A Wearable Technology Project

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Abstract

Wearable technology is an exciting emerging area with the potential to be hugely significant in the way we interact with clothing and electronic technology. Knowledge and skills from a combination of disciplines including computer science, electronics, textile technology, garment and product design are essential for the area to flourish.

A presented case study explores design considerations and processes involved in the development of a wearable electronic jacket containing a lighting system aimed at enhancing the safety of city cycling commuters. Practice based research with an experimental approach to smart clothing and electronic integration was used to form a technical framework in which the requirements of the end user were addressed.

The paper highlights practical considerations and project insights which have lead to the identification of collaboration, project planning and user centred design focus as essential ingredients to those involved in wearable electronic projects.

Introduction

The terms 'smart textiles', 'smart clothing' and 'wearable electronics' have become increasingly familiar in recent years. Developments in new fabrications and yarns combined with the availability of small, lightweight electronic devices present fresh possibilities to how we may interact with the clothes we wear. Dr Patricia Wilson poses an optimistic view surrounding the potential of smart textiles and wearable electronics. *"No longer can we look at a piece of cloth and think of it as technology as old as time. We must start to realise that it holds infinite possibilities when put into the hands of a creative team who strive to answer the question, 'What if?'"* (Wilson 2005, 209). Turning possibilities into a reality is the challenge to those involved in wearable technology, one only has to spend a few minutes on the talk2myshirt wearable technology website to get a sense of how innovative designers are responding to the 'What if?' question. Projects range from socially responsible applications such as a wearable electronic health monitoring system and a renewable power supply bag aimed at assisting third world countries, right through to fun items like illuminated flip flops. Developments such as fabrications that respond to light, use of solar power, and sensors able to respond to sound and mood changes, are just a snap shot of an eclectic list of current endeavours that may play a part in the future.

The work highlighted in this paper explores such technology and contains insights and research experiences gained while developing the final stages of a practice based design project entitled 'City Centred Cycling'. The project, completed in 2009, was specifically targeted at enhancing the safety of city cycling commuters with the aim of developing a wearable electronic jacket. The key factors that were considered were that the jacket should be comfortable to wear, offer protection from wind/rain and be highly visible to traffic.

The research focus explored the design processes and considerations associated with the introduction of wearable electronics, in particular the integration of an LED electronic lighting system to increase visibility to motorists. On a personal level the study was carried out using an experimental action research framework used to gain electronic experience to complement my existing technical and fashion design understandings related to cycling. While the project presents work specifically targeted at cycle commuter use, the electronic integration information presented is transferable for fellow researchers exploring the inter-disciplinary nature of wearable electronics.

Research Significance

The research significance of the project was based around the inter-disciplinary concerns that embrace the field of wearable electronics. In recent years there has been a small increase of commercial product available, yet there remains lack of accessible research material that is devoted specifically to the implementation of the discipline. Specific research material discussing actual practical steps for wearable technology integration is particularly limited. Reasons for this lack of accessible knowledge include commercial confidentiality and intellectual property issues which prevent access to existing product details and design process. More importantly the bodies of knowledge required for wearable electronic integration currently exist in separate domains, mainly fashion design and manufacture or electronic engineering.

The field of wearable electronics is a growing discipline that draws expertise from a mix of related areas, but at this stage a common location to house this new field of expertise does not exist. There are a range of possible factors for this; the relative newness of this field of research, the range of possible technology applications, the interdisciplinary nature of the field and the location of where such research should be placed. This particular research contribution shares understandings and insights that have surfaced as a result of the practice based design approaches and aims to contribute to the growing body of knowledge that is being built around wearable electronics.

Wearable Technology Strategies

Professor David Smith, co-organiser of the 'Wearable Futures' Conference held in Newport, South Wales in 2005, defines the area as "…an emerging trans-disciplinary field bringing together concepts and expertise from a variety of disciplines, ranging from materials science, through computer engineering to textile design" (Smith 2007). Thus far, product innovation and development in textile and electronic technology have been combined to create some specialist wearable electronic items that have tended to feature in the health and sportswear sectors. While it is becoming increasingly apparent that the emergence of the discipline within the commercial sector is still some way away, Smith points out "One is struck by the obvious fact that very little of what is shown appears to be actually 'wearable'. Many excellent ideas do not seem to make the transition from laboratory 'bread-board' prototype to marketable day-to-day application" (Smith 2007, 1).

Smith proposes a theory for this lack of cohesion from concept to final product, suggesting that there may be a lack of understanding by industrial designers and engineers about the technical aspects of fabrication, clothing manufacture and ergonomic body fit. Other considerations are that the specialist fields of electronics and fashion/textiles have different approaches to design and strategic thinking leading to creative and communication boundaries. All of which points towards the need for clear project strategies to deal with the level of complexity involved. Ariyatum and Holland (2005) propose a "new product design" model emphasising the value of focussed collaboration with balanced viewpoints in order to achieve full integration of electronics and fashion, described as "the ultimate goal of smart technology". Further research by Bougourd, McCann & Stevens (2010) adds considerable support for collaboration using user centred design processes. Both cases highlight that by focussing on the intended user the necessary combination of skills and expertise required for successful wearable technology integration can occur.

Design with Purpose

In order for the field of wearable electronics to progress beyond a vehicle to promote electronic gadgets, there is a suggestion that a designer should seriously consider the relationship between wearable electronics and its perceived need in society.

While technology such as a solar panelled bag to electrically charge a laptop, cell phone or MP3 player may have appeal and can certainly be useful, perhaps we should ask some key questions about whether the innovations could move beyond extensions of our existing technology?

The following questions may stimulate discussion to help establish a clear rationale:

- Why should an electronic device be added to a garment?
- What is the purpose of the integration?
- What are the benefits or value to the wearer?

Current research from the 'Smart Clothes and Wearable Technology' research team at University of Wales, Newport, UK concentrates on the full engagement with an older user group to ascertain if and how the introduction of smart wearable technology could enhance quality of life for the elderly. This UK government funded project is targeted to respond to the needs of the elderly community, where issues such as healthcare, mobility and communication may take on different meanings to that of a younger demographic. The project still has some way to go, but will be interesting to monitor the creative and technical responses by the design team developing from this classic 'user centred' product design approach.

Some of the more successful commercial implementation of wearable electronic products also have a strong link with their intended user group. This point is particularly evident in the sport of snowboarding where the use of wearable technologies is linked directly to the sport's youthful identity and understanding of emerging technologies. A clear illustration of this can be drawn from the comment made by Bryan Johnston, Vice President of *Burton*'s Global Marketing; "Music and technology are a huge part of the snowboard culture" (2008). Burton have made the connection that the new sport of snowboarding has its own identity and that young participants are in tune with new developments and show a responsiveness to adapt to new wearable technologies.

Figure 1. The Burton Audex jacket is a joint venture between Motorola and Burton snowboard apparel. The jacket offers wearable communication and entertainment via integrated Bluetooth wireless technology to download music via Bluetooth-enabled phone or portable.

To date the use of wearable technologies has predominantly featured within the specialist areas of healthcare, military and high performance sportswear. New Zealand based company Zephyr Technology have successfully positioned themselves to respond to these areas by specialising in development of smart fabric based technology. Their product range concentrates on high spec heart and breathing monitors. The potential of this technology was fully realised in Sept 2010 when Zephyr Bio Harness products were sent underground to trapped Chilean miners to monitor their health and condition leading up to and during the dramatic rescue at Copiapó.

This success story is of particular significance to staff at AUT University's Textile and Design Laboratory (T+DL) who were involved in a cross disciplinary research partnership with Zephyr engineers in 2008/9. The convergence of electronics and textile expertise during the course of this partnership demonstrated how seemingly non-aligned industries can learn and work together given a common objective, in this case to enhance the aesthetics and wearability of the Bio Harness wearable electronic product, later used in the mine rescue.

Figure 2. Refined BioHarness with additional shoulder strap
Figure 3. Zephyr/AUT integrated base layer garment

A second research project concentrated on the identification of lightweight, breathable yarns with high levels of conductivity which were used for the development stages of a high performance electronic integrated base layer garment containing bio monitoring sensors. The necessity to draw on numerous specialisations places the field of wearable technology as a perfect platform on which to base collaborative projects.

High Tech / Low Tech

As we await widespread use of wearable technology, an interesting phenomenon has emerged as an increasing number of enthusiasts experiment with wearable technology instead of waiting for commercial companies to come up with the ideas. Leah Bueachly from MIT Media Lab, USA, and developer of the Arduino LilyPad system, describes this as the 'democratisation of technology'. On a recent visit to New Zealand she said "I believe the democratisation that we've seen in the software universe that enables people to become journalists and photographers is coming into the physical world" (Bueachly 2009).

The LilyPad wearable electronics system and other Arduino products have provided a platform on which DIY enthusiasts can trial and experiment with electronics in a fun way, essentially simplifying a lot of the complex computer programming and connectivity normally associated with electronics expertise. The 'hands on' theme of Buechley's presentation argues that technology is no longer only in the hands of large companies and that with the advent of the internet, "Online communities devoted to hobbies from crafting to electronics tinkering – where people share designs and construction tips – are flourishing" (Ibid).

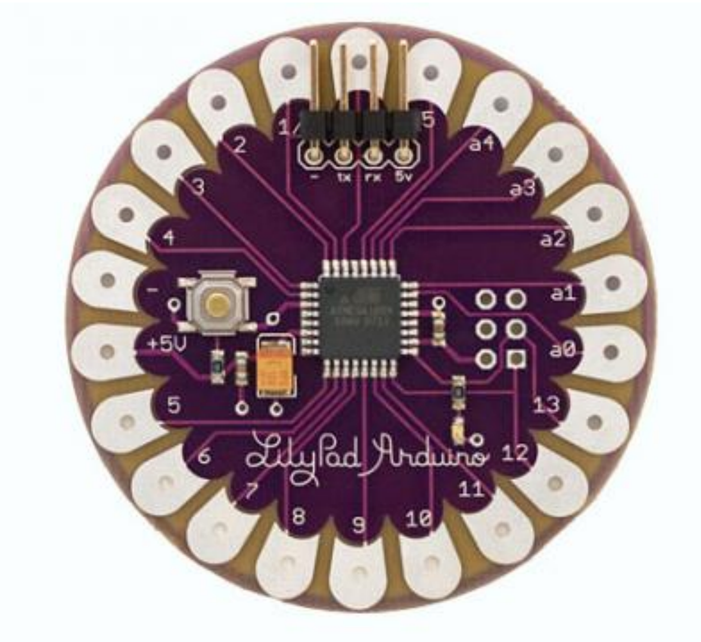

Figure 4. Arduino LilyPad Main board

Many amateur enthusiasts now feel empowered to share ideas and developments within this growing social network, which has become an integral part of promoting the growth of wearable technologies. Websites such as www.talk2myshirt.com and www.fashioningtech.com are just two examples that attract a worldwide following. Publications such as 'Fashioning Technology: A DIY Intro to Smart Crafting' by Syuzi Pakhchhyan (2008) and 'Fashion Geek' by Dianne Eng (2009) present practical approaches and design considerations to encourage new converts to experiment with the possibilities of wearable technology.

Brief Outline of Early Project Research

Preliminary work for the 'City Centred Cycling' project required a personal introduction into the study of electronics to gain a level of confidence that could complement my existing technical and fashion design understandings related to cycling. The initial phase was conducted with the support of an electrical engineering student, and the study was carried out using an experimental action research framework. Essentially this meant that as an active cyclist I was able to test and refine prototypes before leading to further developments.

Figure 5. Cable and circuit board placement
Figure 6. Testing early LED Jacket

Despite experiencing technical difficulties related to durability and weight, the results incorporating a cell phone key pad had a degree of success. Importantly, understandings of clothing and electronic integration were starting to emerge, although limited collaboration restricted my personal understandings of electronics. This issue was resolved with the release of the previously mentioned LilyPad system, part of the Arduino group, an open source electronics prototyping platform containing electronic instructional information. The system is essentially a wearable minicomputer that contains a programmable micro processer that can be linked to a variety of components such as LEDs, switches and touch, light or sound sensors. An additional attraction was the use of conductive thread as an alternative to electrical wire as a means to transmit an electrical signal from the control panel and power source to the LEDs.

Conductive thread

Conductive threads are typically nylon or polyester based yarns that are spun with metallic elements such as silver or stainless steel. Despite the metallic properties they remain soft, light and flexible. In theory there are a number of advantages to using this method of signal transfer, such as the elimination of soldering associated with wire, and the thread can also be sewn directly to fabric ensuring unrestricted natural movement to the wearer. However the actual process of working with conductive thread requires some experimentation. Critical aspects for consideration relate to the exposed nature of the conductive elements; for example, reduction of current occurs over 30cm, and two threads touching can cause the electronic signal to short circuit, so careful planning of seam and thread positioning are essential.

Figure 7. Four ply conductive thread

Early project reflection

These early integration experiences with the LilyPad system proved valuable in gaining confidence in working with electronics. Experimentation led to the development of a working method for the transmission of electrical signals. The method used seam channels on which conductive thread could be discreetly sewn on the inside of the garment.

The following points went on to influence later work:

- Seamed panels containing electrical current should follow straighter lines or a gentle arc to avoid short circuiting or disrupted signal from circuit board.
- Re-designed technical seam lines can present design aesthetic possibilities.
- Limitations of conductive threads led to a decision to revert back to light weight, flexible electronic wiring.
- To eliminate the risk of wire breakage an epoxy resin covering was applied to form a rubberised seal at electrical junction points.

City Centred Cycling Case Study

The intention of the final phase was to show the refinement of the research in relation to the original aim of the project which was to produce a wearable electronic jacket specifically aimed at city cycling commuters. The working methods used for the creation of the final piece involved a variety of high tech methods specifically introduced to give the work a professional finish. Another important factor to the success of the project was the decision to seek expert advice in the form of consultation with an electronics professional to help take the project beyond my personal electronic limitations. For the jacket to function well, the following electronic improvements would be required: the overall reliability of the operating system, ease of operation, weight and size reduction. The consultation process involved four phases, firstly to discuss design ideas, requirements and project planning. This was followed up with two further prototype electronic testing stages before the final implementation was carried out.

Prior experiences had led to the realisation that effective design planning was a key component to the success of the project and indeed future wearable electronics work. This recognition was based on the contention that a designer in this field should consider the effects electronics can have on a garment and the effects a garment design can have on the electronic integration process. Questioning design decisions in a holistic manner can lead to more effective planning, thus increasing the likelihood of project success. An example of this would be questioning the effect on electronic wiring of applying heat sealing tape to garment seams (involving high temperatures and use of pressure) to create a more functional, waterproof garment.

Introducing new technology

Much of the attraction of modern electronics is based on the reduction of scale and weight of products; for example, small cell phones and portable sound devices. It is fair to say that the field of wearable electronics shares similar concerns particularly to ensure that a wearer does not experience physical discomfort when carrying an electronic device. Therefore, appropriate use of design technology should be considered to deal with scale, precision and accuracy. The introduction of technologies such as computer laser cutting and digital print detail not only deal with technical issues but present design opportunities. Digital design elements of the jacket design were imported, developed and transferred into a number of different computer programmes and output devices including:

- 3D visualisation software to revise fit and detailing
- Computer fabric cutting
- Screen printing to apply reflective ink detail
- Digital printing for graphics and design detailing
- Laser cutting of plastic battery housing

3 D visualisation

Figure 8. V Sticher Grid mapping
Figure 9. V Sticher Rendered image

3D visualisation software was used for style development, in particular to revise fit, and position LEDs and print detailing. The particular software, Gerber V Stitcher is a 3D virtual prototyping programme developed by Bronzerwear in South Africa; it is intended for fit, styling and fabrication analysis. The commercial use of this technology is aimed at eliminating the costly sampling process and creating a sharing interface between designer and customer. It is especially useful for individual client customisation. The direct interface to computer pattern shapes for this project enabled sizing information, fabric and construction details to be mapped to a selected avatar, offering 360 degree viewing of various positions including active sports poses, in particular an appropriate cycling pose. As a result, the final jacket shape adopts a specific non conventional fit aimed at providing comfort to the wearer when cycling; the torso is bent forward from the hip while arms positions are angled to hold handlebars.

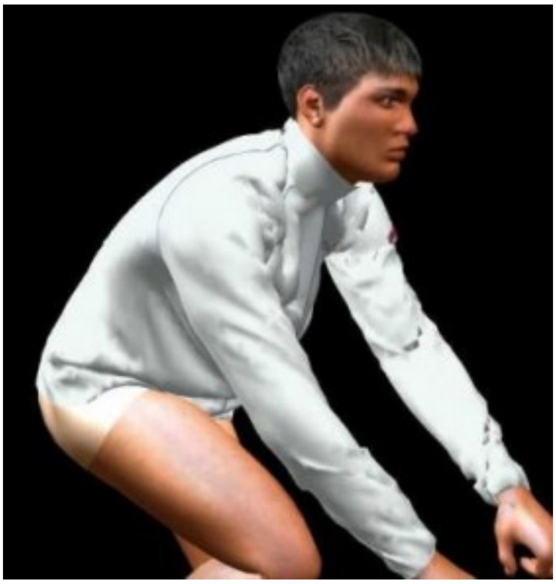


Figure 10. 3-Dimensional rendered image in cycling position
Figure 11. Comparison with actual finished item

A critical point learnt from earlier work was that the simplification of seam lines could aid the electronic integration process. The pattern shaping for the back panels of the white jacket follow a gentle arc between the lower back where the electronics are housed to the LED position on the sleeves (Fig 13). This method proved to be successful as it eliminated the sharp angles and stress points that could cause electrical wire breakage. Likewise, the implementation of exposed conductive thread integration would benefit from this recommendation to prevent the risk of short circuiting or disrupted signal from circuit board.

Figure 12. Back panel seaming angles
Figure 13. Example of computer art work and digital fabric print application

The use of technology created a smooth and accurate transition from concept to final execution. The digital artwork for the jacket was designed to complement the pattern shapes used for fit, styling and electronic integration. The accuracy obtained by both computerised cutting and digital printing methods, which was extremely precise, ensured that a partial garment could be made in anticipation of electronic integration.

Electronic process

The physical process of creating a purpose built LED lighting system was carried out with the assistance of an electronics expert. Programming the micro chip and micro processer which sends an electronic signal to the LEDs was carried out using an industrial programme development kit called Programmable Interface Control (PIC) by Microchip solutions. While the complexity of the process required an experienced operator, the conceptual similarities to the programming of the LilyPad system were striking. Essentially this involves programming a code which then sends an instruction to an electronic component. Specific code programming was particularly useful for the design functionality of the soft touch on/off button and light sequence.

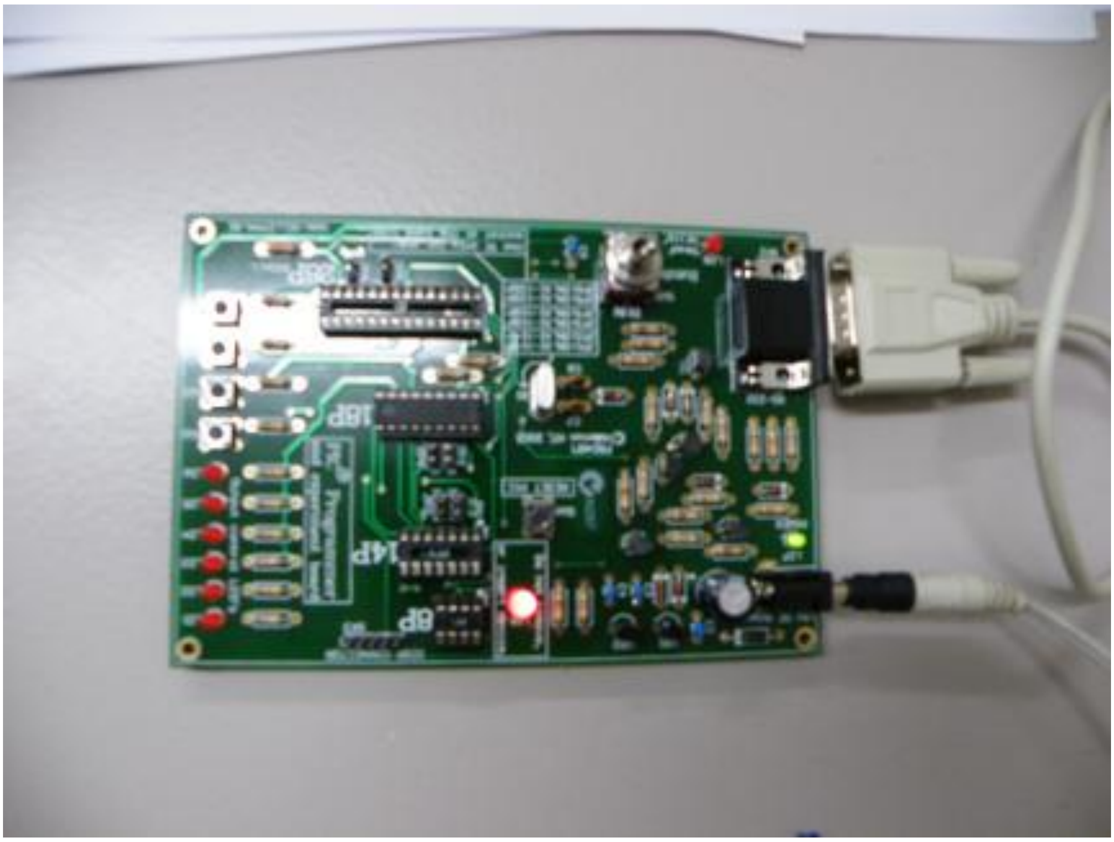

Figure 14. Programmable development kit

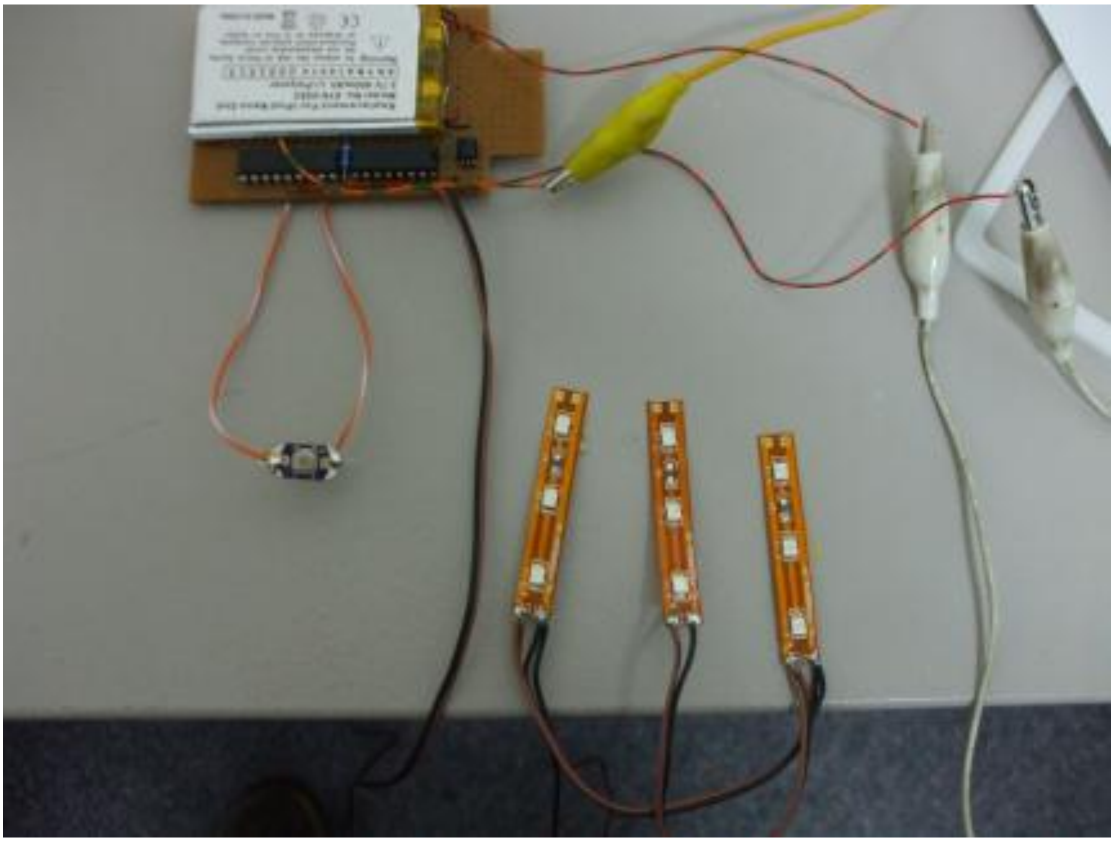

Figure 15. Test phase of lighting system

A single touch on/off button was positioned beneath artwork and fabric of the left sleeve. A single push wakes the system up and starts the flashing LEDs, a second touch reverts back to sleep mode. This simplicity allows for easy operation when cycling, particularly in winter if gloves are worn.

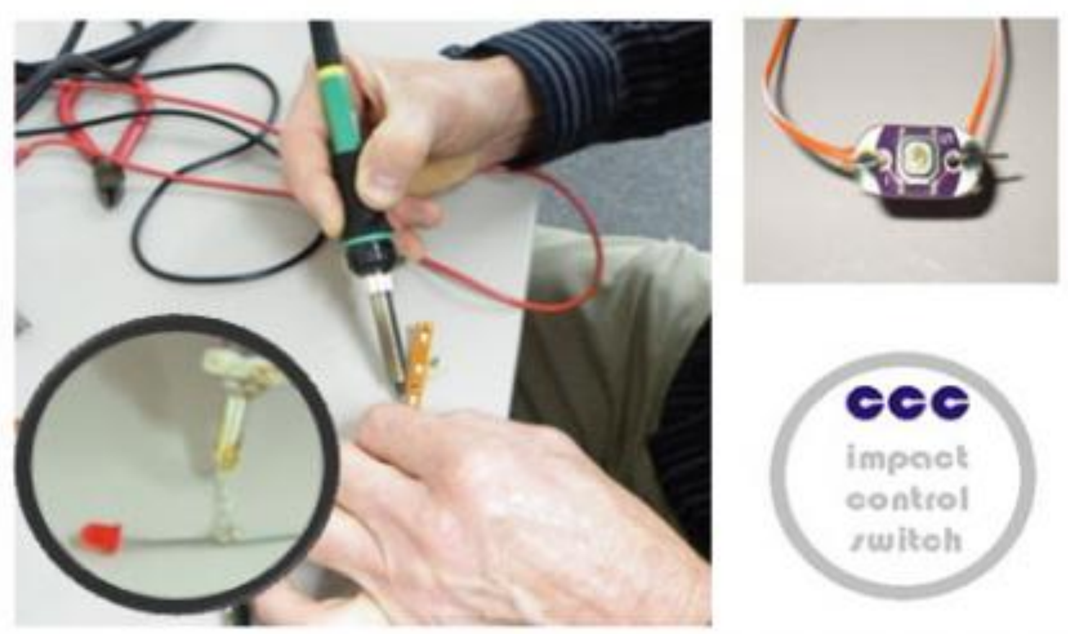

Figure 16. Securing LED’s to electrical wire and the LilyPad on/off button mounted on sleeve

Some programming experimentation with the flash sequence led to power saving. It was determined that an LED flash sequence attracts more attention to motorists than a permanent light and important energy savings are made with every millisecond the lights are off. The life of 2 x 3.7 volt lithium polymer batteries to permanently run 9 LEDs would be 8 hours, but for a 50%-on 50%-off sequence this is doubled to 16 hours. Experimentation finally led to a 10%-on 90%-off ratio, increasing the battery life to 80 hours before recharging was required. Remarkably the red light appears to stay on for much longer due to the speed of the flash and the light delay effect on the human eye.

Electronic integration and garment assembly

By planning how the electronics would fit into the garment the actual electronic integration and garment assembly was simplified. The techniques referred to earlier; smooth seam lines to house electronic cables, computer cutting for accuracy, digital print detail stitch guides for the zip pockets and LED windows, were all included with this aim. Another consideration was the use of transparent plastic placed and sewn to create a protective surface for the LEDs.

Figure 17. Close up of LED sleeve detail

Figure 18. Inside detail showing French seam and cables

A construction method known as 'French seaming' was used for two reasons; firstly the seam finish catches the raw edge of the seam within the seam allowance reducing the risk water penetration. Secondly the seam procedure creates a channel in which electronic cabling can easily be housed. Cabling was positioned in the back/sleeve seam channel and electrically connected later (Figures 19 and 20 show this method applied to left sleeve).

The final electronic connection and adhesive sealing to position LEDs took place after the main garment construction stage. The finalisation of the jacket involved the insertion of a mesh lining and the completion of the pocket detail to house the purpose-built lighting control unit. The unit contains the micro controller, batteries and connector sockets to link to the jacket.

Figure 19. Inside detail showing opening of control pocket detail and sleeve LEDs

Figure 20. Finished front detail showing unit pocket

The location of the plastic covered control unit was located on the inside lower back of the jacket. The position was chosen for electronic ease but presents no discomfort when worn. Figure 21 shows how the specifically designed pocket was cut to exact size with a padded lining to support the unit. A Velcro flap opening conceals the cable connectors and allows for easy access to recharge or remove the unit as required.

Figure 21. Final electronic jacket
Figure 22. Field testing of jacket

Conclusion

Research throughout the project helped to develop electronic confidence, technical communication and understandings of wearable technology, and as such, influenced the approach taken to the refinement stage of the project. The case study presents some practical advice while the following section offers some considerations for fellow researchers embarking on a wearable electronics projects.

Collaboration

My experiences led me to understand that wearable electronics projects can be complex; the time required to combine the technical and design issues from the separate disciplines alone suggests that it would be difficult for any individual or organisation. The value of input, feedback and advice from field experts cannot be underestimated. Therefore, a collaborative approach with focussed outcomes is recommended. If possible, designers should spend some time in all disciplines to establish terminology, protocols and procedures to develop a common language for this new specialist field. The necessity of drawing on numerous specialisations places the field of wearable technology as a perfect platform on which to base collaborative projects.

Design with purpose

In the case of the City Centred Cycling project, a human-centred approach helped to establish a focus in which electronics and clothing considerations could combine with a common goal. Designers involved in wearable electronics projects should adopt a holistic approach to take into account the various possibilities presented to them and, most importantly, be aware that a decision made for electronic purposes may have an effect on the overall garment. Similarly, a change made to garment design may have an effect on the electronic integration process.

Planning and resources

Effective project planning is critical as a major contributor to the success of a wearable electronics project. The complex nature of working in this cross-disciplinary area means that there are so many different approaches that can be taken. I suggest that adequate time and resources are built into project planning to allow for experimentation, reflection and questioning, leading to further development. Resource and product availability is of prime importance, particularly if the finished item is to be of a professional or commercial standard.

Sourcing raw materials can be difficult because, in general, most electronic components are not designed to be used in clothing and as result they are physically hard and may need to be adapted to be accommodated within a garment. Electronic considerations should include choice of components, operating platform, electronic signal method (wire, conductive thread, Blue-tooth, etc.) and power source. Clothing considerations should include garment type, fabric choice, trims and components.

Smart future

At its simplest level, any portable electronic device could be placed on an existing garment but this does not make it a 'smart garment'. The 'smart' label only applies when a designer's approach becomes much more considerate towards the desired functionality. The design integration should consider the relationship between the soft fabric, hard electronics and most importantly how the user connects with the end product.

For the foreseeable future, integration methods such as the ones used in this project may be used, but eventually technical developments to create a blend of soft electronic based textiles will make the current methods seem clumsy and outdated. Indeed, Power Textiles Ltd in Scotland is currently working on the development of flexible textile fabrics into which solar cells will be directly incorporated. This exciting prospect relates back to Patricia Wilson's quote at the beginning of this paper:

> *"We must start to realize that it holds infinite possibilities when put into the hands of a creative team who strive to answer the question, 'What if'?"*

Glossary of technical terms and processes

Conductive Thread: Textile yarn containing metallic elements such as silver or stainless steel. The metallic properties allow for the transmission of electrical signals.

French seam: A seam stitched first on the right side and then turned in and stitched on the wrong side so that the raw edges are enclosed in the seam.

LEDs (light emitting diodes): A semiconductor diode that converts applied voltage to light and is used in lamps and digital displays.

Micro Processor: An integrated computer circuit.

Smart Fabrics: Textiles capable of sensing and responding to external stimuli, such as changes in the lighting or temperature.

Solder: Joining two metals together by using a soldering iron.

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