EMERGING MATERIALS & TECHNOLOGIES

New approaches in Design Teaching Methods on four exemplified areas

edited by Venere Ferraro, Anke Pasold

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3.1. Wearable Textile Systems: design layered intelligence materials

Venere Ferraro

Introduction

Wearables, initially stated as "wearable computing" can be considered as "the study or practice of inventing, designing, building, or using miniature body borne computational and sensory devices. Wearable computers may be worn under, over, or in clothing, or may also be themselves clothes" (Mann, 2012).

Starting from their born back into 1960, wearables have been at centre of huge interest both in academia and in industry field. Placed in between the digital and human world wearables have the potentialities to change the way we live and interact with each other's thanks to the enhanced functionality of sensing, reacting, and/or adapting to stimuli in the environments to which they are exposed.

Wearables fall in many different categories: glasses, jewels, headgear, belts, arm wear, wrist wear, leg wear and footwear are taking on new forms and functions but also skin patches and e-textiles.

There is a major trend towards human hybridization, and wearables represent a generation of hyper-connected products that allow for exploring new design fields between human and advanced technology.

The vision behind wearable computing foresees future electronic systems to be an integral part of our everyday outfits. In twenty years, many applications have been explored in fitness, healthcare, military, automotive areas but the original and still good target for wearables is in some way ubiquity: these electronic devices have to meet special requirements concerning wearability, usability. Wearable systems will be characterized by their ability to automatically recognize the activity and the behavioural status of their own user as well as of the situation around them, and accordingly to use this information to change and modify the system. In this regard, being wearables comparable to the clothes, we can envision clothes provided with a third dimension and becoming "portable informative infrastructure".

The dress is, indeed, the only element able to follow the user in a non-intrusive way, in a natural harmony with the human body: it is a natural and universal interface. To do so, wearable need to be thought, designed and developed by using smart textiles. We consider the new class of ***smart textiles***, the ***active ones***: they contain built in actuators and sensors, they are dynamic and allow new functionality and experiences.

The use of smart textile in field like wearable technologies poses several questions and challenge to meet and solve. How can we design smart "wearable" textiles with no traditional materials but manufactured and shaped within a platform that embraces the electronics features? How can a designer shape smart textile into a clothing/wearable by considering both aesthetics and functionality? Do we need new approaches?

In this chapter, author explores the realm of smart textiles, their application, potentialities and weaknesses by proposing approaches and solutions for a designer working in the field of smart textiles applied in wearable domain.

Smart textiles: from a simple material to a working platform

Smart textiles are defined as textiles (in the shape of shirts, socks, shorts, belts, etc.) that can sense and react to environmental conditions or stimuli, from mechanical, thermal, magnetic, chemical, electrical, or other sources to provide functions such as health monitoring and activity tracking. They are able to sense and respond to external conditions (stimuli) in a predetermined way.

Given, the diversified panorama of smart textiles, a clarification about the meaning of smart textiles is here needed. They can be classified as passive or active smart textiles: the first ones are materials to which a specific function is added by means of material, composition, construction, and/or finishing (e.g., by applying additives or coatings) (Cherenack & van Pieterson, 2012). On the contrary, active smart textiles, are those capable of sensing, reacting, and adapting to the environment or stimuli and integrate actuators and sensors (Vagott & Parachuru, 2018).

We call this category: ***wearable textile system***.

The basic concept of a “wearable” textile system consists of a textile structure that senses and reacts to different stimuli from its environment. In a wide range, a smart textile system has a very simple structure thanks to which it’ s possible to wear a technological apparatus with common clothes.

The sector is heterogeneous and growing it has been estimated that the market for wearable technologies will grow from $20 billion estimated in 2015 to almost $70 billion by 2025.

Wearable textile systems have been mainly designed and developed in health management and sports applications to collect data such as heart rate, sweat rate, breathing rate, muscle tension, posture status, location, and temperature. For instance, they can sense the temperature outside and consequently warm up or cool down, based on the measured temperature (Figure 1).

Fig. 1 - Example of wearable textile systems applied into healthcare and sport

In ***sportswear*** a wearable textile system promises to offer effective solutions for wearers who seek more detailed data about their fitness and performance. Smart textiles can also increase the comfort level of the user and eliminate the use of bulky equipment such as chest straps. Since athletes and major league players constantly strive to improve their performance, an opportunity of storing data for analysis by lightweight devices that can be embedded in their sportswear offers a high potential for further performance enhancement.

Specifically, technology-enhanced sportswear, including compression garments designed for muscle recovery, can provide an appropriate medium for carrying large numbers of sensors close enough to the wearer's skin, to pick up the weak electrical signals generated by physical effort. Multiple extra data types, in addition to heart-rate electrocardiogram (ECG) signals, can be collected today, including electromyography (EMG) for analysing muscle activity. Furthermore, accurate body-temperature monitoring can be useful for monitoring fitness and can also protect the wearer against the dangers of over exercising.

Close-fitting sportswear represents an ideal base for embedding sensors such as MEMS inertial modules, to accurately monitor the wearer's movements. Smart textiles allow accurate sensing by helping eliminate noise that looser-fitting garments could introduce by moving relative to the wearer's body. Sensing motion enables applications allowing to identify areas where technique could be improved, such as running stride or arm action.

Medical applications of wearable textile systems include the monitoring of patients' vitals such as temperature, hearth rate, respiration, stress and sleep levels and so on.

For the ***medical*** and ***healthcare sector*** the main driver for innovation remains the added value in terms of better functionality and performance, but also total cost, compared to established approaches, the continuous integration of new technologies in the development of new products while adapting to new challenges placed by the ageing society – for integrated ICT (Information and Communications Technologies) tools that enable remote monitoring of patients – the enhancement of barrier and comfort properties for professional medical garments. Moreover, in the medical field, the wearable smart textiles integrated with could monitor vitals such as body temperature and heart rate. It would wirelessly transmit the data to the professionals' station. Simplifying the process to gather patient data would streamline the healthcare.

Electrodes manufactured and directly integrated into the wearing surface such as Piezoresistive fabric sensors can be used to monitor the posture and movement of the wearer. These electrodes allow for the monitoring of medical patients over extended periods of time, as the fabric electrodes are reporting the data while the electrode-infused clothing is being worn (Figure 2).

Smart textiles application in wearable domain appears to be very diversified and based on research, which has its foundation in different research disciplines: textile design and technology, chemistry, physics, material science and computer science and technology.

Significant for this research is the ***interdisciplinary approach*** and the interaction between basic research and design activities.

Fig. 2 - Piezoresistive sensors manufactured into flexible textile

According to applications, functionalists, end-user and degree of intelligence smart textile are then also classified according to the design paradigm chosen to integrate electronic functions into the textile architecture. Indeed, in the huge panorama we can find a case in which the textile act as a base for the attachment of sensors, output devices, and printed circuit boards (garment and fabric level integration). Such textiles becoming the actual wearable integrate the desired functionalities "disappearingly" inside a textile sensing/working platform.

Designing wearable that embrace smart textiles means to consider the material per se as a designed/shaped form/object having ***a hybrid layer*** that combine various functional fibres (with differing degrees of complexity) with attached integrated circuit components and off-the-shelf sensors.

This is for sure possible thanks to three main technological drivers: the first is the introduction of new type of textile fibres and structures for example conductive materials; the second is the miniaturisation of electronics, which makes possible to integrate electronics into textile structures and products; the third is different kind of wireless technologies enabling the technology to be wearable and at the same time communicating with other devices such as computers or mobile phones (Cherenack & van Pieterson, 2012).

Besides the above listed drivers, we also need to consider design approaches and tools addressed to the aesthetic/user-oriented and experiential aspects.

Approaches and tools for wearable textile systems

The hybrid layer system required for the wearable textile system needs to meet both technological and aesthetic/acceptance requirement.

This class of materials as all the different recent technologies change the way people behave and interact defining also the behaviour of artefacts, environments and systems (Forlizzi et al., 2004). It is therefore crucial to design them, as they uncover new modes of interaction as well as new ways to engage, entertain and inform people. This approach to applying new technologies to the real world is very much linked with the idea of designing experiences, which means to design not only functional elements (realm of engineers), but also the features needed to involve users at an emotional level.

Based on this ground, a user centred approach (UCD) is required. In an UCD approach, users appear as the ultimate experts, those who can properly assess design prototypes, propose changes, and ultimately, integrate end products within their routines (Assis, 2009).

When it comes to wearable textile system a practitioner needs to design the all layered system by considering human factors and skin requirements by having: a moisture 'base-layer' or the so-called 'second skin', a middle insulation layer, for breathability reason and a protective outer layer (McCann, Bryson, 2009).

A user-needs driven design methodology is here proposed to promote collaborative design with users. It addresses a breadth of technical, functional, physiological, social, cultural and aesthetic considerations that impinge on the design of clothing with embedded technologies, that is intended to be attractive, comfortable and fit for purpose for identified customers. If a product does not look good or work, the user will not be satisfied. Form embraces aesthetic concerns and the importance of respecting the culture of the end-user, and function embraces the generic demands of human body and the particular demands of the end user or activity. In order to aid decision-making, the design process requires an overview of the profile of the target customer in terms of gender, age group, and an indication of the proposed category of smart textile product to be developed. For example, design features that constitute a wearable acceptable and useable garment with embedded smart wearable attributes far a child playing sport will be different tram the needs of a fireman subjected to extreme hazardous environments or from the demands of everyday clothing far an older wearer. Successful wearable system design is the result of designers becoming thoroughly conversant with the culture, history and tradition associated with the particular end-use or range of activities. A design that is considered attractive for a wearer from one community or age group may be totally unacceptable for another.

The designer will benefit from gaining an overview of human physiological issues that impinge on the design of the functional garment layering system. It is necessary to consider practical issues to do with the demands of the body that may be addressed in everyday clothing in terms of comfort. The psychological feel good factor is directly related to appearance and style as well as to the reliability, or the perception of reliability, of the garment system. Designers should carry out primary research observing and obtaining feedback from wearers to identify their needs far the chosen activity or task. An appreciation of the functional needs of the end-user will impact on a breadth of design considerations with regard to comfort, protection, durability, weight, ease of movement, identification and aftercare. The designer's challenge is to engage with the end-user(s) to uncover, understand and priorities a range of issues that set the scene for the specified activity, or range of activities, and inform the development of products that are attractive and fit for purpose in relation to the culture and lifestyle of the intended wearer(s) (McCann, Bryson, 2009).

From the design perspective we are also required to understand and have the knowledge related to the way to translate the user needs into a real wearable textile system meaning to know the fabrication and the possibility to shape the hybrid system.

In this regard, a schematic wearable textile system can be identified through various hierarchical components through a new category of material called ICS Materials (see chapter 2 of this section)

ICS Materials are defined as systems combining inactive materials, active stimuli-responsive smart materials, and proactive materials (Parisi et al., 2018) and shaped exactly as the layered system that answers user demands and acceptance (Figure 3).

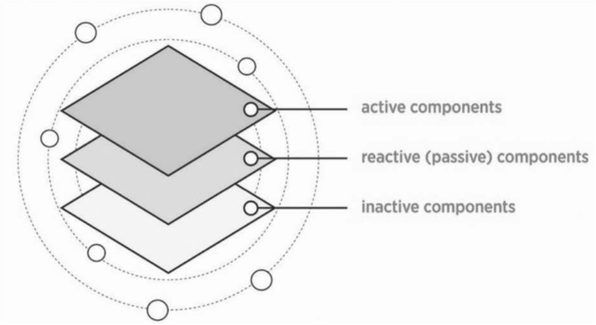

Fig. 3 - ICS Materials layered system

Conclusions and final remarks

Wearable smart textiles are becoming increasingly advanced and helpful in increasing the functionality of both everyday clothing and work wear. They have applications in health management, sportswear, industrial work wear, temperature control, safety, and entertainment. The technologies developed for wearable smart textiles are still being improved and developed. Many designs can still be streamlined to decrease bulkiness and improve the overall integrated feel of the technology.

Textile-based smart wearables have a broad range of potential application markets such as sports, health, personal protection or entertainment. Smart clothes that reveal information on our posture, heart rate or body temperature are being developed. However, while many functioning wearable textile system prototypes have been developed over the last 10-15 years and some niche products have been launched on the market, real wearable textile system seems to be largely absent. Factors combined with a lack of must-have functionality which would persuade users to accept shortcomings, are mainly to blame for the fact that textile-based smart wearables are not more widely in use.

There is a related missing path to commercialization since explorations often stop at concept stage related to materials manufacturing (Barfield & Caudell, 2001). The main problems could be summarized as follow:

- Lack of miniaturization: Limited size and thickness requirements for components in wearable devices, smaller components -more design flexibility, ability to make technology invisible.
- Lack of Flexibility: Flexible mobiles and increasing integration into all wearables increase requirements for flexing/stretching.
- The need for materials and embedded sensors to be lighter and more flexible.

Design and developing wearable textile systems means to take into account not only functional elements (realm of engineers), but also the features needed to involve users. For instance, for sports, fitness and health purpose social acceptability will be enhanced if they enhance an individual's social status as well as providing the functionality needed.

By considering smart materials as a working platform that generate the end product (wearable) a set of requirements need to be met:

- Responsiveness to end-user.
- User centric ergonomic functionality: a new term – 'wearer ware' – may be needed to fill a gap in terminology.
- Ease of use.
- Wearer comfort (weight, bulkiness, flexibility, skin-friendliness).
- Ease of care & maintenance (wash-ability, repairability).

- Connectivity to and from the platform.
- Support for a diversity of sensors.

In order for the industry to start developing such class of products in a massive way we also need to train new professionals having a complementary education that embrace knowledge from design to materials to computer science. Following this, a new curriculum is needed that should overcome the following barriers:

- **Lack of Sensory experience investigation**: Designers must consider the user's cognitive load, sensory and cognitive bandwidth.
- **Missing of collaborative practice**: Need to develop collaboration strategy between design and science, to more fully realize both the opportunities and contexts that Wearable offer (Fairburn et al., 2016).
- **Material/ Technology acceptance** of unknown materials, materials out of context, materials with 'bad reference'.

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Authors' Affiliation

Venere Ferraro, PhD Assistant Professor, Department of Design, Politecnico di Milano.

Anke Pasold, Associate Professor, Material Design Lab, Copenhagen School of Design and Technology.

Pirjo Kääriäinen, Associate Professor, Department of Design, Aalto University.

Sara Lucia Rueda Mejia, Doctoral Candidate, Department of Design, Aalto University.

Tarja-Kaarina Laamanen, PhD Postdoctoral Researcher, Department of Design, Aalto University.

Jari Laine, PhD Senior Innovation Advisor, The School of Chemical Engineering, Aalto University.

Paz Morer-Camo, PhD, Associate Professor, Department of Mechanical Engineering and Materials, University of Navarra-TECNUN.

Aitor Cazón-Martín, PhD, Associate Professor, Department of Mechanical Engineering and Materials, University of Navarra-TECNUN.

María Isabel Rodríguez-Ferradas, PhD, Assistant Professor, Department of Mechanical Engineering and Materials, University of Navarra-TECNUN.

Robert D. Thompson Casas, Scientific Director of Materfad, the Barcelona's Materials Centre of FAD (Fostering Arts and Design).

Stefano Parisi, Doctoral Candidate, Department of Design, Politecnico di Milano.

Valentina Rognoli, PhD Associate Professor, Department of Design, Politecnico di Milano.