2017.440-444

Introduction:
Nowadays people with foresight prepare themselves in case of sub-health and ageing problems, pay increasing attentions to healthcare. Comparing with taking chemical medicine, physical treatment and rehabilitation may have less concern of side effect for some diseases. The daily wearing clothing is like the second skin of the human body, which may play an important role of medicine in the near future as the fast developments of wearable functional products and applications [5],[10]. For functional clothing developers, when the clothing acts as medicine, accurate, specified and individualized fashion design process should be adopted as applying medicine according to individuals' indications. The matching techniques should be considered throughout the whole developing cycle, such as fashion design, pattern design, garment manufacturing, fitting and revisions [1],[3],[12]. A 3D digital functional human models conveying physiological features of each individual is necessary which can visualize and quantify the function design steps from diagnose to functional clothing development.

Due to the physiological importance and close relevance to clothing, pilot studies had been done to create thermal functional human models. Basic thermal human model had been built up, which was based on surface anthropometry and infrared thermography techniques [8]. As the thermal images present the complicated temperature codes of the human body, further data interpretation of infrared data would discover more physiological information for individuals and provide quantified physiological properties. This study was focused on skin temperature physiological distribution information interpretation for thermal functional clothing development based on female subjects, aiming to put forward the model to new stage.

Main Idea:
Experiments
In the experiment, all the data was gathered under thermoneutral condition. The temperature was 24±1˚C, the relative humidity is 60±5% and the air velocity was less than 0.1m/s. This environment would be relatively stable and reduce the heat exchange with the subjects. The Human Solution 3D Body Scanning System with scanning components, controlling computer and customized software and a portable IR camera with supporting adjustable tripod (resolution:160 x 120 pixels, 19,200 pixels of each pictures.) were used in the experiments. The six healthy female subjects wearing only panties and bra, were scanned by 3D body scanner system and captured by an infrared camera in a static body posture according to the requirements of the 3D body scanning system and the measuring specifications of ISO 7250 and ISO 8559. A set of 3D whole body with cloud point data of each subjects

was acquired, see Fig. 1(a) and (b). Whole body thermal images from front and back views of all of the subjects were captured referring to Fig. 1(c) and (d).

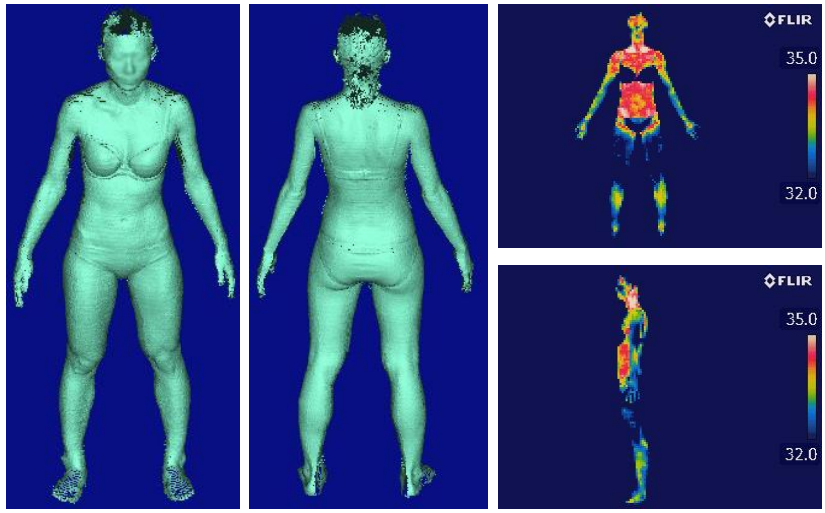

Fig. 1: Examples of original data from the experiments. The original 3D scanned data are the left two pictures. (a) Left one is front view, (b) Left two is back view. The original thermal pictures are the right two pictures. (a) Top one is front view, (b) Bottom one back view.

3D Data pre-processing
As shown in Fig. 1(a) and (b), the raw data from 3D body scanner had noises and minor technical faults [9], the 3D data of each subjects need to be aligned, data cleaned and smoothed with assisted tools such as 3D design software. In this study, Scanworx software of the Scanning system was adopted to pre-process the original data. After this procedure, the surface of each 3D data was presented smoothly. This is the basic 3D geometric model (G-model).

Thermal data interpretation for physiological approaches
The skin temperature distribution is a basic physiological feature of the human body which indicates the thermal physiological condition of a human body and can be utilized as guidelines for developing thermal related functional clothing [2],[4]. For example, the sportswear in warm or hot environment may need more considerations on quick heat transfer from the body to external environment to protect athletes from the danger of heat hyperpyrexia [11]. The skin temperature images captured by infrared camera provide visualized understanding from two dimensions. The graphical utilization of original thermal images may not fully interpret the temperature code of the whole body. As results of each pixel presenting a temperature point captured by a thermal sensor, based on the temperature data set of each subject, the thermal imaging data was further programmed by mathematical software Matlab to reveal the distinguishing features of the skin temperature distribution. By means of the programing following the flow chart in Fig.2, further interpretation of the thermal images were obtained.

This step redefined the original IR data set with customized mathematical expressions. The skin temperature points/pixels of each subjects were located in the 2D coordinate system with X and Y value. T_{sk-fij} and T_{sk-bij} represent the front and back skin temperature at (X_{sk-fij}, Y_{sk-fij}) and (X_{sk-bij}, Y_{sk-bij}) coordinates respectively . i is the number of the subjects. j is the skin temperature point(pixel) of the subjects. This process is an important step to interpret thermal physiological status of the human being with customization and quantification aspects. By respectively running the program with the original temperature data sets of the whole body of each female subject, the thermal

image results were plotted, as shown in Fig.3 for front view and Fig.4 for back view, with a temperature bar ranged from 30˚C to 35˚C simultaneously appearing with a color bar from dark blue to dark red.

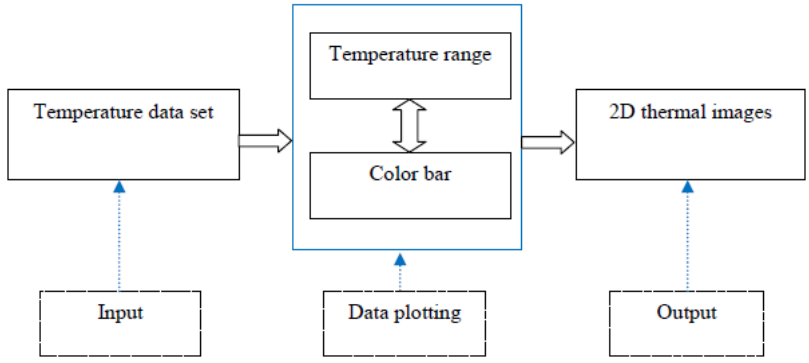

Fig. 2: The flow chart of thermal data interpretation for physiological features.

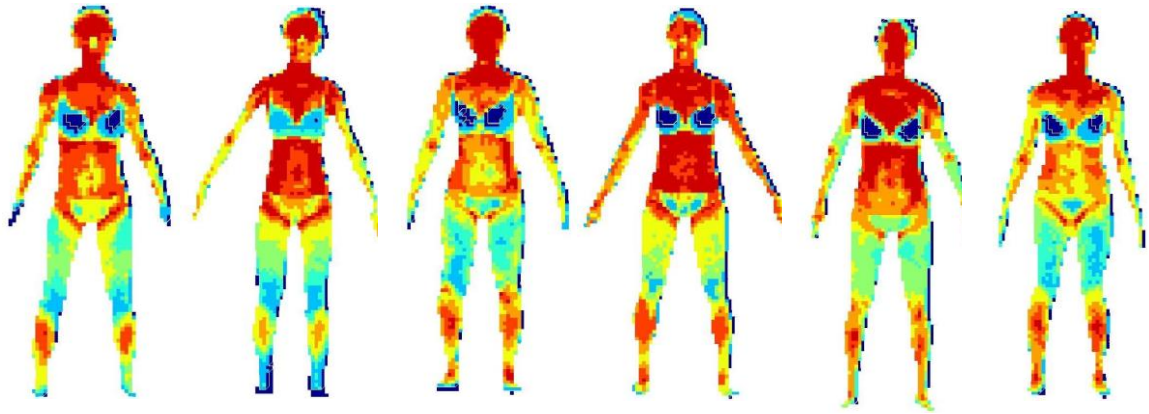

Fig. 3: Thermal data interpretation, front view (temperature bar: 30˚C to 35˚C).

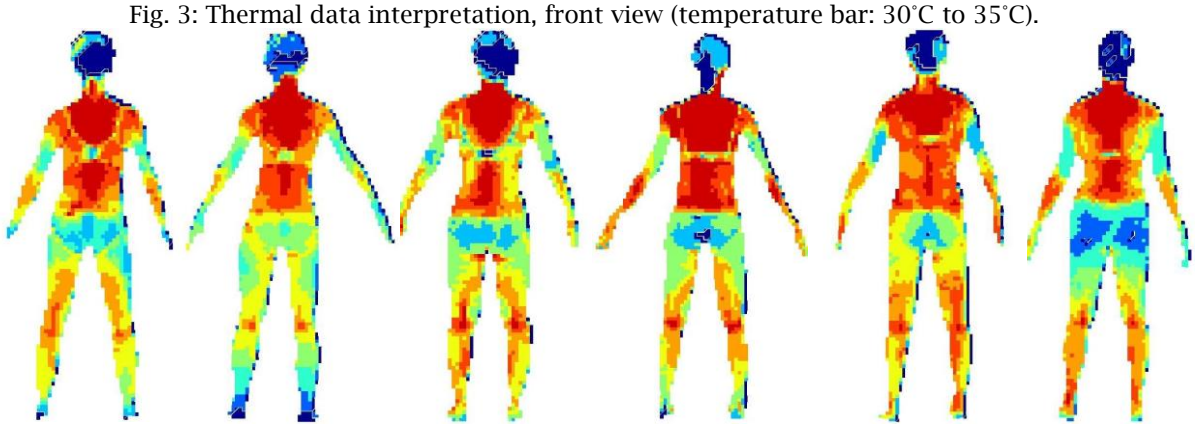

Fig. 4: Thermal data interpretation, back view (temperature bar: 30˚C to 35˚C).

From Fig. 3 and 4, the skin temperature distribution of the female subjects could be observed. All of the subjects had higher skin temperature located on the head and torso, which involved the major

yellow and red areas. The upper limbs and lower limbs had more colors shown in light blue, blue and dark blue which presented lower temperatures. Besides, the skin temperature distribution in the torso and the limbs is physiologically distributed and corresponding to anatomy mapping. As the plotted results of IR data is in 2D visualization and redefined with mathematical language, this process is important for thermal human modelling with physiological functional clothing approaches.

3D Thermal human model (T_i-model) design for female individual

The thermal modelling process was to map the customized plotted 2D thermal image to the 3D Gi-model by means of projection techniques [6-7] from 2D pictures to the 3D object. A commercial 3D design software Rapidform with projection functions was utilized to complete the mapping process including five steps, inputting G-model, data orientation, loading IR texture, creating anatomical corresponding points and operating the texture mapping function. [8] As seen from Fig.6, the results of T_i-model had been created with accurate physical information such as size, surface and volume as well as quantified thermal physiology data, which can be clarified easily adopted for normal functional clothing design and manufacturing.

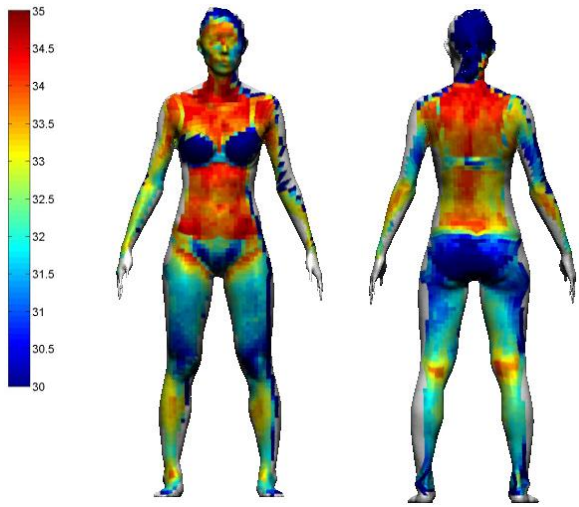

Fig. 5: T_i-model: front and back (female's whole body).

Conclusions:

As shown in Fig.6, the T_i-model can act as an accurate data platform with physiological functional clothing approaches. When developing thermal functional products, an individualized and dimensional based approach to the skin temperature distribution is necessary and can be more specified for the design, manufacturing and effect evaluation process of the functional products, which cannot be replaced by the simulation results based on ideal thermal transport formulas. The customized functional clothing may have more comprehensive applications with the high quality and refined design and manufacturing process.

Acknowledgements:

This study is supported by Guangdong Natural Science Funds for PhD Startup Project. Great thanks have to be expressed to the Hong Kong Polytechnic University.

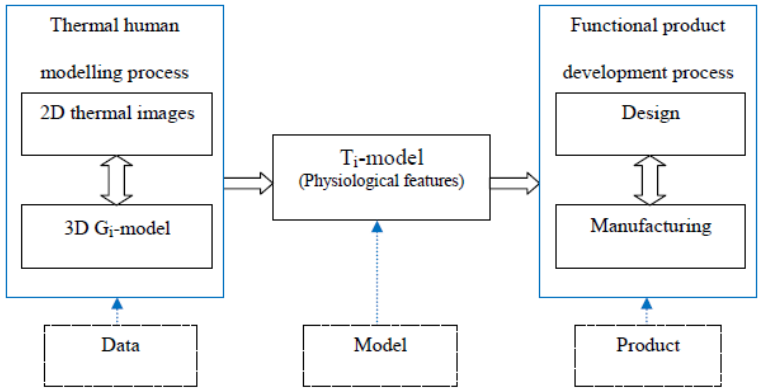

Fig. 6: The application of T_i-model with physiological functional clothing approaches.

References:

[1] Beazley, A.; Bond, T.: Computer-aided pattern design and product development, Blackwell Publishing Ltd, Oxford, UK, 2003.
[2] Blatteis, C. M.: Physiology and Pathophysiology of Temperature Regulation, London: World Scientific, London, UK, 1998.
[3] Burke, S.: Fashion Computing: Design Techniques and CAD, Burke Publications, London, UK, 2006.
[4] Cena, K.; Clark, J. A.: Bioengineering, Thermal Physiology and Comfort, Elsevier Scientific Publishing, New York, NY, 1981.
[5] Chowdhary, U.: Functional Clothing, Body Comfort, and Special Needs, Central Michigan University, Mount Pleasant, MI, 2002.
[6] Haeberli, P.; Segal, M.: Texture mapping as a fundamental drawing primitive, Fourth Eurographics Workshop on Rendering, 1993.
[7] Heckbert, P. S.: Survey of texture mapping, IEEE Computer Graphics and Applications, 6(11), 1986, 56–67. http://dx.doi.org/10.1109/MCG. 1986.276672
[8] Huang, C.; Ameersing L.; Kwok-Wing Y.: Functional 3D Human Model Design: A Pilot Study Based on Surface Anthropometry and Infrared Thermography, Computer-Aided Design and Applications, 12(4), 2015, 475-484, DOI: 10.1080/16864360.2014.997644
[9] Luximon, A.; Huang, C.: Shape Modeling: From Linear Anthropometry to Surface Model, ACHI 2013, The Sixth International Conference on Advances in Computer-Human Interactions Nice, France, 2013, 420–425.
[10] Mattila, H. R.: Intelligent Textiles And Clothing,Woodhead Publishing, Cambridge,UK,2006.
[11] Shishoo, R.: Textiles in Sport, Woodhead Publishing, Cambridge, UK, 2005.
[12] Zhang, M.; Hou, D.; Zhou, A.; Yoshio, S.: Three Dimensional Simulation and Pattern Making of Collar Using Geometric Model. Journal of DongHua University, 18(3), 2000, 53-57.