Seasons: Exploring the Dynamic Thermochromic Smart Textile Applications for Intangible Cultural Heritage Revitalization

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Abstract. Smart textiles have attracted great attention from Human-Computer Interaction and this study explored how dynamic thermochromic textiles may contribute to the transmission and revitalization of textile Intangible Cultural Heritage (ICH). We proposed Seasons which is an interactive cheongsam developed as a novel exploration in traditional craftsmanship of Shanghai-style cheongsam and smart textiles. Seasons consists of animated visual patterns including 4 stages, new leaves sprout and flowers from buds to full bloom as demonstrations of spring and summer, while leaves turn yellow in autumn and snow comes in winter. Subsequently, we presented the implementation process, feedback from the inheritors of ICH and visitors in the exhibition. In conclusion, we explored how computational thermochromic patterns may enhance the aesthetic and expression in traditional clothing. There is a great design space for thermal-activated smart textiles and this paper is believed to contribute to the future development of smart textile applications for ICH.

Keywords: Smart textiles · Thermochromic · Intangible cultural heritage

1 Introduction

Craftsmanship is one of the key elements of Intangible Cultural heritage (ICH) [1], and the traditional craftsmanship of Shanghai-style cheongsam has been listed as one of the representative projects of the National ICH in China [2]. Cheongsam is known as the treasure and "living" carrier of the Chinese clothing culture and cherished by people all over the world. However, as many other ICH, it is still facing challenges of keeping relevant and being welcomed by the younger generation. One direction is the

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revitalization through integration in modern products, previous research reviewed how craftsmanship of embroidery, weaving, blue dyeing included in textile ICH can benefit the modern design. While emerging developments within HCI have shown even more potential for solving the challenges, for example the use of immersive reality technologies to offer users new experiences of visualizing and studying the ICH [3]. While another way is the live protection and transmission by connecting ICH to people's life and novel creation based on the traditional craftsmanship. Smart textiles could offer interesting possibilities in relation to textiles crafts in ICH.

Smart textiles and flexible wearable technology are developing rapidly, and they have broad application potentials in future textiles and smart clothing. Current smart textiles have been widely explored as input mediums, such as gesture interfaces [4] and sensors applied in sports and rehabilitation [5], and as output modalities in the interactive systems, for example, thermochromic display [6], embroidered speaker and smart textile-enabled actuators.

Cheongsam displayed unique artistic charm, inspired by the decorative patterns by hand painting or embroidery techniques which are the important embodiment of oriental artistic aesthetics, we explored how thermochromic may enhance the traditional pattern expression, bringing novel interactive experiences and even extending the market by achieving computational color-changing patterns.

This research focuses on the innovative development of textile ICH in Shanghai, adopting cheongsam as a carrier to explore the intersections between textile color-changing technology and traditional craftsmanship in terms of materials, textile structure, production processes, and finally serve as a living inheritance of traditional ICH textiles. Instead of preserving the original craftsmanship of cheongsam, we explored how to revitalize the traditional cheongsam in case of interactive artefacts.

We proposed Seasons, which is an interactive cheongsam with different areas of the decorative patterns which can be activated and show dynamic color-changing effects. With this exploration, we hope to find new methods of promoting the innovative development of textile ICH from the dimensions of intelligence, personalization, dynamics, and fashion which may create novel experience and motivating users to initiate the culture inheritance.

2 Related Work

Color-changing materials are mainly divided into photosensitive, thermochromic, and electro-sensitive types. Thermochromic dyes can change color with temperature changes, while wearable thermochromic technology is programmable so that it has great potential in the application of textiles and smart clothing. Conductive fabric or threads in a particular pattern are often applied as the thermal layer instead of rigid heating elements to keep the textile more flexible.

For example, Social Textiles [7] provided color-changing feedback by the multi-layer structure, which produced icebreaking interaction opportunities among unacquainted, collocated members. Muhammad Umair et al. explored the feasibility of smart materials for developing novel color-changing textile displays for real time visualization of affective data. Chromoskin [8] and Animskin [9] are two cases of thin-film multi-layer

structures which can be applied directly on the skin and can emit dynamic color animations. Other explorations seamlessly coated the conductive yarns with thermochromic pigments. For example, Devendorf et al. explored the effect of dynamic textile display through the design prototypes of seven crochet products [6].

Regarding the traditional crafts-enabled innovation, digital technologies have contributed to the transmission of skills embedded in ICH's, which can secure the protection of traditional textiles craftsmanship. For example, inspired by the traditional craftsmanship of lace making, Kuusk et al. developed a lace structure with active perception and intelligent color-changing textiles [10]. Hsin-Liu Kao et al. [11] proposed a fabric interface with perception and color-changing functions based on traditional weaving techniques.

3 Seasons

3.1 Mechanism

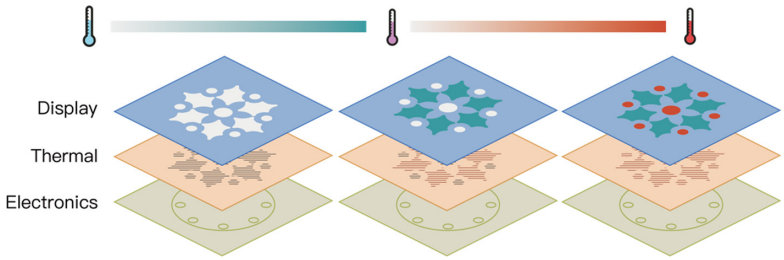


Fig. 1. Three layers structure of the conductive textile-based thermochromic mechanisms.

To achieve the dynamic animation, we adopted the multi-layer structure as shown in Fig. 1. The top layer is the display module where the thermochromic pigments are applied following the graphic patterns. Following is the thermal module where the conductive fabrics or conductive threads are located to heat up the display layer and activate the color-changing patterns. Lastly, the wearable electronics modules which includes sensors and microcontrollers can be embedded or integrated in the normal fabric, to control the activation area and color-changing time.

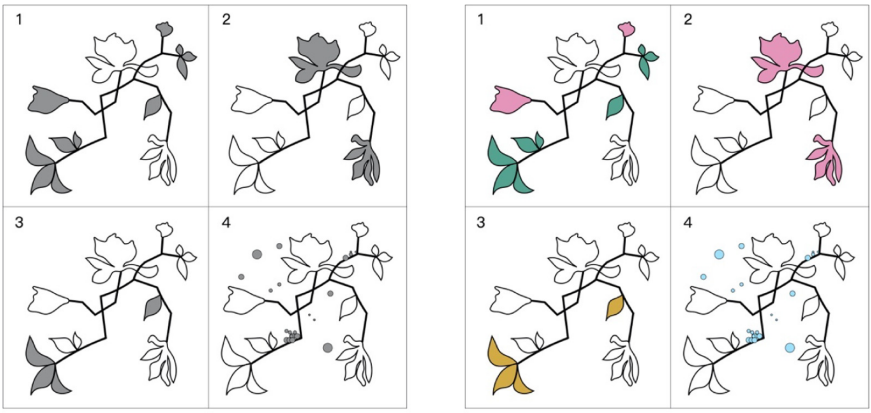
3.2 Design

The interactive cheongsam called *Seasons* (see Fig. 2), is a new attempt to apply color-changing visual feedback textile in Chinese traditional cheongsam, by using the multi-layer structure to provide dynamic and interactive properties for static clothing.

Traditional flower patterns are widely applied in cheongsam design, of which the magnolia is a popular variety and season is also a classical topic in traditional Chinese paintings. To expand the novel experience, we explored how computationally changing thermochromic patterns may enhance the aesthetics and expressive capabilities of the dress. We designed the magnolia pattern and divided the pattern into 4 groups of different areas mapped to the appearance of the flower during the four seasons. Each group can be controlled individually by a custom developed sewable microcontroller to create animated visual patterns (see Fig. 3). The groups are activated sequentially (each of them needs around 5-s fade-in, 10-s on and 20-s fade-out) and the four sections light up accordingly to display the animated patterns. In spring and summer, new leaves sprout and flowers from buds to full bloom, leaves turn yellow in autumn and snow comes in winter.

(a) (b)

Fig. 2. Interactive cheongsam, a) thermochromics pattern are not activated; b) thermochromics pattern are activated.



(a) (b)

Fig. 3. Animated thermochromic patterns in 4 stages. a) Heating up areas in 4 stages; b) Thermochromic pattern in 4 stages.

3.3 Implementation

The developing process of the color-changing cheongsam followed a co-creation process in collaboration with expert craftspeople who are responsible of the traditional craftsmanship of Shanghai-style cheongsam. We try to introduce the technology of thermochromic textiles into the traditional production process at the right time. For example, we created the thermochromic pattern by hand-drawing on the silk fabric pieces cut by experts before dress making. After the basic parts of the cheongsam were made, the heating layer was laid out corresponding to the pattern, and a series of tests have been conducted to achieve smooth animation by identification of the suitable voltage and time. Finally, the cheongsam internal lining was made as a heat insulation layer to embed the circuit layout as well (Fig. 4).

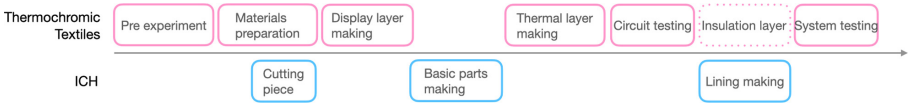


Fig. 4. Codesign process demonstration.

In details, the interactive cheongsam prototype is developed through multi-layer structure consisting of three layers:

1) For the display layer we mixed the thermochromic pigment (activation temperature is 31C) with normal pigments to enrich the color richness and used hand drawing on the silk to preserve the impression of brushstrokes in a Chinese painting;
2) The thermal layer sticks to the display layer, and is based on the EeonTex High-Conductivity Heater Fabric with a resistance of 20 ohms per square inch. The fabric

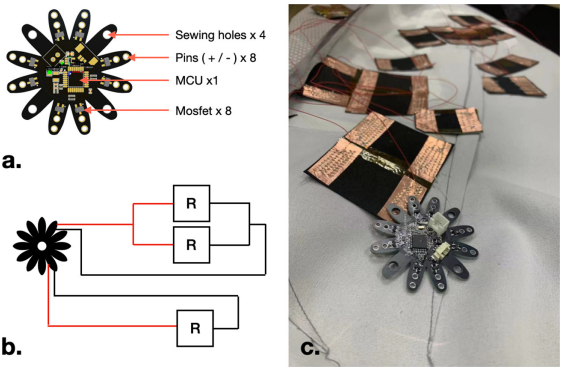


Fig. 5. a) Details of the customized sewable microcontroller board; b) circuit illustration; c) thermal textiles embedded in the dress.

was clipped into the same shape as the pattern (demonstrated in Fig. 3) and the heater fabric is programmable based on the connections to the customized sewable microcontroller. Figure 5a demonstrates the details of the microcontroller and Fig. 5b demonstrates the parallel circuit;

3) Finally, the lining is applied as an insulation layer next to the thermal layer to weaken the thermal stimulations on the skin.

4 Study

Semi-structured interviews were carried out to identify the experts and audience attitudes and acceptance of the interactive cheongsam.

We interviewed 2 experts (PE) of traditional craftsmanship and 8 visitors (PV) when the prototype was displayed in the intangible cultural heritage exhibition area of the second China International Import Expo. Among them, expert interviews were mainly focused on exploring the influence of the combination of wearable technology and traditional handicrafts on its inheritance, innovation and its potential for this application. User interviews were mainly focused on the acceptance and preference of thermochromic cheongsam. After the interviews were conducted, notes were transcribed and a thematic analysis has been performed to analyze the results.

Both experts thought that the combination of crafts and technology is novel and interesting, and they agreed that integration of wearable thermochromic technology and ICH is conducive to the inheritance and innovation of traditional textile craftsmanship. *"Whenever I mention intangible cultural heritage, everyone may feel that it is very old and historical. The integration of color-changing elements is novel and can help attract more young generation's attention…" -(PE 1).* "*This approach is not a concept demonstration, the protection of traditional culture is inherited in an activating and innovative way*" *-(PE2).* At the same time, they expressed their approval and appreciation for keeping the original materials while new techniques are applied, they mentioned the importance of retaining the materials and techniques used in traditional crafts in the future design and production process.

Regarding the audience's attitude and acceptance, all the interviewed visitors expressed their interest in *Seasons*, and most of the visitors expressed their willingness to wear thermochromic cheongsam in their daily lives. Visitors to the exhibition were surprised by the elegant dynamic pattern of cheongsam. Some of them even mentioned *Seasons* may augment their personality and have the potential to show various information. At the same time, they were also curious about the implementation mechanism, and they thought that the circuit board is beautiful and small enough to be acceptable, even exposed on the surface of the cheongsam. While some visitors expressed their concern about power consumption and unsustainability.

5 Discussion and Conclusion

With the aim of providing a dynamic perspective of textile artefact of ICH, we explored how thermochromic smart textile may revitalize the traditional clothing by enhancing the aesthetic and expression. Subsequently, we found that how to design the color-change pattern and implement the animated patterns is challenging as technology and tradition need to bring out the best in each other. Compared with photochromic materials and electrochromic materials, thermochromic materials are more programmable and designable. Thermochromic patterns have great potential for color-changing visual feedback, which can better adapt to different clothing styles and are more acceptable for daily wear because of the non-emissive properties. When using the thermal effects caused by the electrical current to drive the color change, it is necessary to limit the voltage and current within the wearable safety range. The energy consumption of the *Seasons* is large due to the large heating area, while the size and weight of the battery will greatly affect wearability. In the design process, designers should also consider energy consumption to avoid the excessive heating areas.

The cheongsam is a traditional Chinese dress, whose craftsmanship is also listed as an intangible cultural heritage. Combining smart textile technology with traditional manufacturing processes, is not only an attempt of thermal augmented textile in the application of fashion glamor but also an exploration of intangible cultural heritage activation and innovation through enabling technology, the development of textile ICH is an important part of traditional culture. Future work will further explore the integration of thermal-activated smart textiles in interactive clothing and textile products in various applications.

In conclusion, there is a potential design space for thermal-activated smart textiles. Smart textile-enabled dynamic thermochromic mechanisms may enhance the programming ability and pattern creating ability which may contribute to increasing the ability to control the interactivity and aesthetics of textile ICH products.

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