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HUMAN-CENTRED DESIGN BLENDING SMART TECHNOLOGY WITH EMOTIONAL RESPONSES: CASE STUDY ON INTERACTIVE CLOTHING FOR COUPLES

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Abstract

Following the further development of the Internet of Things (IoT), rapid dissemination of smart clothing will begin. Previously, researchers have generally focused on high-tech approaches to implementing smart clothing design, with some success. Nevertheless, the complex sociological aspects of clothing, i.e., its interactive symbolism and properties of emotional expression, should not be ignored. In this paper, interactive clothing for a couple is used as a representative example to investigate the “why, how, and what” design principles, with a human-centred bias. Focusing on blending smart technology with emotional responses, LEDs and range sensors are integrated into prototype clothing design, both design and engineering concepts are employed in the interactive clothing development process. Adjective pairs extracted via a semantic differential method are used for a kansei evaluation. Then, the emotional structure underlying human clothing-related behavior is examined. The development of interactive clothing to date is summarized, along with further perspectives and actions required to proceed from the present development stage of 1.0 to stage 3.0.

Keywords: Design methodology, Design engineering, Evaluation, Interactive clothing design, Emotional expression

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1 INTRODUCTION

Applications of intelligent forms of networking have been extended to apparel product planning and marketing at all levels, to bring more value to the apparel industry and to contribute to its industrial development. Smart clothing is a key component of this revolution, while advanced sensor interfaces constitute compelling new technology that is rapidly being disseminated. Considerable interest is being generated by the remarkable functions of carefully crafted smart clothing (Barfield, 2015; Cho, 2010).

In the exciting and rapidly developing field of smart-clothing technology, researchers have generally focused on high-tech approaches to implementing smart-clothing design, with some success (e.g., Bahadir, 2013; Kan, 2015; Schüll, 2016; Dunne, 2005; Perovich et al., 2014; Wright and Keith, 2014). Nevertheless, the complex sociological aspects of clothing, i.e., its interactive symbolism and properties of emotional expression, should not be ignored.

As a necessity of human life, clothing has six-dimensional sociological properties: (1) providing modesty and protection; (2) increasing warmth and comfort; (3) displaying logos; (4) reflecting a certain level of technological development; (5) conveying certain social and cultural connotations; and (6) facilitating communication and expression (e.g., Gilligan, 2010; Kittler et al., 2003; Toups, 2011; Reed, 2007; Hsu and Burns, 2002). With improved quality of life, individuals tend to focus on emotional wellbeing and social interaction. Clothing is one symbolic medium allowing individuals to communicate with the outside world (Hsu and Burns, 2002; Kaiser, 2006). To develop smart clothing, the use of advanced technology has been investigated; however, the principles of human-centred design and human emotional expression through the apparel medium (Baurley, 2004) should not be ignored.

The aim of this study is to consider three human-centred design factors for the design of interactive clothing for couples (see Figure 1), i.e., the “why,” “how,” and “what.” 1. Why: This factor investigates the reasons why smart clothing should satisfy technical functions and human emotional expression simultaneously. 2. How: This factor investigates the manner in which artistic design perspectives and engineering methods can be effectively combined, blending emotion with smart technology in the form of interactive fashion innovation. 3. What: This factor refers to the approaches used to conduct the research. Interactive clothing for couples was selected as a representative example based on the results of a survey, as explained below. Using these three design factors, a prototype design is developed for the given case study and the *kansei* evaluation method is employed, constituting an experimental demonstration of a futuristic human-centred interactive clothing design.

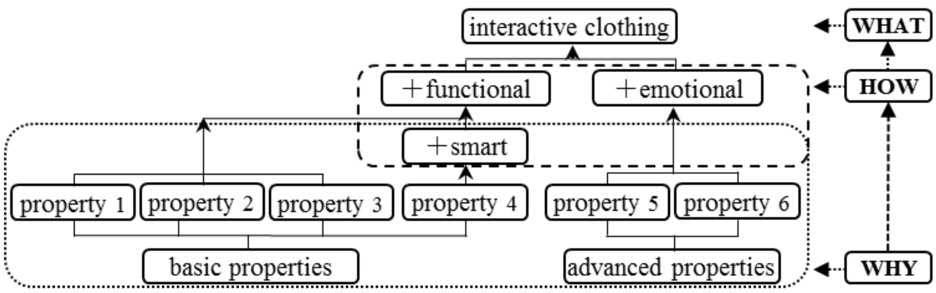

Figure 1. Sociological properties of clothing and R&D direction

2 DETERMINING THE EXPERIMENTAL PROTOTYPE

Product design should be combined with consideration of the future market demand. The future main target consumers of smart clothing are expected to be college students and other young people. According to a questionnaire-based survey distributed to 369 students of two colleges in Dalian, who were studying one of five disciplines (artistic design, materials science, literature, management, or information science), the demand rate for interactive clothing for couples was found to be more than 55%, which is significantly higher than the demand for other types of clothing (see Figure 2). Note that the survey participants were asked to select from the main functional categories of smart clothing: (a) medical-care clothing; (b) interactive clothing for couples; (c) sports monitoring clothing; and (d) nocturnal road-safety clothing. Based on the findings, option (b), i.e., interactive clothing for couples, was selected as the experimental prototype.

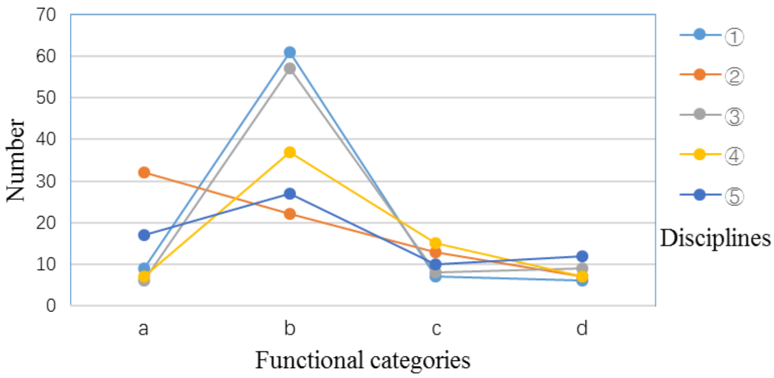

Figure 2. Survey data for prototype selection

3 HYPOTHESES AND METHODOLOGY

3.1 Hypotheses

H1. Interactions may occur between two or more items of smart clothing.

At present, smart-clothing research is focused on the use of clothing to reflect physiological data from the human body, and the majority of individual items of clothing respond to a single person. However, the development of multiple items of clothing worn by different individuals and having a mutual reaction relationship should also be possible.

H2. Interactions between items of smart clothing can be well matched with the emotional relationship of the wearers.

If multiple pieces of clothing having a mutual reaction relationship exist, the main emotional responses of the body can be reflected through this relationship. The relationship such as happiness, anger, sadness and joy between wearers can be reflected by smart clothing.

3.2 Design methodology

The methodology employed in this study combines clothing style design, i.e., artistic design perspectives, with information-sensing engineering, i.e., engineering methods. This corresponds to the second design factor, "how," introduced above. Micro-sensor elements are embedded in clothing and effective integration is obtained, such that the clothing worn by two couples exhibits a mutual relationship, as expressed through a connected performance using light-emitting diodes (LEDs) or colour effects.

4 EXPERIMENTAL APPROACH

4.1 Prototype style design

Figure 3. Clothing designs, labelled a–d (from left to right).

The prototype is based on insulating interactive clothing for couples. The clothing items contain cold-proof liners with cotton filling, which can by freely replaced using differently coloured materials. Thus, one item of clothing can exhibit various colours, embodying the concept of energy-intensive design. The prototype design styles can be seen in Figure 3 (labelled a–d for future reference). The patterns are ignored.

4.2 Material selection

4.2.1 Clothing outer fabric and liner filler material

Transparent material is the material of choice for research on technology in fashion design; therefore, the outer fabric of the prototype developed in this study was thermoplastic polyurethane. The liner filler material was a product known as "Wool Felt Poke Fun" in China, which is widely available in the fabric market and could be freely replaced using different material colours.

4.2.2 Sensor material

The sensors were comprised of WH-335-DT and 5050-60RGB (Shenzhen hongqi lighting fixture Co., ltd., Shenzhen) LEDs in the form of flexible flat ribbon that could be bent into any shape. Note that, using a special clip, these ribbons can be fixed in the shapes of various letters or patterns to meet different design requirements. The LED ribbons are quite small, and a unit can be cut to contain only three diodes; thus, these LED ribbons can be easily installed in very narrow parts of clothing. In this study, 5–8 LEDs were embedded in every item of clothing.

A US100(Telesky Electronic Co., Ltd., Shenzhen) ultrasonic sensor module was also used, which has a 5-m non-contact range function for both general purpose input/output (GPIO) and serial communication. Considering the compatibility of traditional code programs and the operating speed, we also employed an STC12C5A60S2(Hongjing tech Co., Ltd., Shenzhen) single-chip microcontroller. This microcontroller has ultra-high speed and low power consumption, and is fully compatible with the traditional 8501 instruction code. A mic-transformer was also required, in order to regulate the operating voltage between the different modules. Note that the above electronic components are widely available in the electronics market and this design is, therefore, suitable for a resource-limited society.

4.2.3 Electronic embedding design

The power supply ① and sensors ② were embedded in the back centre seam of the clothing, using insulated wire hidden in the hem and side seams ③ (Figure 4). The above materials and the *kansei* evaluation described below correspond to the "what" design factor presented above.

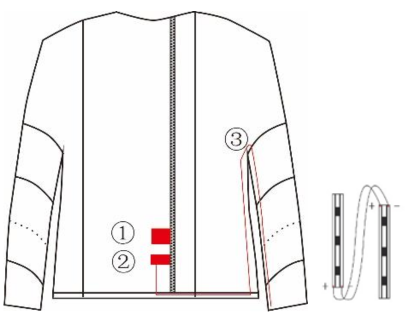

Figure 4. Electronic embedding design (style a)

5 RESULTS AND DISCUSSION

5.1 Realizing interaction between two clothing items

The interactive clothing was proven to correlate well with human emotional expressive patterns (Figure 5). When the distance between two individuals wearing the prototypes was reduced, the LEDs embedded in the two clothing items gradually illuminated. The illumination became apparent at a separation of 4.5 m, with full brightness being obtained when the wearers were separated by less than 1 m.

Figure 5. Photographs of prototypes. (left) Style a. (centre) Style b. (right) Styles c and d.

5.2 Kansei Evaluation

We used the semantic differential method to analyse the effects of the interactive clothing on the psychological responses of wearers. Several emotion models exist. For example, Larsen and Diener (1992) have developed a model divided into eight categories (a–h), which can be applied to both active and inactive smart clothing: a, arousal; b, excitement; c, joy; d, fun; e, composure; f, laziness; g, sadness; h, anger. We employed this eight-way split model as an evaluation reference to consider the relationship between the emotions of the wearers and the clothing worn by various couples. Each emotion was quantified as a value within the range of 1−10, using fuzzy inference.

We conducted a survey evaluation experiment under activate and inactivate range conditions for the LED sensors embedded in each couple's clothes. 34 students participated in this experiment. The survey data for the interactive and non-interactive clothing differed significantly.

In the case of the inactivate range for the LED sensor, Figure 6-1 shows that the main range of the evaluation index fluctuation is within 6. However, for the activate range of the LED sensor, Figure 6-2 shows that the range of the evaluation index fluctuates obviously, with many of the evaluation values reaching the maximum of 10. The average emotion values for the interactive and non-interactive are shown in Table 1. The paired samples *t* test revealed that $P=0.008 \leq 0.05$. From the results of this evaluation, H1 and H2 are validated. This also corresponds to the first design factor, “why,” introduced above.

Table 1. Average emotion values for interactive and non-interactive, for eight-way split model

	a	b	c	d	e	f	g	h
Non-interactive	4.00	5.26	5.59	5.47	4.47	3.50	2.91	1.29
Interactive	5.09	7.82	6.85	8.29	5.62	3.94	3.35	1.50

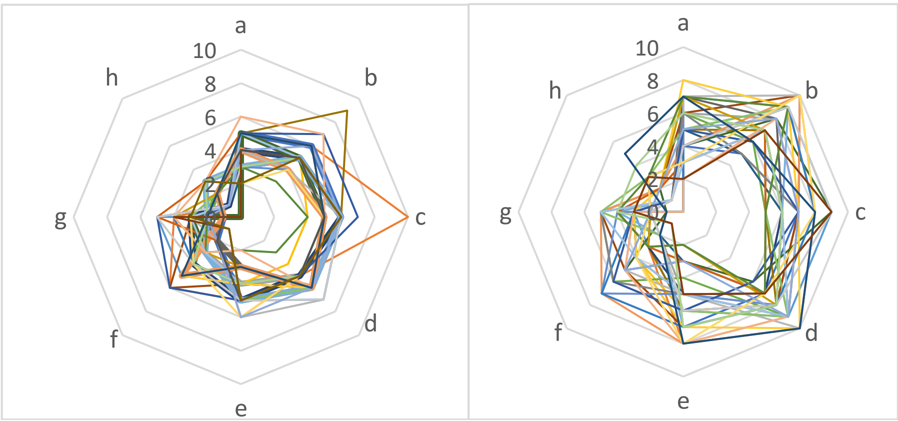

Figure 6-1,2. Results of kansei evaluation of emotional expression

5.3 Expansion of design concepts

5.3.1 Embedding smart technology into clothing

Our experimental prototype was produced using widely available electronic components that were simply inserted into the clothing; however, interactive clothing was still achieved using IoT technology. IoT allows objects in the environment to become active participants in communication, i.e., they share information with other stakeholders of a network. In this manner, the objects are capable of recognizing events and changes in their surroundings and acting and reacting autonomously (Drucker, 2015). Note that the interactive effects and comfort (wearability) of the prototype should be further improved if specialized, advanced, washable, durable, and flexible sensing elements or smart fabrics are developed in the future.

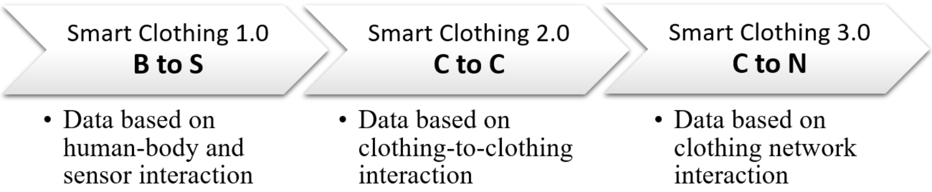

Figure 7. Smart clothing evolutionary roadmap

From an evolutionary perspective, smart clothing has obvious potential applications. The future development of this field can be divided into three evolution stages (Figure 7).

- Stage 1.0: Data on the human-body are obtained via sensor monitoring (B to S). The clothing responds to the human physiology, such as the pulse, temperature, humidity, and even emotional reactions.
- Stage 2.0: The data are based on clothing-to-clothing interaction (C to C). Using stage 1.0 as a basis, mutual reactions between two pieces of clothing can be obtained, such as responses to the mutual distance and other interactive reactions.
- Stage 3.0: The data are based on clothing-to-network interaction (C to N). Using stage 2.0 as a basis, interactions between multiple items of clothing are obtained, allowing the formation of a clothing network.

Both stages 2.0 and 3.0 evolve from stage 1.0, where clothing responses to the human body are obtained; this corresponds to technical extension. The prototypes examined in this study constitute stage 2.0 products. Further challenges and opportunities will be encountered when achieving stage 3.0, as a clothing network is the future research vision. This also corresponds to the second design factor, “how,” introduced above.

Considerable effort from both industry and academia has been devoted to the development of wearable technology and intelligent textiles. Much of the technology employed in this research field is not yet mature, being inconvenient or uncomfortable for the wearer, and only a small number of products have been introduced to the market. However, interactive clothing with advanced sensors is a compelling new technology that will be rapidly disseminated once designers achieve remarkable functionality and carefully crafted products.

5.3.2 Human-centred and emotion-based design

Interactive clothing is designed as a service to the public, rather than to provide items to which individuals must adapt. It is necessary to provide clothing with vitality rather than, simply, embedded IoT technology, if the clothing is to vividly express the wearer’s emotions. Although this is a difficult task, the socially innovative design perspective should be used by deep-thinking designers to identify future subjects (Nagai, 2015). Thus, it is important for forward-thinking designers to embrace this challenge.

The design process for interactive clothing should be human-centred, rather than focusing on technology. Interpersonal communication is the focus of social existence, and for useful technology must to be support socialization (Tao, 2005). Nelson and Stolterman (2012) offered a formulation of design culture’s fundamental ideas, in the design process are applicable to an infinite variety of design domains. Further, Giacomin (2014) has stated that the model of human-centred design is based on a pyramid hierarchy, in which interactive, sociological considerations and the metaphysical meaning contact with the design. Because clothing has a metaphysical attribute, Baurley (2004) has proposed that people can interact with the clothing of others nearby by changing the visual appearance. In the design process, Schutte(2005) and Lee et. al (2002) contributed to balance between functional technology and emotional expressiveness.

The human-centred approach cannot neglect consideration of human emotions. For product design, traditional cognitive approaches have tended to underestimate the user emotions which acts as a critical component of artifact sense making (Spillers, 2004; Rafaeli and Vilnai-Yavetz, 2003). Finally, Wensveen et al. (2002) have designed a mood alarm clock that illustrates the importance of a tight coupling between the emotional level of interaction, and the actual use of such interactive technology.

As shown in Figure 8, we should further investigate the structure of the emotions underlying human clothing-related behaviour, so as to obtain a more inclusive vision of the social psychology of smart clothing. Interactive clothing must satisfy both technical functionality and human emotional expression requirements. In other words, both basic and advanced social properties of clothing must be incorporated.

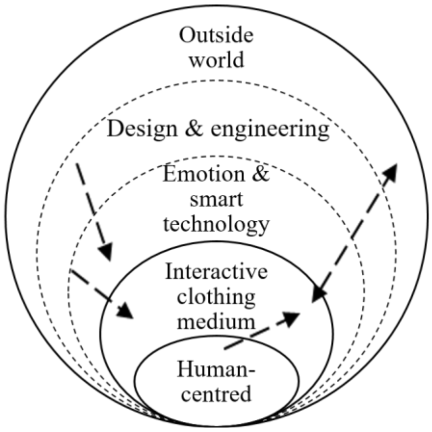

Figure 8. Human-centred R&D process for interactive clothing

6 CONCLUSIONS

In this study, interactive clothing for couples was examined using experimental prototypes. The efficacy of this clothing was then assessed using a *kansei* evaluation. Hence, it was found that the prototypes satisfied the criteria of stage 2.0 of the smart clothing evolutionary roadmap.

For interactive fashion designers, rather than focusing on purely functional behavioural or aesthetic-appeal criteria, emphasis should be placed on blending technological developments in engineering with emotional responses in product design, on identifying artifacts that trigger and mediate emotional responses, and on seeking the emotional structure underlying human clothing-related behaviour.

Artistic design perspectives should be effectively combined with engineering methods during the R&D of interactive fashion products. The primary task of design thinking is to achieve the external aesthetic form without excessive consideration of the technical characteristics of the product. In contrast, the engineering approach aims to realize technological applications without emphasizing the added value or attributes of the product. An effective designer should embrace the opportunities and challenges of achieving interactive clothing evolution from stage 1.0 to 3.0. Such a designer should exhibit both artistic creativity and engineering rigor, integrating design and engineering perspectives, and blending emotional responses with smart technology to achieve interactive fashion innovations.

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