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How to Shape the Future of Smart Clothing *

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ABSTRACT

Smart textiles are garments with integrated sensors and actuators which have a large potential of being beneficial in our future society. These textiles can monitor our health condition during daily life, remind us to do some extra fitness activities or warn us when our blood pressure is too high or when our heart beating becomes irregular. They can be used in hospitals for the continuous monitoring of patients but also to help soldiers navigating the dark and athletes to optimize their performance.

During the last 10 years three major smart textile related developments can be noted. First of all the sensors for wearables have become smaller, more reliable and easier to use. Next to that in the field of textile engineering new, and better electrical conducting yarns were developed which can be handled in textile production processes such as knitting and weaving. Thirdly, in the field of information technologies much more efficient algorithms for data processing and interpretation have been developed and more can be expected from the developments in artificial intelligence.

Based on this the market for smart textiles is expected to grow exponentially but although researchers have been working on smart textiles already for a long time, we do not see them in the shop next-door yet.

In this paper we will discuss the developments and trends, list the challenges and propose a strategy to come to the next generation of Smart Textiles.

CCS CONCEPTS

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KEYWORDS

Smart Textiles, flexible electronics, fabric circuit board, wearable computing

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1 Introduction

Smart textile or electronic textile (e-textiles) are promising. According to the IdTechEx report [1] the market for e-textiles is currently close to the $100m in annual wholesale revenue and is expected to grow towards the $5 bn in 2027. The key market sectors include Sports & Fitness, Medical & Healthcare, Wellness, Home & Lifestyle, Military, Fashion and Automotive. This rapid growth and spreading over the different market sectors is quite fascinating and calls for a more in depth study on how the sectors of electronics and textiles could merge towards a novel market field.

2 Opportunities and obstacles

There are several reasons that the smart textiles field has become quite popular in academics, the main one being that the technology for prototyping has simplified a lot over the past decade. To start with, we now have a wide range of small and easy to use sensors available like the PPG sensor from which both the blood oxygen saturation and the heart beat can be obtained, simple electrodes for ECG (electro cardiogram) and skin conductance measurements, small temperature sensors, movement sensors (accelerometers) as well as flex and stretch sensors. In addition, the development of new conductive textiles and inks now makes it relatively simple to produce your own sensors. A conductive yarn woven into a garment, for example, can already act as a capacitive touch sensor and stretch sensors can be fabricated based on readily available stretchable conducting fabrics (see Figure 1).

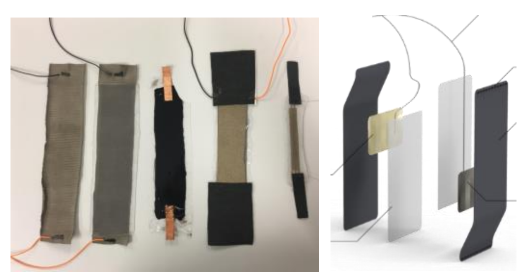

Figure 1: Series of own build textile based stretch sensors

A third reason for why it has become easier to prototype smart textiles is the availability of microcontroller platforms like Arduino (Figure 2) which largely simplifies the control and programming of sensors and actuators and allows also less technical schooled people to design their own interactive textile prototypes.

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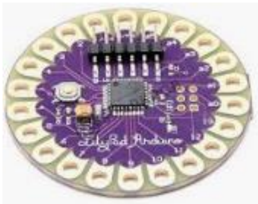

Figure 2: Lilypad Arduino

Some examples of smart textile prototypes developed by students at the TU Delft are shown in Figure 3.

Figure 3: Examples of smart textile prototypes

The question then arises why there are so few smart textile garments commercially available at this moment. In my view there are three main reasons for this:

1. Mass production is still too expensive because the integration of the electronics cannot be fully automated yet
2. Robustness and reliability. It is still difficult to make sure that smart textile products are still functional after multiple washing cycles. Consumers will stop buying products which fail after being used only 5 or 6 times
3. The electronics and the textile industries are currently not cooperating effectively and there is a lack of joint qualification standards.

In fact, what is happening is that the development of smart textiles is following the so-called Gartner Hype Cycle [2] (see Figure 4). Two decades ago the development of conductive yarns led to the first ideas of combining electronics and textiles. Post [3] for example proposed to use embroidery to make textile interconnects in e-textiles and in Google's Project Jacquard weaving technology is used to incorporate conductive yarns in textile [4]. After the start many smart textile ideas were developed (see review papers of Cherenack [5] and Castano [6]) leading to an increase in consumer expectations for smart textiles. However, since commercial e-textiles failed to hit the market, consumers lost confidence leading to a loss in expectations. According to the hype cycle graph e-textiles are now at the 'through of disillusionment' (Figure 4).

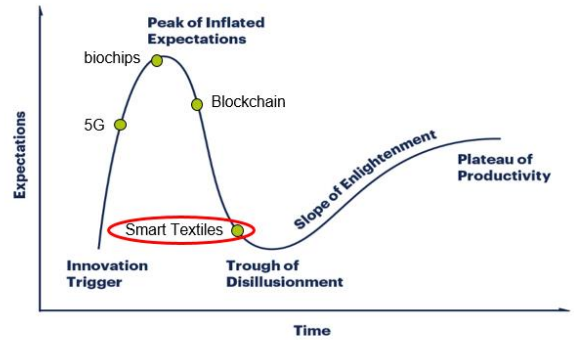

Figure 4: Gartner Hype Cycle for emerging technologies [2]

3 How to proceed

As a way to solve these problems we should do two things. We should adapt the idea of a Fabric Circuit Board and we should go for fully modular e-textile garments.

In Fabric Circuit Boards (FCB's) all the wiring between sensors, actuators, computing nodes and power supplies are embedded in the textile part, in analogy with the Printed Circuit Board technology as used in the electronics industry. The idea of FCB's goes back to the works of Gorlick [7] and Post et al. [3]. Gorlick prototyped elastic suspenders with embedded copper wiring onto which batteries and sensors could be connected with especially designed connectors. Post, on the other hand, used conductive yarns and an embroidery machine to create sensors and to interconnect a series of electronic components in textiles [3]. Later on other researchers followed up. Park et al. introduced the idea of a wearable motherboard with ribbon cables and snap fitting pin connectors [8], whereas Li and Tao used knitted copper wires and a helical spring connection to the sensor elements [9].

Instead of striving to fully fix and integrate the sensors in the textile as is customary, we here propose to go for a smart textile system which is modular and consists of a Fabric Circuit Board garment and a set of separate sensor and data processing nodes which can be added to the base garment by clicking or snap fitting. In this way the garment with wiring system can be mass produced using well known and mostly already proven textile manufacturing technologies. Using computer controlled methods for the knitting, printing or embroidery of the conductive circuitry, also different shapes and sizes of the base garment can be readily produced. On the other hand, the sensor, energy supply and data processing nodes can be further developed by the electronics industry such that they form the thin, flexible and soft devices that are required for the future generation of e-textile products. Advantages of using such a modular system are:

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- Separate mass production of the garments FCB's and the sensor nodes with existing technologies
- A single FCB garment can be used for different applications, depending on the chosen sensor selection
- Broken or defect sensor nodes can be replaced without the need to discard the entire garment
- Smart Garments can be updated by replacing the computing or sensor nodes
- After use the electronics can be easily separated from the textile and separately recycled or disposed

The main problem that then remains is of course the interconnection between the active nodes and the passive Fabric Circuit Board. Such interconnections need to be robust, reliable and above all, standardized. This will not be easy but is in principle possible considering the experience and expertise with interconnect technology that is available in the microelectronics domain.

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