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Smart Textiles in Vehicles: A Foresight

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Abstract

After technical textiles and functional textiles, also smart textiles came into force a few years ago. The term 'smart textiles' covers a broad range. The application possibilities are only limited by our imagination and creativity. This paper gives an overview of the functions that can be achieved by smart textiles in general. In vehicles as well, smart textiles can introduce new features. Two examples are described, namely climate control based on comfort of the passengers, and detection of reduced attention of a driver.

Keywords: Smart textiles, functional textiles, automotive textiles

1. Introduction

What does it mean exactly, 'smart textiles'?[1]

Textiles that are able to sense stimuli from the environment, to react to them and adapt to them by integration of functionalities in the textile structure. The stimulus as well as the response can have an electrical, thermal, chemical, magnetic or other origin.

Advanced materials, such as breathing, fire-resistant or ultrastrong fabrics, are according to this definition not considered as intelligent, no matter how high-technological they might be. The first applications of smart textiles can be found in clothing.

The first generation of intelligent clothes uses conventional materials and components and tries to adapt the textile design in order to fit in the external elements. They can be considered as e-apparel, where electronics are added to the textile. A first successful step towards wearability was the ICD+ line at the end of the 90ies, resulting from a co-operation between Levi's and Philips. This line's coat architecture was adapted in such a way that existing apparatuses could be put away in the coat: a microphone, an earphone, a remote control, a mobile phone and an MP3 player. The coat construction at that time did require that all these components, including the wiring, were carefully removed from the coat before it went into the washing machine. The limitation as to maintenance caused a high need for further integration. Infineon [2] has developed a miniaturized MP3 player, which

[1] X ZHANG and X TAO, *Smart textiles: Passive smart*, June 2001 p 45-49, *Smart textiles: Active smart*, July 2001 p 49-52, *Smart textiles: Very smart*, August 2001, p 35-37, Textile Asia

[2] http://www.wearable-electronics.de/intl/fotos_vorbereitungen.asp

can easily be incorporated into a garment. The complete concept consists of a central microchip, an earphone, a battery, a download card for the music and an interconnection of all these components through woven conductive textiles. Robust and wash-proof packing protects the different components. However, non textile components will always cause a certain discomfort and connections between textile and non textile components remain troublesome. In the second generation, the components themselves are increasingly being transformed into full textile materials.

2. Functions of smart textiles

Basically, 5 functions can be distinguished in an intelligent suit, namely:

- Sensors
- Data processing
- Actuators
- Storage
- Communication

They all have a clear role, although not all intelligent suits will contain all functions. The functions may be quite apparent, or may be an intrinsic property of the material or structure. They all require appropriate materials and structures, and they must be compatible with the function of clothing: comfortable, durable, resistant to regular textile maintenance processes and so on.

2.1 Sensors

Sensors capture parameters from a body or from an environment. It is quite clear that in vehicles, there is less need for monitoring the environment, as it is far easier to integrate sensors in the vehicle itself, where they can be connected directly to energy supply, processing units and communication systems.

Textile cloths on the other hand are in direct contact with the body, so textile sensors are a good tool for measuring body parameters.

Biosignals that are mentioned in literature are:

- Temperature,
- Biopotentials: cardiogram, myography,
- Acoustic: heart, lungs, digestion, joints,
- Ultrasound: blood flow,
- Motion: respiration,
- Humidity: sweat,
- Pressure: blood.

It will be clear to the reader that this list is not exhaustive.

A lot of work needs to be done on finding the right parameters for measuring certain body functions, as well as on developing appropriate algorithms for interpretation of the data.

Suits are available already for measuring heart and respiration rate, temperature, motion, humidity, but they mainly use conventional sensors integrated in a cloth. Some examples are already available of real textile sensors for heart and respiration rate and motion, with quite satisfactory results [3].

Generally speaking, sensors and textile sensors in particular struggle with the following problems:

- The flexibility and deformability required for comfort as well as changing contact when the wearer is moving, interfere with sensor stability,
- Signals tend to have relatively low amplitude (e.g. μV),
- Long term stability is affected by wear and laundry.

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[3] L. Van Langenhove, C. Hertleer, M. Catrysse, R. Puers, H. Van Egmond, D. Matthys, the use of textile electrodes in a hospital environment, World Textile Conference-3rd Autex Conference, Gdansk-Polen, 25-37 juni 2003, ISBN 83-89003-32-5, pp. 286-290.

2.2 Data processing

Data processing is one of the components that are required only when active processing is necessary. The main bottleneck at present is the interpretation of the data. Textile sensors could provide a huge number of data, but what do they mean? Problems are:

- Large variations of signals between patients,
- Complex analysis of stationary and time dependent signals,
- Lack of objective standard values,
- Lack of understanding of complex interrelationships between parameters.

Apart from this, the textile material in itself does not have any computing power at all. Pieces of electronics are still necessary. However, they are available in miniaturised and even in a flexible form. They are embedded in water proof materials, but durability is still limited.

Research is going on to fix the active components on fibers (Ficom project [4]). Many practical problems need to be overcome before real computing fibers will be on the market: fastness to washing, deformation, interconnections, etc. In vehicles, the electronics required for data processing could be integrated in the vehicle itself.

2.3 Actuation

Actuators respond to an impulse resulting from the sensor function, possibly after data processing. Actuators make things move, they release substances, make noise, and many others. Shape memory materials are the best-known examples in this area. Shape memory alloys exist in the form of threads. Because of its ability to react to a temperature change, a shape memory material can be used as an actuator and links up perfectly with the requirements imposed to smart textiles.

Until now, few textile applications of shape memory alloys are known. The Italian firm, Corpo Nove, in co-operation with d'Appolonia, developed the Oricalco Smart Shirt [5]. The shape memory alloy is woven with traditional textile material resulting into a fabric with a pure textile aspect. The trained memory shape is a straight thread. When heating, all the creases in the fabric disappear. This means that the shirt can be ironed with a hair dryer.

Real challenges in this area are the development of very strong mechanical actuators that can act as artificial muscles. Performant muscle-like materials, however, are not yet within reach [6].

A second type of actuators are chemical actuators that release specific substances in predefined conditions. The substances can be stored in 'containers' or chemically bound to the fiber polymer.

Materials that release substances already have several commercial applications[7]. They release fragrants, skin care products, antimicrobial products etc.. However, actively controlled release is not obvious, although some basic research projects have started. Release could be triggered by temperature, pH, humidity, chemicals, and many other.

Obviously, controlled release opens up a huge number of applications as drug supply systems in intelligent suits that can also make an adequate diagnosis.

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4 http://www.fibercomputing.net

5 http://textile.t4tech.com/Application.asp#

6 First World Congress on Biomimetics and Artificial Muscles, December 9-11, 2002, Albuquerque, USA

7 http://www.devan.net

2.4 Storage

Although usually not a goal as such, smart suits often need some storage capacity, as the suit must be able to function as a stand alone unit. Storage of data or energy is most common. Sensing, data processing, actuation, communication, they usually need energy, mostly electrical power. Efficient energy management will consist of an appropriate combination of energy supply and energy storage capacity. Sources of energy that are available to a garment are for instance body heat (Infineon [8]), mechanical motion (elastic from deformation of the fabrics, kinetic from body motion), radiation (solar energy [9]), etc.

As mentioned before, energy supply must be combined with energy storage. When hearing this, one thinks of batteries. Batteries are becoming increasingly smaller and lighter. Even flexible versions are available, although less performant. At Wollongong University (Australia) fiber batteries are being developed. In vehicles, energy can be supplied through direct contact with the suit or via a wireless connection.

Micro capsules are capable of storing liquids that can be released by breaking the capsules or through migration through the coat. The provide chemical actuators as described above. Phase Change Materials or PCMs consist of microcapsules containing waxes. They have the ability to store thermal energy under the form of melting energy and are already introduced in the textile industry.

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[8] C LAUTERBACH et al, *Smart Clothes selfpowered by body heat*, AVANTEX Proceedings, 15th May 2002

[9] K CHAPMAN, *High Tech fabrics for smart garments*, Concept 2 Consumer, September 2002, p15-19

2.5 Communication

For intelligent textiles, communication has many faces: communication may be required

- Within one element of a suit,
- Between the individual elements within the suit,
- From the wearer to the suit to pass instructions,
- From the suit to the wearer or his environment to pass information.

Within the suit, communication is currently realized by either optical fibers [10], either conductive yarns[[11]. They both clearly have a textile nature and can be built in the textile seamlessly.

Communication with the wearer is possible for instance by the following technologies: For the development of a flexible textile screen, the use of optical fibres is obvious as well. France Telecom[[12] has managed to realise some prototypes (a sweater and a backpack). In order to increase the resolution, the concept will need to be reviewed, as currently one pixel requires several optical fibres.

Pressure sensitive textile materials[13] allow putting in information, provided a processing unit can interpret the commands. Communication with the wider environment is very important for certain applications. In the case of a driver, the vehicle should interact with a suit in a number of cases. A

[10] S PARK, S JAYARAMAN, *The wearable motherboard: the new class of adaptive and responsive textile structures*, International Interactive Textiles for the Warrior Conference, 9-11 July 2002

[11] L VAN LANGENHOVE et al, *Intelligent Textiles for children in a hospital environment*, World Textile Conference Proceedings, 1-3 July 2002, p44-48

[12] E DEFLIN, A WEILL, V KONCAR, *Communicating Clothes: Optical Fiber Fabric for a New Flexible Display*, AVANTEX Proceedings, 13-15 May 2002

[13] http://www.tactex.com

direct contact could be foreseen between the driver's suit and the vehicle, for example through the seat. Wireless connection can be achieved by integrating an antenna in the suit. The step was also taken to manufacture this antenna in textile material. The advantage of integrating antennas in clothing is that a large surface can be used without the user being aware of it. In the summer of 2002, a prototype was presented by Philips Research Laboratories, UK and Foster Miller, USA on the International Interactive Textiles for the Warrior Conference (Boston, USA).

3 Some examples

3.1 An overview

Although the vehicles themselves become more and more smart, the level of integration of smart textiles is very low, not to say unexisting. Yet an adequate suit can provide a lot of information on the driver. It can indicate the level of thermal comfort of each individual passenger, the level of concentration of a driver, reduced awareness by intoxication by alcohol, drugs or fatigue and many more.

All these parameters have a direct impact of the quality of driving. Ultimately, the suit could inform the vehicle that it is not allowable to continue driving.

For people at risk, such as heart patients, the suit could indicate when problems are to be expected, so that the driver can stop in time and that if necessary help can be called upon.

The suit could also actively intervene in a large number of situations. It can assist in supplying drugs for instance. Or provide massage during long rides in order to enhance the level of fitness or to reduce stress.

However, most of these applications are still far away because the basic materials and concepts are not yet developed, because only limited information is available regarding body parameters, how to measure them and how to interpret the data.

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4 Thermal comfort

The effect of comfort sensation of a human being is not merely important to himself, but also influences his level of performance. This results into a decrease of productivity and concentration level, an increase in fatigue, occurrence of headache, … Examples both in literature as in every day life are abundant. The effect of the perceived air quality in a room on the human comfort sensation for instance, is expressed through the Sick Building Syndrome (SBS)[14]. And stress is anything but a healthy nor cheap phenomenon. In Flanders that has a population of only 6 mio, the cost to the economy caused by stress is estimated at 3.75 billion €, divided over the cost for the social security system (1.25 billion €) and the cost for absenteeism (2.5 billion €). 60 % of this absenteeism is directly or indirectly caused by stress . Bearing in mind that about 30% of all traffic accidents are primarily caused by sleepiness and fatigue behind the wheel, the importance of this aspect needs no further emphasis.

The level of comfort is to a large extent determined by the *micro-environment* in which the person finds himself. The micro-environment is the collection of all non-genetically determined variables, such as the environmental temperature, the humidity of the air, the velocity of the air, … . These parameters can easily be controlled in vehicles.

Every human being continuously reacts to this physical micro-environment.. These reactions are known as *bio-response signals*,

[14] Wargocki, P., Wyon, D.P., Baik, Y.K., Clausen, G. & Fanger, P.O. (1999) Perceived air quality, sick building syndrome (SBS) symptoms and productivity in an office with two different pollution loads. *Indoor Air*, 9, 165-179

such as skin temperature, transpiration rate, heart rate, dust concentrations … Therefore bio-response signals contain valuable information reflecting amongst others how the human metabolism reacts to the environment in which humans live, dwell or work.

The necessary and complementary steps to achieve optimal comfort are:

- on-line monitoring of human bio-responses: Conventional sensors that can monitor these bio-response signals however, are experienced as disturbing for the wearer and can cause skin irritation when used for long term. Textile materials with sensing capabilities can overcome these disadvantages.
- defining a comfort index based on bio-response monitoring, which is not yet available
- active control of the micro-environment using this comfort index, which requires
  (i) a continuous feedback of information of the most important process part
  (ii) at any moment an accurate prediction or model of the static and dynamic bio-responses [15]

Another approach would be to control the comfort by the textile itself. Two developments can be mentioned in this respect: A new kind of fabric, Polartec Heat™ Technology provides Warmth on Demand™[16]. The jacket that is made out of this fabric (by The North Face) keeps the wearer warm through actively heated panels. The panels are activated by the user, using a controller.

On the other hand, a Cooling Jacket for Formula 1 drivers has been developed by d'Appolonia [17]. A cooling fluid flows in little tubes through the material. There is no personal feedback on the amount of cooling that is given to the driver.

As a conclusion for this paragraph, there is a need for mainly adequate textile sensors, and processing and control algorithms to achieve full optimization of thermal comfort of people riding in a vehicle.

5 Conclusions

Textiles are present everywhere and at any time. They are widely accepted and easy to use. On the other hand, they offer an enormous range of combinations of basic materials (fibers), structures and treatments. So they have the potential to become a powerful tool to monitor general or very specific parts of the body, with high level of reliability and at the same time high level of comfort to the wearer. This will make it possible to expand the range of applying survey and adequate reaction, quite likely at lower price and with beneficial effects on overall comfort and safety. The potential is there, ready to be exploited.

The development of smart textiles reaches far beyond imagination, some stories may seem science fiction. But part of the new materials and structures have already reached the stage of commercialization, although much larger part however is still in full development or still has to be invented even.

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[15] Clarke, D. W. (1988). Application of generalized predictive control to industrial processes. *IEEE Control Systems magazine* **8:** 49-55.

[16] . http://www.polartec.com/contentmgr/showdetails.php?id=221

[17] . www.dappolonia.it