Breathing Clothes: Artworks using the Hairlytop Interface

Masaru Ohkubo
Graduate School of Information Systems,
University of Electro-Communications
1-5-1 Chofugaoka, Chofu, Tokyo, JAPAN
marchalloakbow@vogue.is.uec.ac.jp

Miki Yamamura
Joshibi University of Art and Design
1-49-8, Wada, Suginami, Tokyo, JAPAN
yamamura09014@venus.joshibi.jp

Hiroko Uchiyama
Joshibi University of Art and Design
1-49-8, Wada, Suginami, Tokyo, JAPAN
uchiyama96022@venus.joshibi.jp

Takuya Nojima
Graduate School of Information Systems,
University of Electro-Communications
1-5-1 Chofugaoka, Chofu, Tokyo, JAPAN
tnojima@nojilab.org

ABSTRACT
Breathing clothes are media artworks formed as an application of the hairlytop interface. The hairlytop interface is an assembly of fine, soft and deformable actuators. Each actuator is composed of a shape memory alloy (SMA) and drive circuits. Various types of sensors can be connected to the driving circuits. The actuators can then deform in reaction to surrounding stimuli, including light, sound, and human activity. The high flexibility of this configuration and its unique motion enables us to compose various interface types, such as furry decorated interfaces and new deformable textiles. In this paper, we describe in detail several types of clothes composed of this unique fabric combined with the hairlytop interface. The clothes act based on the wearer's breathing action, which acts as an indicator of the emotional state of the wearer.

Author Keywords
Hairlytop interface; shape memory alloy; soft actuator; haptic; surface display; media art; clothes.

ACM Classification Keywords
H5.2 [**Information interfaces and presentation**]: User Interfaces – *Interaction styles.*

INTRODUCTION
Many animals use their own hair or fur as an indicator of their emotions; for example, bristling hair often indicates anger. This method of expression is also used in cartoons and animations to enhance the expression of emotional poses. For instance, bristling hair can indicate anger, excitement, or surprise. However, this method is not common for human beings. There are indeed hairs over the entire body and they can also indicate inner emotional statements, e.g. as gooseflesh. However, unlike animals, which are covered by this indicator of their emotions, human skin is covered by clothes and the states of the hairs are hard to see. Clothes can provide a great amount of information related to the wearer's social status, personality and beauty. However, they cannot express the wearer's emotional state.

ACE '14, November 11 - 14 2014, Funchal, PortugalCopyright 2014 ACM 978-1-4503-2945-3/14/11…$15.00
http://dx.doi.org/10.1145/2663806.2663860

Normally, communication between humans is conducted by a combination of language and bodily behaviour. However, as the examples of animals and cartoons show, the motion of hair has great potential for use as an emotional display. Unfortunately, humans do not have sufficient hair for such a display, and they are covered by their clothes. Therefore bestowing expression of the wearer's emotional state on their clothes, which are a major part of their appearance, would be synonymous with creation of a new communication channel between human beings.

Figure 1. Two of the series of breathing clothes.

"Breathing clothes" (Figure 1) are a series of artworks composed of kinetic clothes that focus on this issue. In this series, the wearer's abdominal breathing is used as an indicator of their emotional state. These clothes are designed to express the wearer's breathing by waving the kinetic part of the clothing. The kinetic part is composed of the hairlytop interface, which is covered with specially designed textile covers that fit into the concept of the clothes. The hairlytop interface is a system that is composed of a cluster of flexible, filament-like soft actuators [10]. In this project, these soft actuators are used to form the kinetic part of the clothes. The breathing action is detected by measuring the displacement of the wearer's body using a stretch sensor around their waist.

RELATED WORKS

Some researchers and artists have previously developed kinetic clothes [1, 2, 12, 15]. In these works, the kinetic garments have been used for personal expression or for expression of the wearer's emotions. Unfortunately, these previous works emphasized the aspects of the shape-changing structures of the clothes too heavily. When considering expression of emotion, or for future flexibility, sensing of the human state should be considered. Clothes that sense the wearer's state have actually been developed. Eskandar's work expresses the wearer's mood as captured by galvanic skin sensors [5]. The kinetic dress [4] by Cutecircuit measures the wearer's movements and reflects the measured information using an electroluminescent display sewn into the skirt. Along with these works, many other parameters can express the human inner state, including the heartbeat, brain waveforms, and blood pressure. In our study, we focused on breathing for sensing of the wearer's inner state. Breathing is a vital human biological activity, and it changes in response to a person's emotions [8]. Some previous works have also focused on this matter [13, 14]. Unfortunately, while they have formed interactive systems to express the wearer's breathing, the complexity of the mechanisms used to realize kinetic motion limit their future diversity. When designing various kinds of kinetic clothes, the mechanisms that give motion to the clothes should be simple. The hairlytop interface offers a solution to this issue with its simple structure. The filament-like soft actuators of the hairlytop interface can easily be used with various textiles, because of their light weight and simple structures.

Hairs and furs are media used by many animals to express their emotional states. In addition, soft filamentary materials are often used to compose various types of interfaces and artworks. Flagg et al. developed a fur interface that could recognize touch gestures [6]. They focused on emotionally-based touch between a person and a furry social robot. However, the fur system was not shape-changeable. Furukawa et al. focused on fur as an output medium [7]. They developed a new fur system and controlled its bristling using vibration motors and natural fur. Unfortunately, their system requires natural fur because artificial fur cannot produce the required effect. Nakayasu et al. developed a system named "plant", which is an application of their proposed shape memory alloy (SMA) motion display [9]. The plant is composed of 169 artificial leaves made from SMA to represent the rustling of natural leaves

In contrast, the hairlytop interface has a simple structure and sufficient flexibility in its configuration. It should therefore be able to act as a fundamental tool to compose soft kinetic materials such as kinetic clothes.

THE HAIRLYTOP INTERFACE FOR KINETIC CLOTHES

Basics of the hairlytop interface

The hairlytop interface is a cluster of fine and flexible soft actuators, as shown in Figure 2. Originally, this interface was intended to be used as a fundamental material for composition of various types of human-computer interface. To comply with this goal, the lightness and slenderness of each actuator, the flexibility in its configuration and the real-time control method used for the actuators have been subjected to serious study [11].

Figure 2. Composition of the hairlytop interface.

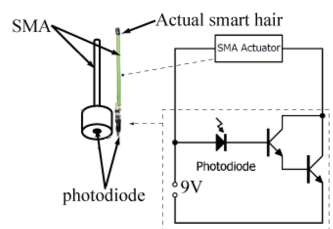

Figure 3. Structure of the soft actuator that was used in the original version of the hairlytop interface.

Figure 3 shows the basic structure of the original version of the hairlytop interface. As shown in the figure, the soft actuator of the hairlytop interface is composed of a silicone tube integrated with fine SMA. The current size and weight of the soft actuator are less than 6 mm and 1 g, respectively, including the driving circuit shown in Figure 3. This soft actuator bends when the SMA is heated. The amount of bending is simply controlled via the amount of current supplied to the SMA, which generates Joule heat. In this original version, the electric current is controlled using sensory information based on the light intensity.

Application of the hairlytop interface to kinetic clothes

When we consider that light-emitting diodes (LEDs) and other light emitting materials are often used in emerging textile areas, it seems quite reasonable to make kinetic clothes using hairlytop interface technology. For example, if clothes have LEDs, the hairlytop interface can easily convert light signals into kinetic motion by simply placing the sensor-integrated filament-like actuators on them.

Our motivation in this project is to develop kinetic clothes that can express the wearer's emotional state. In addition, as previous research shows [8], the state of a person's breathing can be used as a signal for their emotional state. Thus, as the first step of this project, we decided to use a single breathing sensor instead of numerous light sensors. In this project, we have developed electrical systems, including sensors and filament-like soft actuators, based on this concept. We then concentrated our efforts on design for appearance-related issues.

Electrical system design

An overview of the developed electrical system is shown in Figure 4. The wearer's breath is measured by a breath sensor composed of a conductive rubber cord around their waist. This material changes its electrical resistance with the expansion and contraction. When the waist deforms the material during breathing, the amount of variation is sent to the Arduino Nano microcontroller in the circuit box. Considering that the application here is to breathing clothes, it is assumed that the number of actuators will increase and that the hardware should be as simple and small as possible. To meet this requirement, we use the TLC5940 from Texas Instruments, which has 16 pulse width modulation (PWM) outputs. By using this IC, the system can move each actuator independently, corresponding to the wearer's breath. At the same time, modularization to expand the number of actuators is possible.

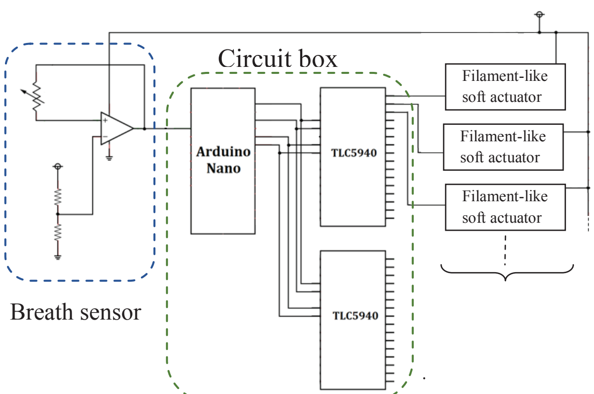

Figure 4. Electrical system design.

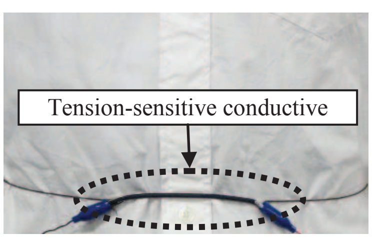

Figure 5. Breathing sensor using variable resistance rubber.

Breathing feather

In this section, we introduce breathing feathers, which form one type of kinetic clothing that uses the hairlytop interface technology. This clothing uses filament-like soft actuators to express the wearer's emotional status in a mild manner through deformation of these actuators. These clothes were developed between November 2013 and March 2014.

Because it is difficult for conventional kinetic clothes to become everyday clothes, we produced novel clothes by virtue of hairlytop interface technology. These feather-type kinetic clothes are designed especially for women. 18 actuator-installed feather garments around a collar move upwards when the wearer draws breath, and downwards when the wearer exhales (Figure 6). Figure 7 shows the feather shaped garment. The garment is 20 cm long and 5 cm wide. The actuator is 15 cm long.

Figure 6. Breathing clothes: feather-type (Left: normal state; right: bristling state).

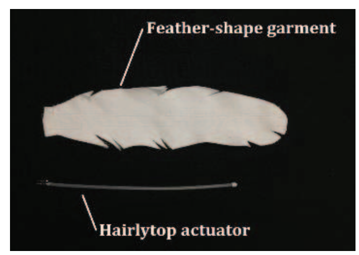

Figure 7. Composition of the feather-shaped garment.

DISCUSSION

Based on our observation of the motions of these artworks, we can confirm that the soft actuators of the hairlytop interface have sufficient potential to be used as an actuator for these kinetic clothes. Issues with regard to flexibility are discussed from three viewpoints below.

Fixation of the actuator

When the clothes expressed the wearer's breath, the unevenness of the actuators became a concern. The cause of this issue is thought to stem from the method of composition of the soft actuators. To form these actuators, the SMA and the silicone tube are assembled manually. We found that the tension applied to the SMA during the assembly process greatly affects its motion performance. To solve this problem, we reviewed the actuator manufacturing process to improve the evenness of their motion.

In addition, actuator fixation problems must also be solved. The problems sometimes affect the comfort of the kinetic clothes. To use the bending motion of the actuators, a fulcrum must to be fixed on the clothes. In the breathing feather case, the collar is used as a fixation point. A collar is slightly stiffer than the rest of the clothes, and thus can be used as a reasonable fixation point that would not affect the wearer's comfort.

Comfort of the clothes

Because the motion of the actuator is controlled via the Joule heat induced by an electric current, the movement of the garments should be designed with due consideration of the temperature. The current drive circuits for these actuators cannot control the temperature of the SMA, which could easily overheat. To solve this issue, addition of a resistance-feedback circuit offers a good solution [3]. Figure 8 shows clothes temperature measured just after 5 minutes actuation. The left picture shows the actual view of the developed clothes, the right picture shows the temperature. This picture reveals that the temperature of the clothe goes up to 39.9 degree Celsius, at the most. It may not be comfortable for persons wearing this clothes for long time. However, the temperature is low enough then it would not harm the wearer.

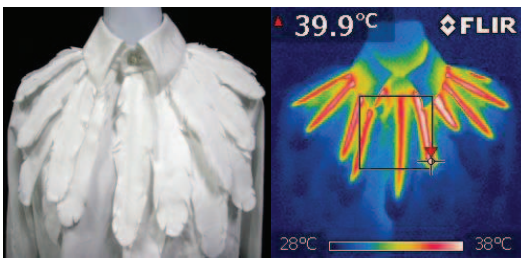

Figure 8 Clothes temperature just after actuation.

Electrical power consumption

A single filament-like soft actuator requires almost 1 W of electrical power for its motion. When we consider the use of hundreds or thousands of actuators, this will become a critical problem because of the power source requirements. The electrical power that can be provided by conventional batteries is limited. To solve this problem, both circuit design and motion design must be improved. Simultaneously, the kinetic motion design must also be carefully designed to reduce power consumption.

CONCLUSION

In this paper, we propose using the use of hairlytop interface technology to compose kinetic clothes. We introduce kinetic clothes that use this technology called "breathing feathers". In our future work, we will continue to make kinetic clothes to widen the range of possible expressions using these clothes. For example, the filament-like soft actuators used in this paper could only bend in one direction. However, we have developed multi directional actuator that can bend in multiple directions [10]. Currently, this actuator is not used in artworks shown in this paper. However, this multi-directional type of actuators should improve the way of expression of kinetic clothes in the future.

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