

Textiles, Shape and Sensor: Integration of Textile Design and Technology

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ABSTRACT

This research project demonstrates creative and innovative design ideas explored through the integration of new technologies, sensors and materials within a focused design context. It also explores synergies between interdisciplinary approaches considering a range of research methodologies and approaches to research collaboration.

1. CONTEXT

Technical Textiles is a rapidly developing sector based on cutting-edge technology, performance materials and escalating profitability. Products are used in vital and diverse industries: aerospace, biomedical, sportswear. Smart products, including wearable electronics have generated significant interest among both manufacturers and consumers. Nike's strategic link with Apple provides a good example with the launch of innovative Nike+iPod products (Nike 2006). Possibly the most publicised technical innovations have been related to smart clothing and smart-fabrics. However, the technical textiles report (Just Style 2007) remains sceptical about such propaganda, stating that despite many years of research and development, only a few "wearable electronic" smart textile products have been developed. Numerous problems have resulted from the fact that the developers of smart textiles technology have mostly been either academic institutions, which have largely focused on the exclusive requirements of the military, or electronics based companies who have not fully understood the user needs or the methods utilised for product development within the textiles industry. In contrast this research intends to adopt an interdisciplinary and experimental approach that maximises the potential how new technologies and materials can be explored. We intend to explore both the opportunities and synergies that this collaboration offers. Examples of smart clothing that are already commercially available include wearable electronics, appearance changing garments, shape memory products and non-electrical thermal control. Each was found to have different commercial and market potential by the global market review (Just Style 2007). However, there is likely to be significant scope to supply appearance changing garments to the rescue services, outdoor workers, mountain rescue teams, as well as cyclists and joggers. There is also potential for smart-clothing to address the sustainability agenda, as identified by Allwood et al (2006) and to consider a range of new creative opportunities. The design implications are vital to this investigation. The purposes, look and feel of the garment or product are imperative in an 'image' and fashion obsessed culture so that these technologies should not be viewed in isolation. Design is an imperative part of this process.

2. INITIAL RESEARCH

This initial research is concentrating on technical textiles that integrate smart materials, 'smart' sub-miniature sensors, advanced miniature lighting technology

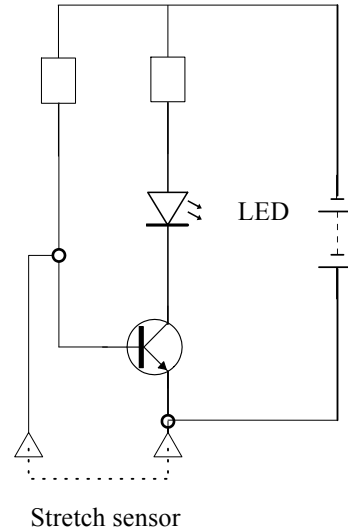
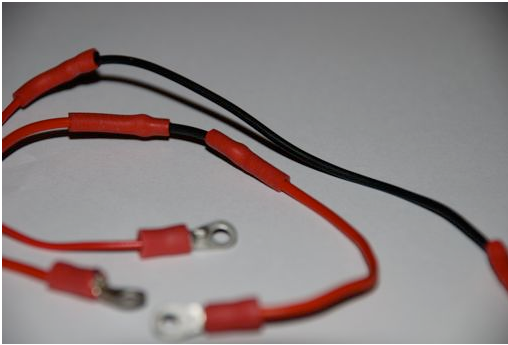
and feedback devices. These could be developed as wearable products, or portable products. The development of these 'kinetic' fabrics might have design applications. The research aims are to review the material technologies available and develop prototype samples. It will identify technologies that could be integrated with different types of fabrics and yarns. Then progress the research to incorporating these technologies (smart materials and/or sensors) with constructed textiles such as, woven or knitted fabrics, or by applying them by using surface processes such as print or embroidery. Two such technologies are delineated here, and reasons given for selecting one of them to take further into the design process.

3. SHAPE MEMORY ALLOYS

Shape memory alloy (also known as a smart alloy, memory metal, or muscle wire) is an alloy that is capable of "remembering" its shape. After a sample of SMA has been deformed from its original configuration, it regains its original form by itself during heating or, at higher ambient temperatures, simply during unloading (pseudo-elasticity or superelasticity) (Braga 2002). Shape memory effect describes the process of restoring the original shape of a plastically deformed sample by heating it. This is a result of a crystalline phase change known as "thermoelastic martensitic transformation". A combination of approximately 50% nickel and 50% titanium is the most common Shape Memory Alloy, known commercially as Nitinol (NiTi). Nitinol has the ability to change its shape along its phase planes where other metals slide along slip planes when there is an induced stress. Heating (or providing an electrical current) to the material converts it to its high strength, austenitic condition. There is a hysteresis curve for every Nitinol alloy that defines the complete transformation cycle. The shape memory effect is repeatable and can typically result in up to 8% strain recovery. The potential use of smart alloys and smart polymers are categorised by Colchester (Colchester 2007). One potential use could result in a labour saving fabric coating which could remove creases from a garment in response to applied heat. This heat could be provided 'naturally' or by means of an applied electrical current. The design challenge here is to investigate the parameters and synergies between both technical limitations and aesthetic qualities. Chalayan in his fashion collection of 2000 made some initial investigations in this area, however, as Lee states 'clearly functional applications for SMP based textiles abound, but what of the aesthetic potential' (Lee 2005). Certainly claiming ambitious aesthetic and conceptual goals at the outset (as funding structures often lead us to do) can lead to disappointment in actual achievements. Beilharz and Vande Moere for example, present a wearable concept drawing on the metaphor of folding, but fail to recognise in their paper the chasm between the visual resolution of their source material and their output (2008). Di Mainstone and Joey Berzowska have attempted to address some of these issues with their work with SMAs, finding that felt is a natural fabric to combine with this technology due to its weight, which pulls the deformed plane back again. The slowness of this return to original form is both a constraint and a design opportunity, being quite organic but in some situations barely noticeable (Mainstone 2008). Despite our initial brainstorming around this technology, it remains future work, which we anticipate with excitement. In part, this has been in recognition of the intense engagement needed to realise aesthetically as well as functionally successful work as outlined above; but it has also been due to a fortuitous relationship developed through an earlier project bringing together one of the authors and Merlin Robotics, the manufacturers of a new form of stretch sensor (Merlin Robotics 2008). This material has provided us over the past few months with a similar range of interesting design challenges and opportunities, and these are covered in depth in the rest of the paper.

4. STRETCH SENSORS

The Merlin Stretch Sensor, figure 1, uses the latest 'Smart' material technology and has uniquely flexible attributes that can undertake measurements when it is curved around corners or woven into fabric. It is a flexible sensor with a small form factor.



Figures 1: Merlin stretch sensor with connection 'tags'; Figure 2: Circuit schematic diagram, stretch sensor & LED

This Stretch Sensor is a flexible cylindrical cord shown with electrical connectors at each end. The sensor performs like a variable resistor; the more it is stretched the higher the resistance value. This simplistic function and output of the sensor will allow for relatively simple integration and control utilising solid state and/or passive electronic components. Figure 2 illustrates a simple circuit diagram, the basic schematic diagram shows two resistors, an NPN transistor, an LED and a power supply (battery). As the sensor is stretched the Light emitting diode (LED) increases in brightness. The stretch sensor is being tested for its suitability as yarn that can be integrated into both woven and knitted fabric, and used in surface techniques such as embroidery. Variations and combinations with other yarns are being experimented with to develop structures with may enable garments and products to create light or sound emissions. Stretching of the fabric will increase the resistance of the sensor providing a simple 'control' function that is to be investigated for controlling LED's and other electronic devices.

5. MATERIAL-LED INVESTIGATIONS

As stated earlier in the paper, one of the main drivers of the research is the aesthetic potential of the material of the stretch sensor. A strategy for the integration of the rubber cord into other fabrics through lacing, embedding and surface laying was devised to begin our hands-on exploration. These were created horizontally, vertically and in freeform with knit, weave and embroidery techniques (Breedon et al forthcoming). Through these investigations it has become clear that aesthetics, when dealing with functional materials, occur at various levels, which may or may not intersect, but which should not be thought of as inherently superior or inferior to each other. That is, there is an aesthetics of visual impact, of sculptural formal impact, of handle and texture, and of course, in the case of digital materials,

potentially of interaction. Further, we are aware that any of these sensual realms may merge into others synaesthetically.

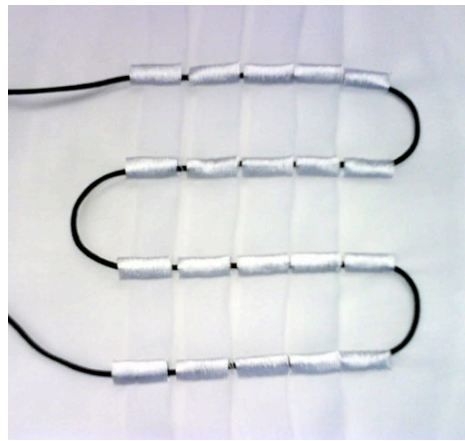


Figure 3: embedding with knit; Figure 4: surface laying with embroidery

6. SPECIFIC CONTEXTS FOR DESIGN

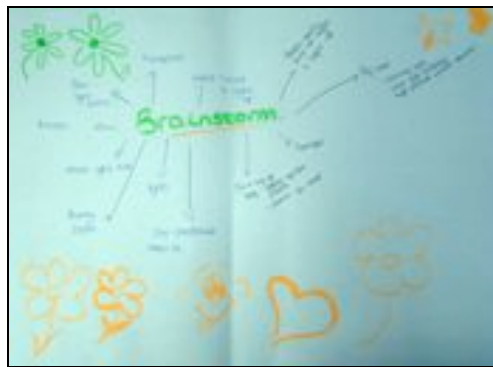


Figure 5: Extreme Materials Workshop, NTU, 10 July 2008: woven fabric as a design prompt and example of brainstorming results

There were (at least) two quite different approaches open to us as ways to design with the stretch sensor, and we understand these to be generalisable for the interaction and wearables technology design communities as a whole. The first is a classic user-centred methodology which considers the needs and use-contexts of a predefined group of users; the second is often referred to as being ‘design-led’ and expressly considers the material and formal properties of a material, technology or process. In interdisciplinary design projects it is the differences between these two broad design philosophies which can cause unexpected problems, or conversely, opportunities. Currently part way through the Technical Textiles project, and having set out our stall to produce designs successful by both sets of criteria, we are continuing to experience and reflect on the emergent methodology those differences force into being. The early material explorations described in the previous section and in Breedon et al (forthcoming) were to some extent proof of concept prototypes, which then led to more assured manipulation of the stretch sensor for its visual impact and ‘handle’ (figures 3, 4). The sample swatches produced could then become ‘props’ in physicalised brainstorming sessions to suggest applications and contexts of use. The first example of this type of brainstorming was a schools workshop designed to introduce teenagers to technical textiles as a potential career path (CELS 2008, The Industrial Trust 2008), and proved to be a rich source of

creative ideas for the project (figure 5). Table 1 below lists a selection of the students' suggestions.

Personal alarm Light sensor Visibility at night via movement Activity wear (biking, riding) Development of disabled children Austin Powers party Drawstring bags Light switches Belt Carpet Kitchen – extractor hoods Wallpaper Advertising Toys Counter in kids' games, wearable Disco lights Stairs in public buildings Bicycle suspension Trampoline Biosensing, health monitoring Recognition in the street Tyres Car dashboard lights up Bouncy castles	Fairground rides Signage Lighting – domestic, street, car Fridge doors Intruder alarms on doors and windows Skipping ropes Sound identification of rooms for the blind Exercise resistance bands Dog leads, with dog whistle response Boob tubes Trying on clothes Baby weight/growth monitor Toddler trainers Tennis racquet strings Hammock Toddler blanket Rape alarm, in belt Musical jewellery, braces Massaging Glo sticks Pressure sensitive walls and floors – light responsive Boat sails – lit at night, wind measurement
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Table 1. Application ideas generated by high school students

Our materials-led approach has so far produced samples, but in the way that textile designers might produce highly resolved work while referencing only the broadest contexts (fashion, interiors), these samples remained outside of any context of use. Because they obviously revolve around a technology, this remains an insufficient design methodology. Creating and responding to a more usual (in product design and interaction design) user-centred design brief challenges us now to discover the next set of understanding, found only in attempting to create a whole product. Two specific applications are being pursued, HUG and Aeolia.

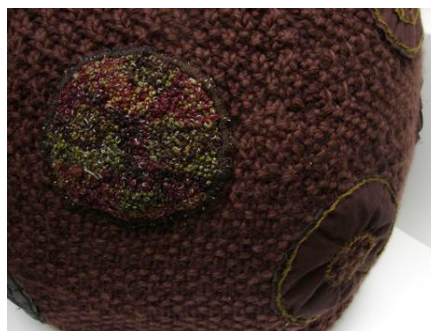


Figure 6: Prototype HUG Autumn 2007

The reactive HUG ball (figure 6) was originally developed by one of the authors for inclusion in an interactive art exhibition and is now being developed for affective care environments and stress relief scenarios (Kettley 2007, Travelling Gallery 2007). Aeolia is an art project which has attracted R & D funding from Alt-w, also

in Scotland, and which seeks to connect sculptural textile works in the landscape with worn pieces in the city (Alt-w 2008).

7. PROTOTYPE ELECTRONICS DEVELOPMENT

The proposal for the development of HUG is based on the varying light intensity as the user hugs the cushion. In terms of operation this is quite straightforward with the light intensity being dependant on the movement of the stretch sensor as described by the simple operation of the circuit shown in Figure 2. The stretch sensor is to form part of the weave of the cushion fabric with the electronic circuitry and power supply positioned and attached in the centre of the cushion. Suitable lighting sources are currently being researched and evaluated based on a flexible LED strip light or emissive optical fibres; examples can be found at Marktech Optoelectronics (2008) and Luminex (2006) (figures 7 and 8).

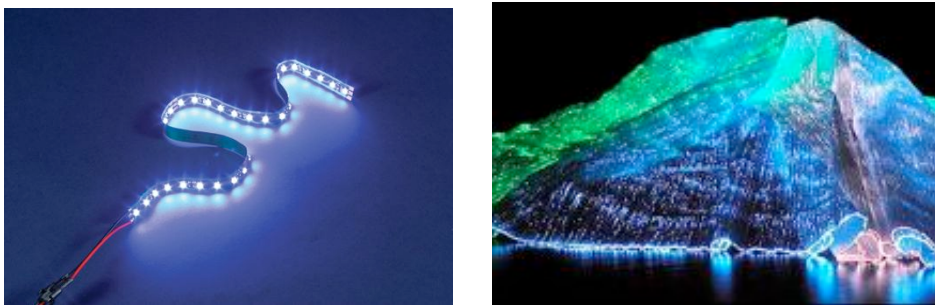


Figure 7: Flexible ultrabright LED lighting strip; Figure 8: Luminex sample

Flexible lighting strips are available in 400mm lengths which may be cut down into shorter 100mm lengths if required, or soldered together end to end to form longer lengths. The lighting and stretch sensor circuit would be powered by a 12v DC supply and extended testing and analysis will verify if a suitable and commercially realistic power source could be identified based on the LED illumination current required to adequately illuminate HUG. It is feasible that hug could be powered by a 240 volt to 12v DC power adapter, linking the cushion by an extended power cord. Whilst limiting the portability of HUG this would of course provide unlimited use of the 'device' whilst attached to a mains voltage supply and also charging HUG if rechargeable batteries were used.

8. FURTHER WORK

The Human-Computer Interaction (HCI) research methodology is currently being considered in consultation with affective care providers for the analysis of HUG with primary and secondary users, and we hope to be able to report on results later in 2009. Aeolia will allow us to bring an art concept to public and academic audiences for experiential feedback of the stretch sensor in different environments, and this will be shown at the 15th International Symposium on Electronic Art in Belfast, also in 2009 (ISEA 2008). In the immediate future we are looking forward to working with two fashion designers to create a series of concept visualisations which will be used as props for further development and dissemination.

REFERENCES

Allwood, J et al ,2006, Well Dressed?: The present and future sustainability of clothing and textiles in the United Kingdom, Cambridge

Alt-w. (2008). Alt-w Awards Announcement. <http://www.mediascot.org/alt-w>. Retrieved 30/09/08.

Beilharz, K. & Vande Moere, A. (2008). Sonic Drapery as a Folding Metaphor for a Wearable Visualization and Sonification Display. In A. Cranny-Francis & C. Hawkins (Eds.), *Visual Communication Special Issue – Wearable Technology*, Vol. 7(3): 271-290. August 2008. Sage Publications.

Braga N C, 2002, *Robotics, Mechatronics and Artificial Intelligence, Solenoids, Servomotors and Shape Memory Alloys*, Newnes, pp.119-135.

Breedon, P., Briggs-Goode, A., Kettley, S. & B. Sparkes (forthcoming). Design Innovation: sensors and fabrication. In *Proceedings The 86th Textile Institute World Conference*, Hong Kong, 18-21 November 2008.

CELS (2008). Nottingham Trent University: Centre for Effective Learning in Science: What Is CELS? http://www.ntu.ac.uk/cels/about/what_is/index.html. Retrieved 20/08/08.

Colchester C, 2007, *Textiles Today a global survey of trends and traditions*, Thames & Hudson:London, p. 56.

Industrial Trust 2008. *Industry and Enterprise Inspiring Young People*. <http://www.industrialtrust.org.uk/>. Retrieved 21/07/08.

ISEA (2008). Call for Papers. <http://www.isea2008singapore.org/ISEA2009CallforPapers.pdf>. Retrieved 30/09/08.

Just Style (2007). Global market review of technical textiles in apparel – forecasts to 2011. March 2007. <http://www.juststyle.com/store/product.aspx?id=48477&lk=ea>. Retrieved 30/09/08.

Kettley, S. (2007). HUG. Jewellerytalks. http://jewellerytalks.blogspot.com/2007_09_01_archive.html. Retrieved 30/09/08.

Lee, S, 2005, *Fashioning the Future*, Thames & Hudson:London, p 121.

Luminex (2006). *Luminex Idea*. <http://www.luminex.it/>. Retrieved 30/09/08.

Mainstone, D. (2008). Haute Tech. Talk given at The Distance Lab, Scotland. 20 May 2008.

Marktech Optoelectronics. (2008). www.marktechopto.com_ Retrieved 30/09/08.

Mattila, H. R. (Ed.) (2006). *Intelligent Textiles and Clothing*. Cambridge, UK: Intelligent Textiles and Clothing. Woodhead Publishing in association with The Textile Institute.

Merlin Robotics (2008). Two world firsts for British ‘Robosnake’. http://www.merlinrobotics.co.uk/merlinrobotics/newsdesk_info.php/newsdesk_id/24. Retrieved 20 August 2008.

Nike (2006). Nike and Apple Team Up to Launch Nike+iPod, Global Collaboration Brings the Worlds of Sports & Music Together Like Never Before. <http://www.apple.com/pr/library/2006/may/23nike.html>. Retrieved 30/09/08.

Travelling Gallery. (2007). Access All Areas. <http://www.travellinggallery.com/default.aspx?location=61b356e9-4811-443e-a075-1b4fad8e7b14>. Retrieved 30/09/08.

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