Changing the Fabric of Society: An exploration of smart textiles in product design

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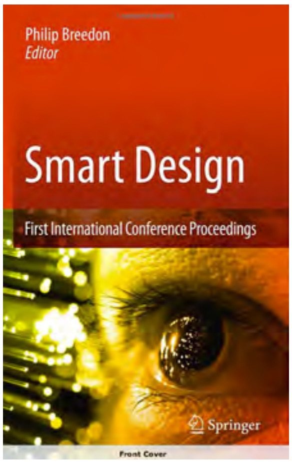

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Abstract

There has been a flurry of activity in the area of smart textiles over the past decade or so [see, 1,2,3,4,5,6,7,8 for instance], and we are now beginning to see the transition from protypical items, to commercial applications. Yet the uptake of textiles in product design is relatively poor. Whilst there are some notable exceptions [2,9,10] the majority of applications remain prototypical. Yet why is this, and what can smart textiles offer the field of product design? This paper interweaves some of the developments and applications of smart textiles, drawing examples from other domains, such as art, architecture, engineering and bio-medical fields, as well as materials science, in the process, exploring future applications of smart textiles in industrial and product design.

Keywords

Smart textiles, product design, new materials

Introduction

Textiles gave birth to the industrial revolution, taking cottage production of cloth to mechanical production on a massive scale. In the process the textile industry fast-tracked other industries, setting a trajectory to the future, and in turn changed the very fabric of society. Textiles are not just the stuff of clothes, apparel, and home furnishings though. Today textiles have radically changed other industries, from electronics to construction, medicine to architecture. With the development of smart materials – materials that can either *sense*, *react* or *adapt* (or any combination of these) to their environmental conditions or to other stimuli [11] – a new field of smart textiles promises to cause further radical changes across a broad range of industries, and its impact on society "has the potential to transform many aspects of our lives". [12]

Smart textiles and smart use of textiles

There has been a flurry of activity in the area of smart textiles over the past decade. Philips Design in 2000 explored the idea in their project and book, *New Nomads: an exploration of wearable electronics by Philips* [3]; Ellen Lupton's *Skin* [5] in 2002 showcased some fascinating work; and in the UK between 2004-2007 the *Smart Textile Network* [13] was established as a think tank linking research in academia and industry. Meanwhile, a number of universities, particularly in Europe and the US, and companies such as Philips have their own research programs devoted to smart textiles [10, 14].

There are already examples of incorporating electronics into clothing on the market. For instance, UK-based company, ElekTex® [9] produce an electro-conductive textile that is lightweight, soft and flexible, yet highly durable. The textile is also washable, and can work over a temperature range of -40°C to +70°C so provides a great choice for apparel and clothing. From a men's suit by leading UK retailer Marks & Spencer, to cycling shorts by Pearl Izumi, to snowboard jackets by O'Neill, a number of fashion houses have incorporated the ElekTex® touchpad – a fabric-based controller designed for use with an iPod – in their clothing ranges.

The fascination with textiles has not just been confined to clothing and apparel – textiles have been embraced by artists, architects, and engineers, providing inspiration to challenge and explore the realm of the possible. Artists such as Anish Kapoor, in collaboration with the engineering firm Ove Arup and Partners, stretched the boundaries of fabric in his installation sculpture, *Marsyas* – an extraordinary 150m long red trumpet-like installation consisting of three metal rings connected by a PVC coated polyester skin – that filled the Turbine hall in London's Tate Modern gallery [15]. Our understanding of three-dimensional geometry is enriched by works such as this. This point has not been missed by architects, many of whom, with the aid of advanced computational software and textiles, have explored the unique forms and surfaces that textiles can deliver. In 2006 a book, *Architextiles* [4], was devoted to this theme. In more humble ways, textiles have also been readily adopted by the construction industry – be it geotextiles used in civil engineering projects to prevent erosion and stabilise ground works, or breathable fabrics such as Tyvec® [16] used in many building projects. Much of the transport industry relies on textiles, be it for engineering or interior applications. In aircraft and marine craft, much of the structure of the vehicle is based upon woven composites, and as light-weighting and fuel-efficiency become increasingly important in the automotive sector, more structural components and panelling are adopting woven composites over metal predecessors. More obviously, textiles have always had an important role in the interior of vehicles, and there is a great deal of research and testing of new textiles for interior applications, be it fabrics that wick away sweat from the driver, or are stain-resistant, or can heat or cool to provide maximum comfort for the driver, textiles have an acknowledged and important place in these industries.

More recently, BMW's Geometry and functions In 'N' Adaptations (GINA) concept car has explored shape-shifting fabric as the vehicle exterior [17] – an inspirational design and perhaps the promise of things to come – yet whilst this might be a smart application of textiles, it in itself is not utilising smart textiles. But, smart textiles could automatically perform the shape-shifting of the vehicle exterior in response to speed – using a woven or knitted matrix of pressure-sensing piezo-electric fibres that generate electricity in proportion to air pressure (*ergo*, speed of the vehicle), shape memory alloy filaments that can change the form of the fabric, in addition to fibre-optic filaments that can transmit data through the fabric, along with woven fibres of carbon, carbon nanotubes and aramid for strength – a smart vehicle skin could not only be lightweight, but have a form of material intelligence that responds automatically to its conditions. [18]

Smart textiles in products – expanding senses and sensibilities

But what of product design? Has this field embraced the potential of textiles? There are some stand out areas – mainly in the realms of sporting goods, furniture, and accessories for electronic components – but there are few commercial examples of products. The ElekTex® soft keyboard, designed by Sam Hecht [19] in 2001 is a notable exception, and later IDEO's collaboration ElekTex® and Logitech in 2004 saw the *Logitech Keycase* keyboard win an Industrial Design Excellence Award; but by and large the foray into consumer electronics has not really been taken up since. This is understandable given the research and development focus on interactive displays for mobile and computer devices over the last few years, but smart textiles may yet come of age.

There is now great interest in the ability to screen-print a number of smart films directly onto fabric, or to directly weave conductive fibres with electroactive polymers (materials that can move or give off coloured light for instance), so that dynamic screens can be seamlessly integrated into fabrics. A number of fabrics have incorporated either electroluminescent wires, fibreoptics or discreet LEDs to light up the material in the dark or else to produce a flexible display. For instance, Philips have produced their *Lumalive* [10] fabric and their research division are looking at the application of OLEDs in textiles and products, and Kodak have a research program dedicated to flexible displays and textiles [20].

Whilst most consumer electronics consist of simple input devices (a keyboard, button or switch for instance), some electronic signal-processing, and simple output devices (such as a screen, or an audio device), a smart textile can be both an input device and an output device. Further, the power required to operate a device could actually be generated by the fabric itself. Professor Zhong Lin Wang and his colleagues from Georgia Tech have developed a fabric that incorporates zinc oxide nanowires coated in tetraethoxysilane (a weatherproofing protective coating) that can generate electricity from small motions [21]. Whilst the fabric does not produce a lot of electricity – about 80 milliwatts per square metre – this can be sufficient to power portable electronic devices such as MP3 players or medical implants. This gives new meaning to power dressing and power walking – going for a walk in your shirt and suit could actually power the mobile office.

A smart fabric can also be used to regulate temperature, airflow, or moisture levels, by tightening or loosening threads in the weave and weft of the fabric to open up a gap in the material. For clothing there are obvious advantages – providing more or less insulation to maintain heat or to cool the person, or venting the clothing to help reduce sweat build up (the fabric could also have an active deodorising system, whereby the material can release micro-encapsulated perfumes at set conditions, triggered by heat or an electric current for instance). Regulating temperature of an electronic product could also benefit from the use of smart textiles. Typically heat sinks, consisting of a highly conductive material with a large surface area, are used to cool computer chips. As the processing power of computer chips increases and they get a lot smaller, they also generate more heat and so, paradoxically, the larger the heat sink needs to be to cool the chip. Smart fabrics offer the potential to address this problem in three ways. Firstly the material can be designed to change and increase its surface area or increase airflow through the material as required, in the same way described above. Secondly, either thermoelectric cooling textiles that incorporate Peltier elements that transfer heat from the inside to the outside of the fabric, or Phase Change Materials that absorb and later dissipate heat energy by changing form can be used. Finally the layout of the electronics upon the fabric itself can consist of a more distributed processing unit (instead of a Central Processing Unit (CPU) a Distributed Processing Unit can perform the same functions), much like how a neural network operates.

This final opportunity is incredibly exciting for the benefits it could offer in how we interact with technology. Textiles can be embroidered or printed upon using conductive materials, and so flexible circuitry can now relatively easily be incorporated onto a fabric. The difficulty up until recently has been to ensure the circuitry can flex without damage, but advances in processing technologies and coatings has now addressed this. As electronic components are getting smaller and smaller, they too can be incorporated into a fabric, and so the time of truly wearable electronic devices is now here.

Whilst there are plastics that can be impregnated with scents (eg Auracell® by Rotuba [22]), fabrics have for millennia had the capacity to carry and give off smells (sometimes not desirably!). So smart textiles can also have this ability – whether pre-impregnated with a particular smell, or washed or perfumed from time-to-time. Further, in the same way that conditioners and coatings can be applied to fabrics by washing them, so too with most smart textiles. This offers an interesting opportunity for the ultimate customisation of worn technologies – these products can be coloured, perfumed, softened and textured, or treated to be hypo-allergenic, simply by laundering. Given that our sense of smell can be an important recal of memory, and is also a useful way of triggering an alert response (the smell of smoke or gas typically draws an immediate response whilst awake), the safety applications are also of value. A worn device that could provide warning signals by tightening (using shape-memory polymers or alloys, or a hydrogel);

vibrating (piezo fibres) or changing temperature (a phase change material or a simple resistant wire), or even give off a distinct smell (triggered by heat for instance) could expand the way we currently interrelate with technology.

The sensory opportunities that smart textiles afford design, especially the tactile and haptic qualities, are of real interest – particularly as a way of interacting with technology. Some smart textiles can change temperature, colour, or their pliancy, so the range of tactile feedback can be more greatly attuned than current product interfaces. Sharon Baurley, Head of Design at Brunel University, and former coordinator of the *Smart Textiles for Intelligent Consumer Products* [2, 13] program, has explored the opportunities to augment remote interpersonal communication and emotion with tactile feedback. Her *Emotional Wardrobe* [23] project has produced a number of prototypical garments, such as *Communication-Wear* that augments a mobile phone with tactile feedback using electronic textiles that can touch/stroke the wearer (gentle squeezing) by incorporating shape memory alloys into the fabric. In essence a reassuring phone call or a message to a loved one could come with a hug or a pat on the back.

In a similar fashion, Philips Research has developed *The Emotions Jacket* [14] for enhancing the cinema experience, so that the wearer can literally feel some of what the characters on screen do. The applications from their research into the sensory experience will no doubt begin to manifest in home entertainment and gaming devices in the not too distant future. Such an immersive world is no longer the stuff of science fiction but thanks, in part, to smart textiles is progressively becoming real. Smart textiles offer us the opportunity to expand our sensory interaction with technology, and could also change the way we think of products, and in so doing blur the boundary between technology and us.

Conclusion

There are some significant problems of utilising smart materials for product application, however, as identified by Oliver and Toomey, “The key challenge is turning the designs into real products and systems, a result of the restricted availability of active materials in design friendly formats. … A current challenge is obtaining sufficient quantities of materials … to be able to incorporate into implementable design led products”. [12]

Whereas fashion, architecture, art and engineering domains can afford to create the bespoke, and indeed only one-off items may be required, product design has a culture of designing for mass production. This is perhaps what we are seeing in regard to the application of smart textiles – the circumstances have not yet been right for product design, but incredible advances are being made. This is perhaps the pivotal turning point for smart textiles. The Industrial Revolution was predicated on the ability to mass-produce textiles; in turn, industrial design as a discipline was formed, and mass production became the *modus operandi* of product design and manufacture. Mass-producing smart textiles will see a new revolution, and perhaps textiles once again will change the fabric of society.

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