Hairware: Designing Conductive Hair Extensions for Seamless Interfaces

Katia Vega[1(✉)], Ricardo Aucelio[2], and Hugo Fuks[1]

[1] Department of Informatics, Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro, Brazil
{kvega,hugo}@inf.puc-rio.br

[2] Department of Chemistry, Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro, Brazil
aucelior@puc-rio.br

Abstract. Due to increasing advances in electronics, devices are getting even more small and powerful, making it possible the widespread of wearable computing. However, most wearable devices have the electronics very distinguished and placed on clothes and accessories. Our proposal is Beauty Technology, a wearable computing subfield that uses the body's surface as an interactive platform by integrating technology into beauty products applied directly to one's skin, fingernails, and hair. This paper presents Hairware, a Beauty Technology that fosters a seamlessly looking approach to wearables. It is artificial hair extensions that are chemically metalized to maintain a natural coloration and when connected to a microcontroller could be used as both, input and output devices. This paper describes the design process in creating these conductive hair extensions and discuses lessons learned in the development of them.

Keywords: Hairware · Conductive hair extensions · Beauty technology · Wearable computing

1 Introduction

The fact that big software companies such as Google, Motorola, Apple and Microsoft are creating wearable tech, and also the fashion industry icons like Nike and Adidas are making significant investments in this area is an indicator that wearables will become mainstream devices in the forthcoming years [1]. Google Glass [2] could be one of the clearest examples of wearable devices that have garnered great attention in recent years. These glasses embed a display coupled with a location awareness sensor, illustrating the potential of wearable computing technologies to tap into apps and enable the user to access information. Start-ups are also investing in wearables technologies. For example, Pebble [3] created a wristwatch designed to interact with an iPhone and in a short period of time it has broken records on the crowdfunding platform Kickstarter. However, currently most of these gadgets are designed for men and are supposed to be worn as clothing and accessories, where the technology is visible and the gestures needed for interacting with these devices are noticeable.

A. Marcus (Ed.): DUXU 2015, Part II, LNCS 9187, pp. 696–704, 2015.
DOI: 10.1007/978-3-319-20898-5_66

Given today's wearables revolution, the human body will become a new design standpoint. Thus, the next logical step in wearable computing seems to be the use of the body's roughly two square meters of skin as a canvas for applying sensors and attaching other computing devices in ways that enhance human experience. The body surface, i.e., the skin, nails and hair, plays crucial roles as a protective barrier, sensory monitor, heat and moisture regulator, and an integral part of the body's immune system. Nevertheless, humanity, since its inception, has used beauty products to adorn the body for a variety of reasons. Nowadays, beauty products have become quite sophisticated with advances in chemistry but have still remain an aesthetically functionality. Even more, the billionaire beauty business is constantly growing and most of women use these products in their daily basis, beauty products have not yet been thoroughly explored in relation to their use as wearable computing. Our goal is to disrupt this frontier by adding new functionality to beauty products using technology in a personal, seamless and fashionable way. Our proposal is Beauty Technology, a Wearable Computing subfield that uses the body's surface as an interactive platform by integrating technology into beauty products applied directly to one's skin, fingernails, and hair.

This paper makes use of (modified) hair extensions to design interfaces that, when applied to the body's surface, foster novel interaction possibilities. We propose Hairware, a Beauty Technology based on conductive hair extensions that are attached to a microcontroller in order to be used both as an input and an output device. Hairware acts as an input device by detecting a variety of strokes for triggering different devices. It also acts as an output device by controlling actuators like LEDs and vibration motors attached directly to the conductive hair extensions.

Section 2 identifies previous work on conductive materials for wearable computing and on body technologies. Section 3 presents our process for chemically metalizing hair extensions, to create a conductive material that when attached to a microcontroller could detect hair touch gestures for triggering devices and turn on actuators attached to this hair. Section 4 reviews the lessons learned from prototyping and using Hairware. Conclusion and future work are shown in the last section.

2 Related Work

Developments in novel materials are improving the ease of embedding technologies into fabrics as well as the use of implantable devices and biosensors [1]. Nanotechnology, biotechnology, information technology and cognitive technology are converging - making it possible to foresee wearables with their own power generation, flexible displays and electric-responsive materials [4]. Even more, the miniaturization and availability of electronic components has made possible the widespread adoption of wearable computing, moving from the realm of science fiction to the marketplace in areas such as fashion, health, and wellness for the aging and the disabled. Fibrous materials, such as textile and paper, are flexible, foldable, easily cut and attached to flexible substrates. Once they get electrical conductivity and good mechanical endurance against external deformation, they become attractive for flexible and wearable electronics [5]. Conductive fabrics that are created for wearable technologies are already at the marketplace. Conductive yarn, plated fabric, printing on fabric, and sewing on fabric are some approaches to create e-textiles that are used to embed electronics into textiles [6].

Wearables are already causing a rethinking of the boundaries of the body. Lucy McRae [7] envisions future possibilities of merging technology and the human body. Through artistic showcases, she redefines the body by mimicking its musculature, thus, changing the perception of our own body to create futuristic human shapes. Along these lines, LED eyelashes [8] expose the desire of many Asian women to show more of their eyes by lighting the eyelashes that follow pupil and head movements.

In previous works, Beauty Technologies presented Conductive Makeup [9–11] (Fig. 1) that is an aesthetic interface for detecting voluntary blinking, thus triggering devices according to programmed events. Conductive Makeup includes conductive eyeliner and black fake eyelashes that act as blinking switches. While conductive eyeliners connect sensors and actuators by using conductive materials that stick to the skin, replacing conventional eyeliners, conductive fake eyelashes sense the voluntary blinking. In order to prove the feasibility of the prototype as a conductive component, some applications were developed. Blinklifier [9] uses blinking for switching LEDs on and off on an artistic head dress. Arcana [10] uses blinking for changing music tracks and images visualizations. Superhero [11] (Fig. 1b) is another artistic application that makes use of Conductive Makeup for triggering a remote control to levitate an object.

Wigs could be used as to enhance someone's appearance and also to follow cultural and religious traditions. SmartWig [12] is a wearable device that uses the base of a wig for hiding electronics that communicates wirelessly with other external devices. SmartWig suggests applications that could fulfill a number of functions, from acting as a health care device that monitors users' vital signs to helping blind people navigate roads, or changes slides in a presentation by tapping their sideburns, under which buttons are hidden. A further potential improvement of the wig may use ultrasound

Fig. 1. Conductive makeup. (a) Conductive eyelashes and eyeliner in natural coloration. (b) Superhero project that levitates a drone by blinking.

waves to detect objects around a user. Hair accessories that vary from clips to corsages could be used for creating discreet and fashionable gadgets attached to the hair. First Sign Hair Clip [13] is a hair clip with electronics inside that communicates with a mobile application to automatically call for help and collect evidence when the user is in danger. The clip detects head impacts associated with a violent crime by using an accelerometer and gyroscope, which automatically triggers the alarm, while evidence is collected with a microphone.

3 Designing Hairware

The hair is public as everyone could see it, personal as it is a body part, and malleable as it suits cultural and personal preferences [14]. This work proposes the use of (modified) artificial hair extensions as a novel electronic device to be used in wearable computing. We used a chemical platting technique that makes the l hair extensions to be conductive but, at the same time, looks like human hair. Then, they could be connected to a microcontroller to be used as sensors or actuators. We use hair clips for attaching the circuit to the hair extensions in order to be easily removable and replaceable. Also this makes it possible to put the circuit in different accessory such as a hairclip, headband, brooch and the top of the hair extensions.

This section describes the materials and the prototyping process used. It also shows the feasibility of this technology as an input and output device.

3.1 Chemical Process for Creating Hairware

Artificial hair extensions are chemically metalized for acquiring electrical conductivity and also keeping a natural coloration. We used 6 strands of hair extensions of approximate 1.5 by 25 cm each. Before passing by the chemical process, they are cleaned and weighted. Tests are performed at DC voltages of 5 V, with a multimeter and a balance.

The chemical process is carried out in two phases: Activation and Electrolysis. During the first phase, artificial hair extensions, being plastic non-conducting surfaces, require some kind of activation to enable them to be submitted to an electrochemical process. For the first activation, hydrogen and tin (II) chloride are used. Then, a silver nitrate solution is added for the second activation, where the extensions are set up to catalyze electron transfer reactions, making them ready for metalizing. Next, electrolysis is used for platting them. Copper is electrochemically deposited for making them electrically conductive while “black nickel” gives the natural black effect. A copper plaque is needed for the electrolysis process. Table 1 shows the formulations and times needed for creating Hairware.

After the chemical process, the hair extensions are weighted. Table 2 shows each of the hair extensions initial weight, the final one and the percentage of weight variation. The hair extensions got an average of 21 % more of their original weight. Also electrical resistances of each hairpiece were measured with a multimeter. It is highly conductive with a surface resistivity of less than 5 ohm/sq.

Table 1. Hairware electrochemical process

	Formulation		Temp (º C)	Time (Min)
Activation 1	1 L	Final solution	21	7
	10 g	$SnCl_2$ ($2H_2O$)		
	40 mL	HCl (≫37 %?)		
Activation 2	1 L	Final solution	21	7
	2 g	$AgNO_3$		
	10 mL	NH_3		
Copper electrolysis	1 L	Final solution	40	10
	14 g	$CuSO_4 \cdot 5H_2O$		
	30 g	Potassium sodium tartrate ($KNaC_4H_4O_6 \cdot 4H_2O$)		
	10 g	NaOH		
	40 mL	Formaldehyde (CH2O)		
Copper acid	1 L	Final solution	21	10
	220 g	$CuSO_4 \cdot 5H_2O$		
	34 mL	H_2SO_4		
	10 mL	Cupracid solution		
	0.5 mL	Cupracid brightener 210 Part A		
	0.5 mL	Cupracid brightener 210 Part B		
	0.12 g	NaCl		
Black nickel electrolysis	1 L	Final solution	21	10
	120 g	$NiSO_4$		
	40 g	$NiCl_2$		

Table 2. Hairware features

	Initial weight g	Final weight g	Δ Weight g %	Resistance Ω
Hairware 1	1.35	1.74	22.41	3.8
Hairware 2	1.08	1.16	6.90	4.2
Hairware 3	1.55	1.85	16.22	4.7
Hairware 4	1.34	1.55	13.55	4.8
Hairware 5	0.79	1.17	32.48	4.9
Hairware 6	0.85	1.29	34.11	4.4
	1.16	**1.46**	**20.94**	**4.47**

3.2 Hairware as an Output Device

Figure 2 shows our first application for showing the feasibility of Hairware as an output device. Different kinds of actuators such as buzzers and LEDs could be attached to the conductive hair extensions to be triggered by a microcontroller. We connected 2 Hairware strands to LEDs using hairclips. Its positive pin connected to the sender pin in

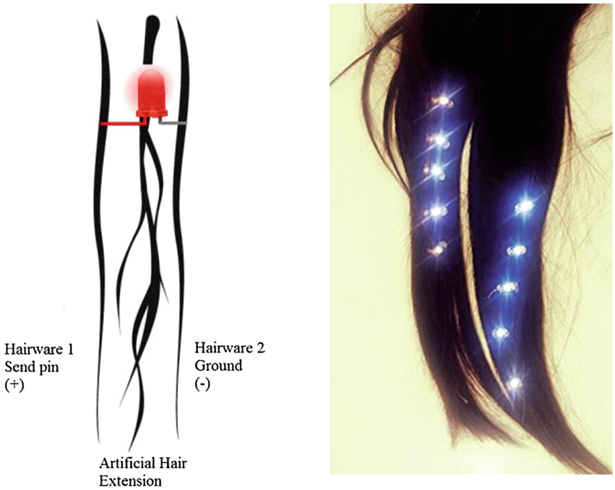

Fig. 2. Hairware as an actuator. (a) Placing an LED on the conductive hair extensions. (b) Lighting Hairware.

the Arduino and the negative one connected to ground. Artificial hair extensions with no conductivity are placed between the conductive hair extensions for isolating them. This wearable turns on the LEDs attached to the hair and changes their intensity and the lighting effects could also repeat the rhythm of music. Other actuators such as buzzers and vibration motors could replace LEDs.

3.3 Hairware as an Input Device

In order to show the feasibility of using Hairware as an input device, we used it as a capacitance sensor that detects the touch on the extensions. We used an Arduino microcontroller, LEDs, resistors and 2 Hairware strands. Each of the Hairware strands is connected to a send and receive pin of the microcontroller and 2 LEDs are also connected. Figure 3 shows Hairware's capacitance sensors functionality. When the receive pin's state change by making a low touch on a strand, the corresponding LED is turned on. Thus, each LED is ON when this sensor detects when someone touches Hairware. This circuit creates a delay in the pulse that is the time the capacitor takes to charge and discharge. In this way, Hairware is used as a conductive surface that detects when another conductive surface approximates to it. Therefore, as the human body is conductive, the average internal resistance of a human trunk is $\sim$ 100 Ω [15], touching Hairware will affect capacitance and result in a different charging time.

Other approach of the use of Hairware as an input device is to use hair extensions as layers on the conductive hair extension. Three layers of non- conductive hair extensions are added for isolating the hair from the skin. Also, these layers improved the capacitor sensor values. Each time the user touch the top, middle or tip, the capacitor sensor differentiates these values. The circuit compares an output that transmits the pulse and an input, which receives the pulse. When a finger touches Hairware, it creates

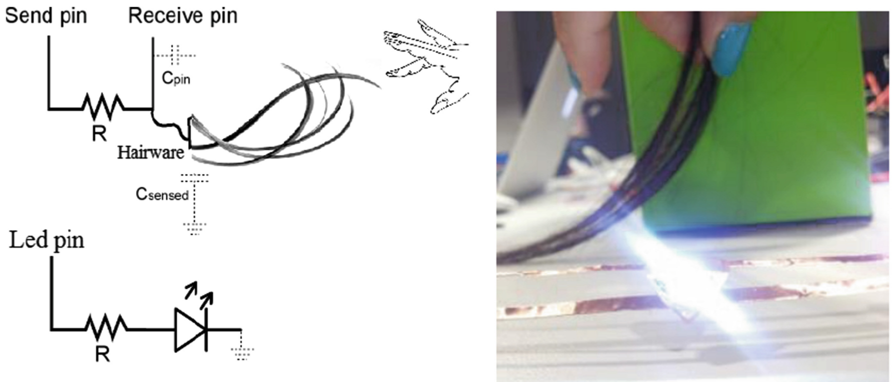

Fig. 3. Hairware as a capacitive sensor. (a) Circuit of Hairware as an input device. (b) Touching Hairware to trigger LEDs.

a delay in the pulse, and this delay is recalculated by the Arduino microcontroller. The circuit diagram is also composed with four 1 MΩ resistors and one 100pF capacitor. The resistors selects the sensitivity, bigger the resistor, the farther away it detects a human. With 4 MΩ resistors between the output and input pins the circuit is tuned to start to respond one inch away, just the sufficient to overcome the non-conductive hair layer. The small capacitor (100 pF) placed from sensor pin to ground improves stability and repeatability. Some LEDs were added to the system to give feedback to the user whenever a touch is detected.

4 Lessons Learned

Due to the proximity with the body, the term cyborg is commonly associated with wearable computing, and science fiction has foretold the merging of man and machine for many years, but it is usually presented as a human with electronics emerging from his skin. We will no doubt recognize that today's wearable technologies are nevertheless very 'distinguishable'. In this project, we propose interfaces "becoming" cyborgs but without having their stereotypical visual aesthetics. Our approach for using Hairware as an input device that senses human gestures with hair proposes that not only a technology is seamless, but also the gestures that trigger devices are unnoticed by an external observer. In this way, depending on the way Hairware is used, there are some concerns related to privacy that could be controversial.

Our first attempts in creating Hairware as an input device were measuring deformation of the object when it is squeeze. Thus, we enrolled the Skweezee workshop at TEI 2014 [16] that measured squeeze on deformable objects fulfilled with conductive wool. They measured the resistance difference when squeezed, thus the conductive filling lowering the resistance between any pair of electrodes. This approached didn't fit this project because almost doesn't change its resistance when it is twisted.

We observed that after the Copper electrolysis step, the extensions got a golden color. Our aim was to get a darker color thus we applied the "black nickel" electrolysis.

But, the metalizing process could be stopped there for a golden color of the hair extensions and also our chemical formulations could be modified with other materials in order to obtain different hair colors.

Due to the skin resistance, Hairware must be placed on any non-conductive material for isolating it from the skin like a shirt. Also other conductive materials like jewelry could affect the way it operates. Future works will include a new step in our chemical process that isolates all conductive hair extensions but preserving its capacitance sensitivity. Also part of it will be totally isolated to work as switches in different lengths of the hair, thus, gestures could be recognized.

The hair extensions after the chemical process gained almost 21 % of weight. Even that, we observed that is not a noticeable weight for a slight device. Even that most of the hair threads were totally conductive, a higher resistance was presented at some hair threads (about 120 ohms) and from the very beginning of the hair to the end.

5 Conclusion

Our aim is to develop wearable technologies that transform the body surface in an interactive platform in a way that a simple gesture could be an input for other devices and actuators could be placed on it. In this way we transform the body into a circuit's board. Beauty Technology that extends the concept of beauty products from altering and highlighting someone's appearance to giving her the power of digitally connect with herself and her environment. It hides technology on beauty products and places them on the body surface such as the hair, skin, and nails. Previous work showed Conductive Makeup, Tech Nails and FX e-makeup as the first beauty technologies. This work presented Hairware, conductive hair extensions with embedded hardware that can be used as both, an input and output for several devices but also looking as regular hair extensions. Our approach modified artificial hair extensions into a conductive material using a chemical process. Other materials such as conductive ink and gel hair could present conductivity but it is easily dried or taken away when the user touches it. Our chemical process could be modified with other reagents in order to get a different coloration of the hair. Braids and different hairstyles could be combined in order to keep the hair in a specific position.

The circuit that is connected to a microcontroller could be placed at the base of the hair extension, in an earring, in a necklace and at a hairclip. Due to the proximity of the hair and the sensitivity of the head, vibration motors could be include in order to make vibrating feedback noticeable for the user. Future works will add an isolator material at the end of the process so users won't need to have a direct contact with the conductive material. When it will be used as an output device, other actuators could replace the LEDs such as vibration motors and buzzers. When it will be used as an input device, it could be combined with other wearable devices such as glasses, brain waves and conductive makeup. Other materials such as beards and mustaches could be transformed into conductive materials and other techniques could be explored like the use of conductive polymers.

The gestures recognition in gadgets and the communication between them and smartphones is not new for wearable technologies. Our approach will recognize voluntary gestures on a part of the body. The big challenge for our gesture recognition system will be to differentiate the voluntary gestures of the user and her natural gestures with her hair in a way that do not interfere with her everyday activities. Future evaluations for comparing noticeable and seamless interfaces will be conducted.

Acknowledgments. Hugo Fuks (Project 302230/2008-4) is a recipient of a grant awarded by the National Research Council (CNPq). This work was partially financed by Research Support Foundation of the State of Rio de Janeiro-FAPERJ/INCT (E-26/170028/2008) and CNPq/INCT (557.128/2009-9). Katia Vega is a postdoctoral fellow with grant funding from PNPD/CAPES Portaria 086/2013. Ricardo Aucelio acknowledges FAPERJ (E-26/201.406/2014) and CNPq (302888/20132-6) scholarships. We also thanks to Hugo Rojas from EAQ Labs for his first insights in the chemical process used on Hairware and Paulo José dos Santos from the Department of Chemistry (PUC-Rio) for his support during the chemistry process.

References

1. Ranck, J.: The wearable computing market: a global analysis. (2012)
2. Google: Google Glass. http://www.google.com.br/glass/start/
3. Peeble: Pebble: E-Paper Watch for iPhone and Android. https://getpebble.com
4. Pearson, I.: The future of fashion. J. Commun. Netw. **4**, 68–72 (2005)
5. Lee, H.M., Choi, S.-Y., Jung, A., Ko, S.H.: Highly conductive aluminum textile and paper for flexible and wearable electronics. Angew. Chemie. **125**, 7872–7877 (2013)
6. Locher, I., Kirstein, T., Tröster, G.: Routing methods adapted to e-textiles. In: Proceedings of 37th International Symposium on Microelectronics (IMAPS), Long Beach (2004)
7. McRae, L., Hess, B.: LucyandBart. http://www.lucymcrae.net
8. Park, S.: LED Eyelashes. (2009)
9. Vega, K.F.C., Fuks, H.: Empowering electronic divas through beauty technology. In: Marcus, Aaron (ed.) DUXU 2013, Part III. LNCS, vol. 8014, pp. 237–245. Springer, Heidelberg (2013)
10. Vega, K., Fuks, H.: Beauty technology: body surface computing. Computer.(Long. Beach. Calif) **47**, 71–75 (2014)
11. Vega, K., Fuks, H.: Beauty technology as an interactive computing platform. In: Proceedings of the 2013 ACM International Conference on Interactive Tabletops and Surfaces, pp. 357–360. ACM, New York (2013)
12. Tobita, H., Kuzi, T.: SmartWig: wig-based wearable computing device for communication and entertainment. In: Proceedings of the International Working Conference on Advanced Visual Interfaces, pp. 299–302 (2012)
13. Sign, F.: Products - First Sign. http://www.firstsign.us/products/
14. Hallpike, C.R.: Social hair. Man. **4**, 256–264 (1969)
15. Webster, J.G.: Medical instrumentation: Application and Design. Houghton Mifflin Company, Boston (1973). 197& g
16. Tangible, E.: E.I.: Design Challenge. In: Seventh International Conference on TEI 2013. http://www.tei-conf.org/13/dc