Virtual 3d thermal human modelling

In recent years, with the revolutionary changes and remarkable innovations on functional and intelligent materials, a growing trend on functional and smart wearable products have been introduced and accepted by the market. Clothing is one of the most common branches. For some fit or tight fit functional clothing, more design elements on human anatomy, physiology, pathophysiologic and biomechanics have been undertaken by them to enhance the special functions such as body protection, recovery, rehabilitation, treatment, shaping and performance enhancement.

Mannequins, as one of the efficient design tools, also known as human model, arefrequently-usedby fashion designers, patternmakers and manufacturers, which equip them with tangible or virtual 3D model. Besides, digital 3D human models are increasingly adopted to enhance the efficiency and sustainability in these human centred disciples. Geometry human model (G-model) presents the basic dimensional information of human body. In front of these new revolutions on design and technology trends, the traditional G-model may not respond well to the emerging new requirements on design and manufacturing progress of functional clothing. The digital human body applied to fashion and functional design and manufacturing need be endued with more efficient information of the human body. There is a necessity toward launching functional human model, as an accelerating, enhancing and inspiring tool for fashionable and functional product design, especially for functional clothing design.

Body temperature is a vital feature of human beings, which indicates the comfort and health status of the human body. As a heat transfer system, human body requires well-balanced thermoregulatory control loop. Clothing

is often regarded as the second skin of the human body which can fulfil the functions of balancing the heat and moisture conditions and thus provide thermal comfort.

Besides, problems like sub-health and ageing population gradually attract more attentions on healthcare. Due to the significant importance of body temperature in indicating the pathophysiologic features of the human body as emphasized by medical researchers in clinic, functional clothing with thermal functions like rehabilitation and treatment will be a meaningful, practical and innovative functional product to take care of the human body, like a special wearable medicine.

Science and technology are changing the life of the human beings. Unquestionably, functional and smart products are the ongoing trend for the future. The thinking of the insiders, like researchers, designers or product developers, must be progressive with the tidal current of advances in science and technology.

To develop thermal related functional products, a visualised and quantified human model is essential and prerequisite. Without accurate and reliable thermal information revealing the inside secrets of the human body, the process of functional product development is like that a blind man feels an elephant. Aworkmanmustsharpenhistoolsifheis to dohisworkwell. There is a knowledge gap and a tool absence for accurate and visualised functional design and manufacturing. To launch the thermal human modelling (T-model) is a far-sighted and necessary step.

With the rapid developments of medical imaging and anthropometric technology, 3D body scanning and 2D Infrared thermography (IRT) provide relatively accurate and visible information of the human body, which help to further understand human body from physical, physiological and pathophysiologic aspects. 3D body scanners, as instruments to capture the whole body and create a set of dimensionally accurate data, are widely used in many areas, such as human modelling and human-centred product development in fashion industry. IRT has been used as an effective and non-invasive medical diagnosis tool, which helps to monitor the skin temperature distribution and evaluate the health conditions of the human body in an ocular way. These two facilities lay a solid foundation for the practicability of thermal human modelling.

1. 2 Aims and objectives

According to the knowledge gap and the tool absence for accurate and visualised functional design and manufacturing, besides the practicability based on the increasingly advanced medical imaging and anthropometric technology, five major aims and objectives of the research had been set up as shown from a to e.

- An in-depth discovery of the potential relationship among physically anthropometric parameters and physiological properties like body temperatures.
- A systematic approach on constructing visualised, quantified and individualized 3D thermal human modelling (T_i-model) with physiological features.

- A systematic approach on constructing visualised, quantified and individualized 3D thermal human modelling (T_i-model) with pathophysiologic features.
- Averaged 2D thermal images to be comparable with individual's IR images to detect the invisible abnormity of individuals for healthcare and diseases monitoring.
- 3D thermal human modelling (T_a-model) to be comparable with T_i-model to detect the invisible abnormity of individuals for healthcare and diseases monitoring.

1. 3 The significances of the research

This study will provide brand new and far-sighted solutions for the accurate accomplishment of functional products development, in special for functional clothing, with quantified and visualised T-models. The multi-disciplinary research broadens the field of vision for the human being and presenting the connections of physical, physiological and pathophysiologic features from aspects of statistics, 2D and 3D. The significances of the research are to be made in two aspects.

For theoretical foundation, this research will built up a linkage between physical and physiological features of the human being which can awake the thinking on further quantitative between them and providing advisable index in functional design application. Besides, this study will advance the knowledge on the commonality of the skin temperature distributions of the human beings, which have great meaning for physiological study, clinic diagnose and ergonomic design applications.

For individual applications, this new model can be applied to functional product development. Especially for functional clothing developers, they will be able to do 3D functional design, 3D pattern making and virtual fitting in an accurate, efficient and traceable way. In the times of 3D printing technology, it is an indispensable tool and platform for the antecedent parties in healthcare areas.

1. 4 Research methodology

A multidisciplinary methodology crossover thermal physiology, medical diagnose, computer graphics, ergonomics and functional design is adopted to accomplish the aims and objective of the study. The medical imaging and anthropometry technology help to acquire physical and physiological data of the human body from individual experiments. From the viewpoint of statistics, 2D and 3D dimensions, generalization and individual approaches on human thermal properties are to be analysed by means of statistical software, mathematical programming software and 3D design software.

1. 5 Thesis organization

This study has been conducted in the background stated above. The overall organization of this thesis is shown in Figure 1-1.

Chapter 1 is the general introduction of the whole thesis including the background the research, aim and objectives of the research, significances of the research and research methodology.

Chapter 2 is the theoretical foundation of the whole thesis including the literature review on two emphasized and carried out research areas, human

thermal function and clothing, and 3D human model applied to Computer Aided Design in fashion industry.

Chapter 3 introduced the research methodology of this study. The developments of medical imaging and anthropometry technology, an in-depth and specific foundation had been taken to further understanding human body in physical and physiological aspects. The computer graphic technology provided dependable software and tools to achieve the desired research aims and complete the interdisciplinary research.

The employment of the data acquired from the individual experiments were introduced in Chapter 4, 5 and 6 which constitute a systematic understanding platform of the human body from the viewpoint of statistics, 2D and 3D dimensions, universality and individuality on thermal properties.

In Chapter 4, statistic analysis by means of correlation analysis and Principal Component Analysis (PCA) were conducted to find out the relationship among anthropometric parameters and body temperatures, which built up quantified connections of physical and physiological features of the human beings.

Individualized thermal human modelling methods and results were introduced in Chapter 5. In this chapter, systematic introductions and illustrations were presented step by step on how to construct a T ¡ -model with physiological and pathophysiologic features. The first step was to pre-process the 3D body scanning data including data alignment, data cleaning and component selections. Simultaneously, skin temperature data sets were pre-processed by plotting into 2D thermal images with physiological or

pathophysiologic features by mathematical programming. The last step was thermal model construction. The 2D thermal images with physiological or pathophysiologic features were projected to 3D human body and the corresponding T_i-model with physiological or pathophysiologic features was created. This chapter was to quantify and visualise the invisible body code conveyed by the skin temperatures in the aspect of three-dimension and individualization.

Chapter 6 introduced the studies on distribution regularity of skin temperature from two dimensions with averaged IR images and its application on three-dimensional thermal human modelling (T_a-model). In the programming environment of Matlab software, mathematical calculation and anatomical landmarks of the human body were combined to find out the regularity of skin temperatures distributions of the human beings. The mapping process from 2D IR images to 3D individual G-model created T_a-model. The examples of comparing with individual's IR images and T_i-model had been presented, which helped to detect the invisible individual differences for healthcare and diseases monitoring. This research progress bridges over the gap between science research and technology applications on thermal studies with quantified and visualised methods.

Chapter 7 were the conclusions of the works and the suggestions for future research work were brought forward. Bibliography and Appendix I to V for previous chapters were sequentially attached behind Chapter 7.