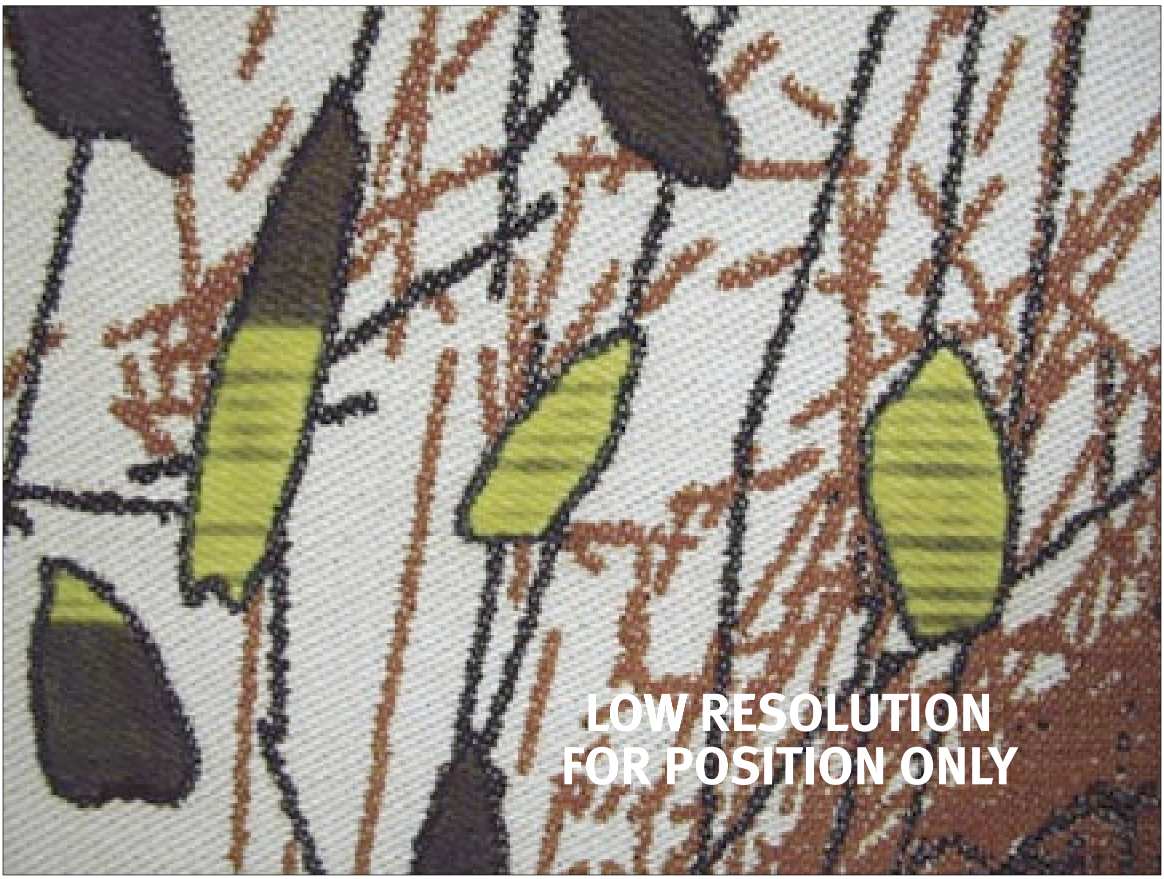
Electronic Textiles: Wearable Computers, Reactive Fashion, and Soft Computation



Abstract

Electronic textiles, also referred to as smart fabrics, are quite fashionable right now. Their close relationship with the field of computer wearables gives us many diverging research directions and possible definitions. On one end of the spectrum, there are pragmatic applications such as military research into interactive camouflage or textiles that can heal wounded soldiers. On the other end of the spectrum, work is being done by artists and designers in the area of reactive clothes: "second skins" that can adapt to the environment and to the individual. Fashion, health, and telecommunication industries are also pursuing the vision of clothing that can express aspects of people's personalities, needs, and desires or augment social dynamics through the use and display of aggregate social information.

In my current production-based research, I develop enabling technology for electronic textiles based upon my theoretical evaluation of the historical and cultural modalities of textiles as they relate to future computational forms. My work involves the use of conductive yarns and fibers for power delivery, communication, and networking, as well as new materials for display that use electronic ink, nitinol, and thermochromic pigments. The textiles are created using traditional textile manufacturing techniques: spinning conductive yarns, weaving, knitting, embroidering, sewing, and printing with inks.

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Electronic Textiles: Wearable Computers, Reactive Fashion, and Soft Computation

Electronic textiles, also described as smart fabrics in popular media, have become quite a fashionable research area. An electronic textile refers to a textile substrate that incorporates capabilities for sensing (biometric or external), communication (usually wireless), power transmission, and interconnection technology to allow sensors or things such as information processing devices to be networked together within a fabric. This is different from the smart textiles that feature scientific advances in materials research and include things such as better insulators or fabrics that resist stains. Electronic textiles allow little bits of computation to occur on the body. They usually contain conductive yarns that are either spun or twisted and incorporate some amount of conductive material (such as strands of silver or stainless steel) to enable electrical conductivity.

The field of electronic textiles combines the worlds of textiles and electronics, and explores techniques that redefine construction methods and streamline production processes. Its close relationship with the field of computer wearables leads to many possible intersections and diverging research directions. On one end of the spectrum, there are pragmatic applications such as military research into interactive camouflage or textiles that can heal wounded soldiers. On the other end of the spectrum, work is being done by artists and designers in the area of reactive clothes: "second skins" that can adapt to the environment and to the individual. Fashion, health, and telecommunication industries are also pursuing the vision of clothing that can express aspects of people's personalities, needs, and desires or augment social dynamics through the use and display of aggregate social information.

Whereas textile research is often motivated by consumer demand in the fashion or interior design industries, electronic textile research remains heavily influenced by funding sources and policy decisions. Many current projects and applications reflect the funding structures and interests of the consumer electronics industry, the military, or the health industry and are predicated on advances in health monitoring or biometric sensing, the need for time management devices, and growing security concerns. What is often forgotten in current research is the intimacy of textiles, their close proximity to the body, and their potential for personal expression and playful experimentation.

Wearable Computers

My first exposure to wearable computing occurred as a graduate student at the MIT Media Laboratory. I was working in close proximity with cyborgs such as Steve Mann who define wearable computing as the act of wearing a computer on their bodies. They are motivated by their claim that personal computers have not lived up to the promise of being truly personal machines insofar as they are not sufficiently integrated into our personal, social, and cultural sense of self.

The current Wearable Computing Lab at MIT, called the Borglab, focuses on the idea of incorporating a personal computer into one's daily wardrobe to allow ubiquitous access to computational power and universal connectivity (MIThril 2004). The computer is decomposed into individual components (such as the motherboard, batteries, and wireless communication card), which are repackaged and distributed around the body in pockets. Instead of a computer monitor, cyborgs use various kinds of head-mounted displays, attached to hats, glasses or straps. For input, they use unobtrusive input devices such as the Twiddler, a combination keyboard and mouse that fits in the palm of the hand and incorporates an ergonomic keypad designed for pressing several keys simultaneously, or "chord" keying, to generate a unique character or command (Handykey 2004).

Together with personal wireless local area networks, communication tools, context-sensing software, and communities of colleagues (intellectual collectives), the wearable computer can act as an augmented reality "intelligent" personal assistant. For example, the Remembrance Agent (Rhodes 1997) is a wearable proactive memory aid and data system that continually reminds the wearer of potentially relevant information based on the wearer's current physical and virtual context.

The wearable computing vision implies that people in the future will wear personal computers in the same sense that we wear clothing, in order to facilitate context-dependent interactions with the world and the people in it.

The Meaning of Wearable

It is ironic that although they are powerful, these wearable computers are not very wearable. Their various components are made of hard plastic, metal, and silicon. They are heavy and angular. Their weight is uncomfortable for extended use and the advantages of wearing such devices are not clear to a majority of people.

The transition of the computing device from the desktop to the body is a physical leap that also requires a conceptual leap. Materials need to change, functionality needs to evolve past the point where wires hang along the user's body, and the computer housing (the clothing) needs to be more attractive. Most importantly, the wearable computer needs to be less fragile. Users who wear such a thing should be able to do so without the fear of hurting their wearable. They should be able to run, jump, dance, and push their way into a crowded subway. They need to wear the computer easily and effortlessly, without the fear of dropping or breaking the components. Furthermore, it should not be awkward, or dangerous, to get caught in the rain.

In order to become wearable in the same way that a cashmere sweater or a pair of Spandex pants are wearable, wearable computing needs to integrate and assimilate ideas and methods from another wearable technology, one that is thousands of years old and much more appropriate for housing the body. In order for the wearable computer to be more wearable, it needs to be knit onto the body and conductive yarns need to replace wires.

Textiles, whether knit or woven, are tougher, more flexible, more durable, and much more wearable than a printed circuit board (Post *et al.* 2000: 218–24). Textiles have mechanical, aesthetic, and material advantages that make them ubiquitous in both society and industry. The woven structure of textiles and spun fibers makes them durable, washable, and conformal, while their composite nature affords tremendous variety in their texture for both visual and tactile senses (Post *et al.* 2000: 218–24). Electronic textile research aims to combine wearable computing with textiles and move towards the vision of a seamless integration of computation on the body. There have been many technological innovations in the field of electronic textiles in the past twenty years, many of them driven by military research in the US. These innovations are starting to trickle down into consumer applications.

Military Research

The genesis for much of the current electronic textiles and wearable computing comes from technological innovations developed through various well-funded military programs. The Objective Force Warrior Program at the Natick Soldier Center in Massachusetts and the MIT Institute for Soldier Nanotechnologies (ISN 2004), founded in March 2002 with a $50 million contract from the US Army, are two such programs expected to produce ideas and innovations that will percolate down to future commercial and artistic applications.

Electronic textile research into better and stronger soldiers includes the development of integrated sensor arrays and various embedded sensing technologies for deployment in clothing, backpacks, tents, or vehicles. Sensing can function both inward and outward. Biofeedback can track a soldier's vital signs to enhance endurance and overall health, such as socks with pressure sensors that alert you to put your feet up to lower blood pressure (Voss 2001). Environmental sensing can detect enemies or potential biochemical threats, such as a woven conductive fabric with embedded button-size microphones that detect the sound of remote objects such as approaching vehicles (Dean 2002). By comparing the sounds from each microphone, a microcontroller can algorithmically determine the direction of the sound. The fabric, woven using existing textile manufacturing methods, allows for the construction of very large computing systems with integrated sensors and power supplies. Currently, pockets in the fabric hold batteries to power the system but scientists predict that future circuit boards and batteries will be woven directly into the material.

A second active research direction involves smart, dynamic, responsive, or interactive camouflage: uniforms that possess chameleon-like qualities and can change color when a soldier moves from a desert environment to an urban one. This exciting area of research will lead to many applications for visually adaptive clothing that displays personal information or changes according to mood, time of day or other internal or external input.

A third major direction, leveraging nanotechnology research, consists of textiles that can facilitate medical diagnosis, provide treatment, and endow the soldier with improved strength like an exoskeleton. Current research includes bandages that warn of the beginnings of an infection and even identify the responsible bacterium and the appropriate antibiotic needed to treat it (Voss 2001). Longer term projects include textiles for chemical suits that can automatically self-repair if torn.

Electronic, computer, and communication devices are also being woven into fabrics so the materials can react automatically to stimuli. MIT's ISN (2004) focuses on technology that can make soldiers less vulnerable to enemy and environmental threats. The ultimate goal is to create a futuristic battle suit that combines high-tech capabilities with light weight and comfort. Projects include the study of deformation and failure in high-performance fabrics, in order to develop new ways to provide the future soldier with superior ballistic protection as well as the development of microbicidal, antiviral, and antisporal fabrics and other materials (ISN 2004).

Biofeedback and Wearable Health Monitoring

According to a 2002 market study, worldwide shipments of fabric-based wearable products are expected to total over $47 million in 2006. Textile-based biomonitoring products are expected to reach the market for medical, public safety, military, and sporting applications sooner than that (VDC 2002). These products will be designed to monitor the wearer's physical well-being and vital signs such as heart rate, temperature, and caloric consumption.

Companies such as BodyMedia already offer wearable products to collect, store, process, and present physiological and lifestyle information such as calories burned, personal activity levels, and sleep states (Bodymedia 2004). FitSense focuses more explicitly on performance monitoring systems for runners and walkers that provide instant feedback on speed, distance, and heart rate (FitSense 2004). VivoMetrics produces the LifeShirt vest with embedded electrodes for heart monitoring and three conductive bands that gauge the movement of the heart and lungs from changes in their magnetic fields (Vivometrics 2004). Their sensors record more than forty health parameters, both vital signs and indicators of psychological state, like sighing. A belt-mounted device records the data and can send it to a doctor who might notice dangerous patterns and adjust medications accordingly (Hardesty 2001).

The SmartShirt System developed by Sensatex incorporates advances in textile engineering, wearable computing, and wireless data transfer to permit the convenient collection, transmission, and analysis of personal health and lifestyle data. Leveraging electronic textiles research, Sensatex has developed proprietary interconnection technology to allow sensing, monitoring, and information processing devices to be networked together within a fabric (Sensatex 2004). Originally developed for the US Navy, the SmartShirt can expedite diagnosis and medical intervention of wounded soldiers on the battlefield. The protective garment is capable of detecting the penetration of a projectile, monitoring the soldier's vital signs, and alerting medical triage units stationed near the battlefield (DARPA 2004). Described as "the shirt that thinks," the SmartShirt measures and/or monitors individual biometric data—such as heart rate, respiration rate, body temperature and caloric burn—and provides readouts via a wristwatch, personal digital assistant (PDA), or voice synthesis. Biometric information is wirelessly transmitted to a personal computer and ultimately, the Internet (Sensatex 2004).

Surveillance and Privacy

Other research involves medication compliance monitoring, biometric monitoring of young children and elderly patients, as well as tracking of children or Alzheimer patients. The loss of personal privacy implicit in such monitoring and tracking is often presented as a welcome necessity in these scenarios and is indeed easier to accept when faced with the fear of losing one's children or the fear of threats to national security. The idea of intrusive domestic connectivity and ubiquitous biometric monitoring might also be appealing to people whose only other choice would be to reside in a nursing home or other assisted living situation.

Research at the Georgia Tech Residential Laboratory measures human acceptance of such lifestyle computing and personalized information devices. A medicine-on-demand project studies the use of a SmartShirt to assist in the health monitoring of infants and older adults as well as a general platform for telemedicine and the study of comfort, communication latency, and privacy (AHRI 2004). In other projects, researchers use environment and activity sensing technologies to allow older adults the freedom to manage themselves in their own home, with on-demand access to medical expertise and intervention (Mynatt *et al.* 2000). They outline three areas of interest: recognizing and adverting crisis, assisting daily routines, and supporting peace of mind for adult children.

An MIT project called House_n uses various sensors to track its occupants' daily habits (Voss

2001). Research projects test effective human–computer interaction techniques for the proactive encouragement of healthy behaviors related to sleep, diet, socializing, exercise, or medication adherence. Particularly for the elderly, changes in baseline activities of daily living are believed to be important early indicators of emerging health problems–often preceding indications from biometric monitoring (Intille *et al*. 2002). Small and low-cost biometric and accelerometer devices are worn for days or weeks to collect data on what people are doing. The devices are being validated by the medical community for use in monitoring activities of daily living (House_n 2004).

Despite the promise of increased security and independence, electronic freedom activists find such a surrender of basic privacy disturbing, in particular when faced with the potential for abuse and misuse or these technologies. As a partial response to such concerns, MIT's PlaceLab will be made available in the future to researchers interested in studying privacy and trust issues raised by highly instrumented responsive environments, including opt-out strategies, data review techniques, and methods to address the perception of control (Placelab 2004).

Privacy concerns become more urgent when considering products such as the VeriChip, which consists of a miniature digital monitoring device that can be implanted in people and has the potential to be used in a variety of personal identification, security, financial and potential healthcare applications (Digitalangel 2004). Although it is intended to assist in locating missing children or to monitor the heart rate of high-risk patients, we have to actively question our uses of such monitoring and tracking technologies—whether they are implanted under or over our skin.

Consumer Products

While much of the research and the underlying technologies are being developed for military applications, there is a strong consumer interest in computer wearables and electronic textiles. In the last few years, technology itself has become quite a fashionable thing and emerging technologies in particular are becoming fashionable lifestyle accessories.

We carry growing amounts of attractive portable computing and personalized digital devices on our bodies. We increasingly believe in the idea of being wired and connected with others and in the idea of monitoring ourselves and others. At the same time, a technology aesthetic is infiltrating our cultural language and visual style. We know what technology can do for us and we want more of it, in a ubiquitous and seamless way. The Givenchy Fall 99 *haute couture* collection featured hard shells that looked like printed circuit boards (PCBs) enveloping the body. Some of them were outfitted with glowing red LEDs (light emitting diodes). They encased the models, hinting at images of cyborgs, objectifying their naked bodies and promising a future where computer motherboards will be printed on our bodies or woven to house our bodies, offering us added functionality and superpowers.

Universal Connectivity

Marc Weiser argues that digital technologies have evolved from mainframe computers to the desktop computer and that we are now entering the age of Calm Technology where computing will become unobtrusive and ubiquitous (Weiser and Brown 1997). This next qualitative change will include the deployment of countless wireless wearable devices, allowing the Internet to spread from desktops to all aspects of daily life, opening thousands of new communication, entertainment, and commerce opportunities. Wireless Internet will also reach billions of people who are not yet connected because of infrastructure requirements. We will see telephony, health care, games, Post-It notes, diaries, and photography all based on wireless wearable Internet communications.

Developing the vision of ubiquitous computation capabilities, communication, and information access, Xybernaut designs small wearable computers for specialized worker applications where mobility, portability, and hands-free operation are a strong concern. They feature head-mounted displays and other wearable input and output devices that do not interfere with vision and activity range. In user studies, the Xybernaut Mobile Assistant Series has been shown to increase productivity, performance, and safety by providing critical data to workers (Xybernaut 2004).

Looking more towards fashion, lifestyle, and health applications, Charmed Technology aims to deploy wireless mobile devices to navigate the Internet through eyeglasses, jewelry, or other fashion accessories. They currently manufacture the Charm Badge, an electronic business card that can upload and transmit user information through infrared technology and the CharmIT wearable computer (Charmed 2004).

Looking towards the future of electronics applications, Philips Smart Connections has developed a range of prototype garments where communication technology such as mobile phones and GPS (global positioning system) devices are embedded into clothes. They study the potential of such technology to help protect children, enabling parents to pinpoint their location and to communicate with them. The garments also have a playful element: fabric antennaes, radio tagging and miniature remote cameras allow children to play games (Philips 2000).

Lifestyle Products

While many of the Philips Smart Connections garments are in the prototype stage, a range of lifestyle jackets developed in collaboration with Levi Strauss has already been put on the market. These jackets are waterproof and feature electrical components (a phone, MP3 player, unified controller, microphone and headphones) that can be removed before the jacket is washed. Their high price and the fact that many early adopters did not want to purchase duplicate electronic devices was problematic and the jackets were not a great commercial success.

More recently, Burton Snowboards collaborated with Apple to introduce the Burton Amp smart ski and snowboard jacket. The sleeve of the jacket is augmented with pressure-sensing technology from SOFTswitch to create a soft, flexible, fabric-based keypad that controls an integrated Apple iPod digital music player. Songs can be chosen and volume altered by pressing the soft keys on the sleeve, without the need to access the iPod itself.

Textile products for warmth and comfort have been made possible by Malden Mills, the manufacturer of Polartec fleeces (Malden Mills 2004). They have developed a fleece that conducts heat through proprietary stainless steel fibers that are washable, supple, and soft. Land's End has licensed the technology to create the Polartec Heat Blanket, which provides an even distribution of heating without the apparent wiring that is typical in conventional electric blankets. Malden Mills has also licensed the technology to North Face, which is using it for the high-end MET5 jackets powered by lightweight lithium batteries. Down the road, these conductive fibers could relay not only heat but also data, opening the door for truly wearable, electronic textile-based computer wearables.

At the same time, conferences such as WearMe and Eurowearable in the UK, UbiComp in the USA or the e-culture fair in the Netherlands hold fashion shows to consider the aesthetic, technical, and social aspects of wearable, hand-held, and portable technologies.

These fashion shows invite projects that are less functional and more fun, expressive, and poetic. Puddlejumper, by Elise Co, is a luminescent raincoat that glows in the rain. Silk-screened electroluminescent panels on the front of the jacket are wired to conductive water sensors on the back and left sleeve. When water hits one of the sensors, the corresponding lamp lights up, creating a flickering pattern of illumination that mirrors the rhythm of rainfall (Co 2000). Elroy by Megan Galbraith is an illuminating dress that encodes time information through the visual arrangement and animation patterns of the electroluminescent panels (Galbraith 2003). Inside/Outside by Katherine Moriwaki is part of a body of research that focuses on the behavior of people in urban public space. Inside/Outside integrates pollution sensors with an ordinary fashion accessory to provide an aesthetically and functionally integrated object (Moriwaki 2003).

Soft Computation

My research with XS Labs focuses on the development and design of electronic textiles, responsive clothing, wearable technologies, reactive materials, and squishy interfaces, considered in a social and cultural context. I develop hardware and design electronic fabric applications that focus on aesthetics, personal expression, and the idea of play, as opposed to the prevalent utilitarian focus of wearable technology design on universal connectivity and productivity applications.

I develop dynamic clothing that has the ability to change color, shape or texture over time and reactive clothing that responds to input with sound, animation or some other state change. The behavior depends on materials used in the construction of the garment, either structurally, as an embedded element or as decoration. We can think of clothing as a second skin that allows us to construct meaning in interaction with the world.

One application of reactive fashion is to enable the idea of changing our skin, our identity, and our cultural context. In my current production-based research, I develop enabling technology for electronic textiles based upon my theoretical evaluation of the historical and cultural modalities of textiles as they relate to future computational forms. I use conductive yarns and fibers for power delivery, communication, and networking, as well as materials for display that use electronic ink, nitinol, and thermochromic pigments. At the same time, I work with traditional textile techniques and technologies such as weaving, knitting, sewing, embroidery, quilting, etc. to create textiles that can sense, transmit power or data, and change state.

The tradition of electronics design and manufacturing is to produce hard components encased in square boxes. The tradition of textiles is to produce soft structures that encase the human body. By merging the two, we can create soft circuits and develop new methods for electronics design, sensing the body, and transmitting power and data. I call this "soft computation:" the design of digital and electronic technology that is composed of soft materials such as textiles and yarns, as well as predicated on traditional textile construction methods to create interactive physical designs. It involves the use of conductive yarns and fabrics, active materials, and flexible sensors to enable the construction of electronic circuits on soft substrates. It implies a move away from traditional electronics and an exploration of emergent materials that can enable physical computation. The goal is to achieve the seamless integration of technology into the tradition of textile and fashion design.

Experiments in Reactive Fashion

At XS Labs, we are developing wearables that embody key concepts in soft responsive computation. Materials such as thermochromic pigments, light-emitting components, miniature speakers, and conductive yarns are used together with input devices such as soft fabric switches, variable resistors, and capacitive sensors to construct reactive garments. We are particularly concerned with the exploration of simple interactions that emphasize natural expressive qualities of electronic circuits and of the body.

The Blazer project, developed by Vincent Leclerc, integrates LEDs into a sleeve to create a simple emissive display.[1] We use conductive snaps to switch current and we have also explored simple ways to incorporate light into fabric, using hard fixtures such as grommets and snaps to integrate LEDs into existing sewing practice.[2]

Blazer uses the idea of retinal persistence to make sense of an apparently random pattern of flashing lights. When the LEDs are not moving, their animated flicker pattern does not form a legible symbol. When they are moving at a particular speed, each pattern becomes arranged in space and can be read by the eye as a letter. If they move at the correct speed, the five LEDs can effectively displays text (Figure 1). So when the body is still, we see noise. When the body is in motion, the noise becomes a message as text is displayed.

The SoundSleeves project deploys the sleeve as a musical instrument (Figure 2). When the sleeves are worn, various sounds are generated as a function of the user's movements in space. Moving the arms in different directions and touching/rubbing them together creates subtle sounds that emanate from the end of the sleeves. By extending the body, we increase the consciousness of the body as an entity in space and augment body movement with simple sound. The sleeves give additional meaning to body movements and act as a tool that enhances the arms' capabilities. The sleeves become an instrument that invites play.

Figure 1
Blazer Sleeve with the illuminated snap switch. Photo by Joanna Berzowska.

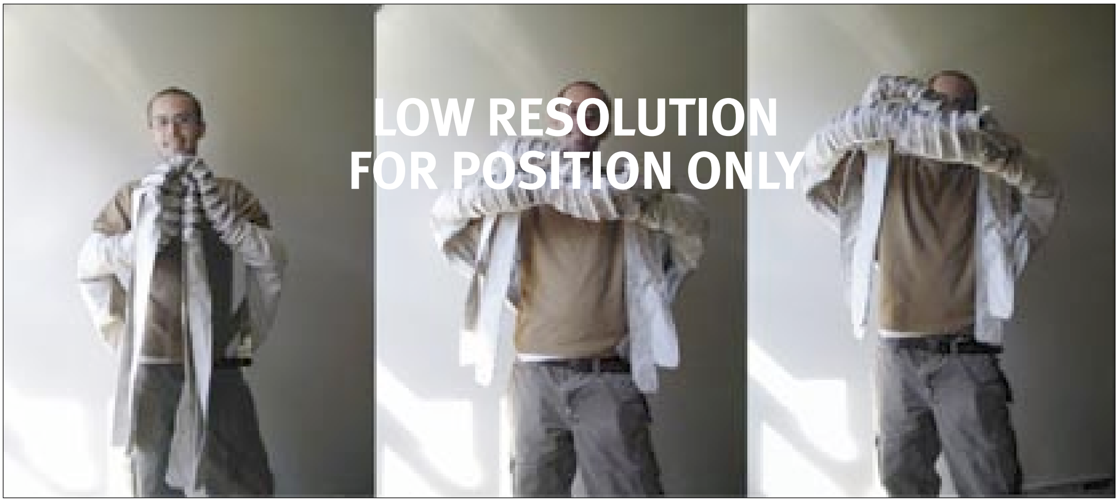


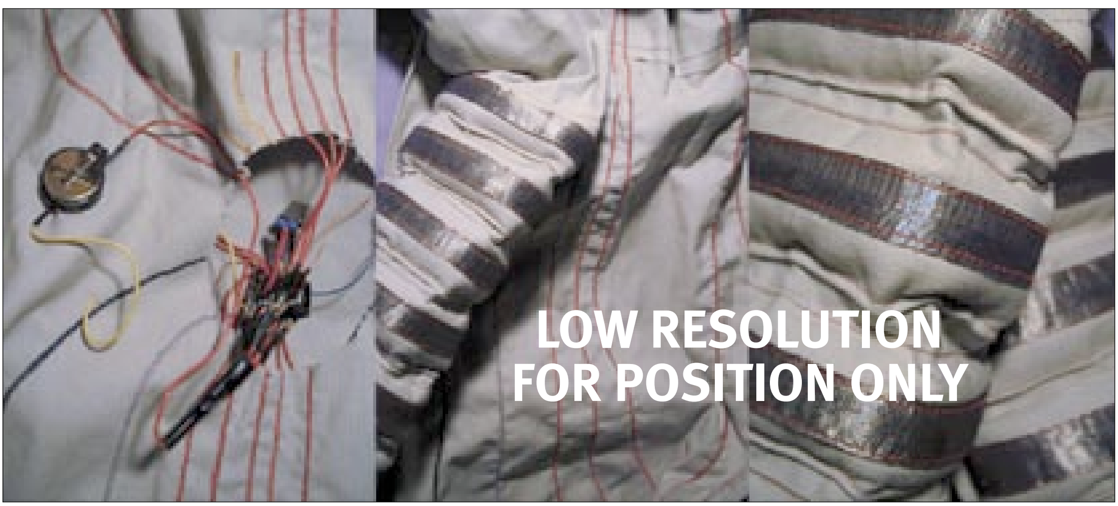
Figure 2
Vincent Leclerc wearing the SoundSleeves. Photo by Joanna Berzowska.

Figure 3
Textile electrodes and soft electronics in the SoundSleeves. Photo by Joanna Berzowska.

The electronic circuit in the sleeves is constructed entirely of metallic silk organza—for contact switches and grounding elements—and simple sewing techniques to stitch circuits using conductive yarns. We built a large sensor array out of soft switches, using small building blocks to create a larger sensing unit. The only hard components are two small speakers affixed at the end of the sleeves and a tiny microcontroller attached to the conductive yarns to generate the sounds (Figure 3).

Visually Interactive Textiles

The idea of dynamic, reactive or interactive fashion is predicated on visually animated materials that can be embedded or incorporated in a fabric. In the computer world, there is also a lot of interest in developing fully addressable displays on textiles, not least because of the interest in reactive camouflage. Technically



this is a long way away. New materials for display such as LEDs, electroluminescent (EL) material or high brightness LEDs coupled with woven optical fibers such as the Luminex textiles offer a lot of potential for wearable displays or animated fashion.

Non-emissive materials, such as electronic ink (E-INK) and various photochromic or thermochromic pigments, are materials that do not emit light. In contrast to emissive technologies such as LEDs or EL material, these inks simply change color and do not light up. This distinction is significant because textiles with emissive displays are visually appropriate for night or "rave-wear," whereas non-emissive animated textile displays remain closer to the tradition of weaving and textile printing.

Thermochromic materials are especially interesting because they have different color states at different temperatures. They literally change color in response to temperature fluctuations. Photochromic inks respond to variations in exposure to ultraviolet light (primarily sunlight). Both materials are reversible and will change colors repeatedly with the appropriate exposure. Other emerging color-changing technologies include hydrochromics, which change in response to water, and piezochromics, which change color in response to pressure. Depending on the application, color-changing inks can be applied with a number of printing processes, including offset lithography, flexography, gravure, and screen printing. These are highly specialized inks that combine standard ink components with one of several color-changing agents.

I use thermochromic leucodye materials that can be engineered to change from a specific color to a clear state at arbitrary temperatures between −25°C and 66°C. Many colors are possible and unexpected color changes can be obtained by combining thermochromic and regular inks. By mixing inks that change at different temperatures, a more complex effect can be achieved. The inks can be applied with a various printing processes, such as screen printing. In existing products, color change is activated by body heat or through resistive heating that employs a layering of conductive and thermochromic inks (on battery testers), in which case the conductive/resistive ink heats up and changes the color of the ink.

Shimmering Flower

Shimmering Flower deploys simple technology to create a color-change textiles (Figure 4). It functions as a non-emissive display that changes color without emitting light. It is made of soft components—conductive yarns and fabrics, thermochromic inks, and custom electronics components—which allow the construction of soft, washable, addressable, color-change animated displays.[2] Control electronics that drive the textile display consist of a PCB with various electronic components that is used to send power to different areas of the electronic textile in order to activate the thermochromic inks.

This textile can have up to sixty four fabric pixels arranged in an arbitrary design. Each pixel is individually addressable (with conductive yarns) and is controlled to slowly change color. Each color change can be programmed in the custom electronics board or controlled in real time when the display is connected to a computer through the serial port. The visual color composition of the textile animates through several different patterns, resulting in a smooth transition between different designs. The design allows for the creation of many dynamic

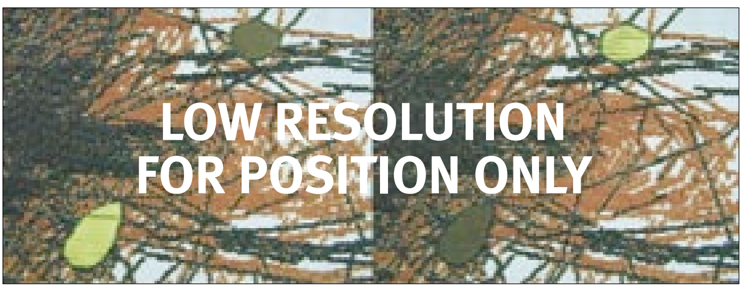


Figure 4
Example of color change in the Shimmering Flower weaving. Photo by Joanna Berzowska.

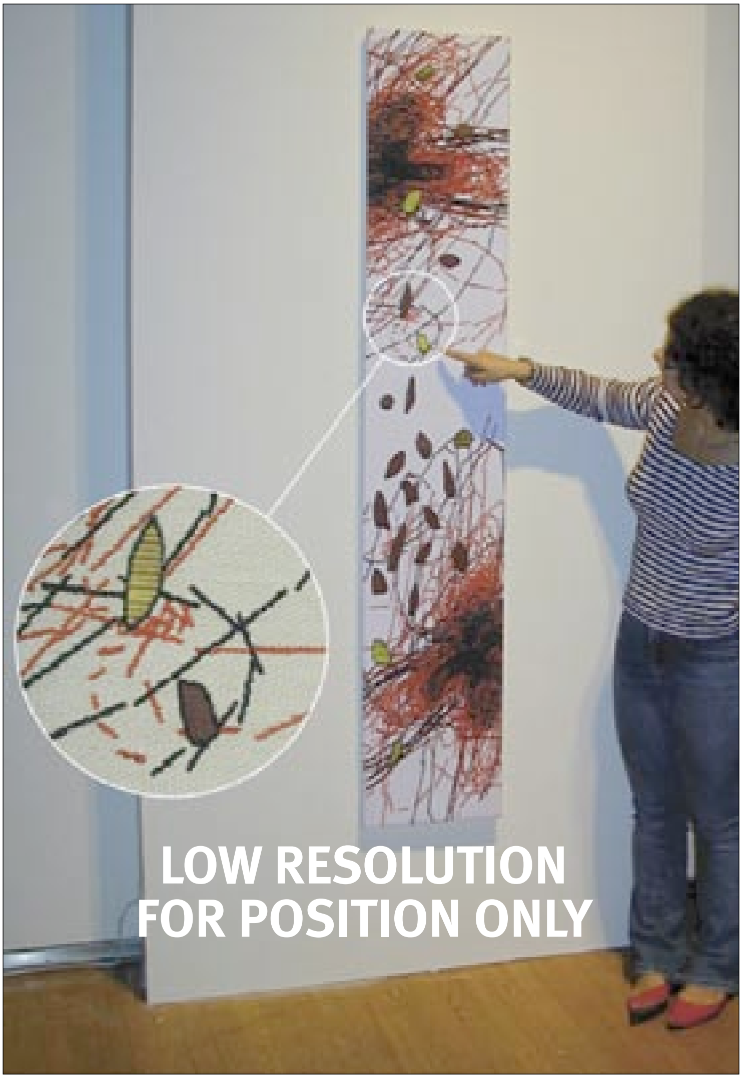


Figure 5
Shimmering Flower. Photo by Arkadiusz Banasik.

and diverse designs on a textile. Its visual properties (color and pattern) are determined by the pattern and physical configuration of the conductive/resistive yarns and the inks integrated into its surface (Figures 5–8).

Initial prototypes were woven on a hand loom and demonstrated simple, orthogonal designs. The Shimmering Flower textile was woven on a Jacquard loom, which can create complicated weave structures, including double and triple weaves. Each warp yarn is individually addressable, so that complex and irregular patterns can be woven. This allows me to explore the tradition of weaving to create soft circuitry. By incorporating conductive yarns with the non-conductive yarns, three-dimensional fabrics can be constructed to mimic simple

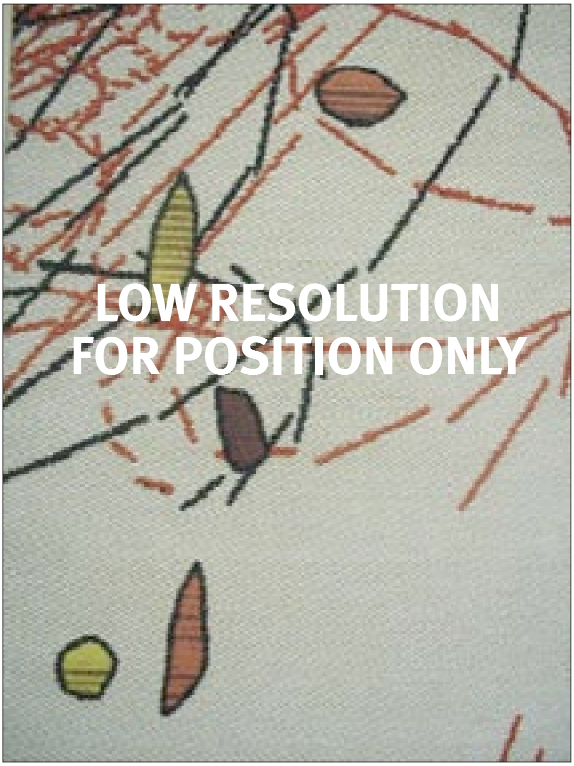


Figure 6
Shimmering Flower detail.
Photo by Joanna Berzowska.

way, referencing the process of weaving, knitting and other textile construction techniques. Resulting imagery blurs the boundaries between digital image and textile design motif. The aesthetic of the patterns and the animation references the idea of "pixel," traditional quilting and weaving practice, as well as emerging research in visual display technology.

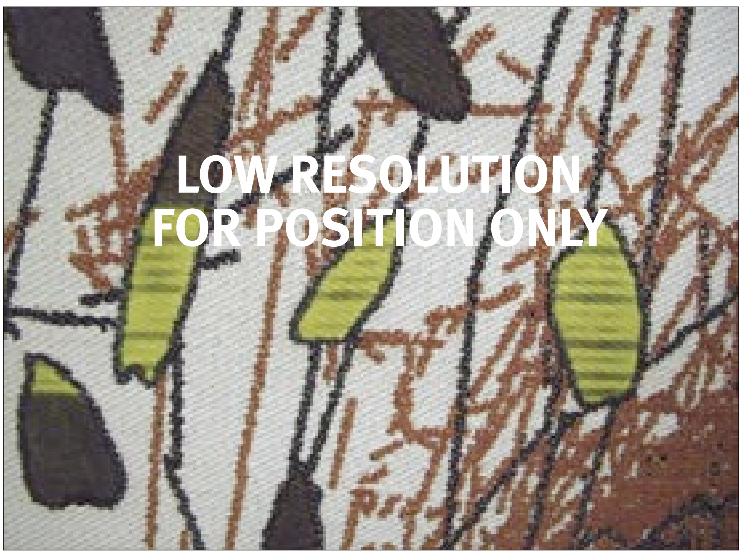
The slowness and subtlety of the piece references the fact that current technological development is largely focused on speed and hard-edged progress. Textiles have

electronic components. Double weaves can create conductive and insulating textile surfaces that function like a woven circuit board.

Shimmering Flower is not a wearable textile. The power requirements are too high and the thermochromic inks need to function in a temperature-controlled environment. The prototypes show a possible direction for the development of addressable color-change textiles, but they exist as wall panels and animated paintings. We have solved many technical problems in the production of these pieces, but many still remain.[3]

The aesthetics of the display mirror the soft qualities of the construction. The textile changes in a slow and contemplative

Figure 7
Shimmering Flower detail. Photo by Joanna Berzowska.



a uniquely intimate relationship with the human body. Designers of electronic textiles need to focus on personal expression and the social, cultural, and economic history of textiles instead of striving to replace (or “augment”) human experience. In a time that is more and more dominated by the visual image and the cult of communication, textiles also have the ability to display our needs and desires, as well as our artworks.

Intimate Technology

As designers of wearable technologies, we need to step back and ask why we want our fabrics to be electronic. What kind of information processing do we want to carry out on our bodies? What kind of functionality do we want to enable inside our clothes? The clothing and electronic industries are looking for the killer application, the next big thing that will introduce wearable computing to a mass market. However, many research directions are misguided. The focus on health monitoring and surveillance technologies clearly reflects the military funding structures and fails to deliver appealing product ideas that respond to personal, social, and cultural needs.

We live in a complex world composed of bits and atoms. We regularly interact with people, computers, and other objects in the environment. The computing and communication capabilities we integrate into physical objects are rapidly increasing, but do not necessarily translate into “rich” interactions. As thinkers and designers, it is imperative to ensure that the interactions between people, computers, and the physical environment are useful, enjoyable, and, most importantly, meaningful.

Mihaly Csikszentmihalyi writes that physical artifacts help us objectify the self in three ways. They can be viewed as symbols of personal power, symbols of the continuity of the self through time, and symbols of the permanence of relationships that define the individual in a social framework (Csikszentmihalyi 1993). Similarly, the idea of costuming is thousands of years old and is effectively used to hide, reveal, and distort the self that we present to the world. We use clothing to express a lot of things: social class, economic class, mood, self-esteem, sexuality, profession, religion, and overt labeling through labels with the associated lifestyle promised by advertising.

The killer application for wearable computing is to convey personal identity information. This is called fashion and it is mostly visual. Wearable technology in the form of clothes is thousands of years old. Clothing is also one of our most intimate and personal technologies; it functions as protection, disguise, and interface to the world. We need to think carefully about what we want our electronic textiles to do. Many technologies will trickle down from military research labs to fashion design houses, but in the meantime, we have to examine the funding structures for this research and the implications on the research directions that are pursued. We should not forget about the intimacy of electronic textiles. Research should not be afraid of the conceptual proximity of these technologies to the body, and should explore the potential for playful disguise, personal expression, and experimentation.

Notes

1. The Blazer project was developed by Vincent Leclerc during my "Second Skin and Soft Wear" course at Concordia University.
2. All the projects, products, and research that share a common interest in electronic textiles run into similar problems. There are many technical and manufacturing issues to be resolved. One of the biggest problems with conductive yarn is how to connect to it and then how to insulate it properly. Soft computation precludes the use of PCBs, insulated wire or soldering. Methods such as tying knots, weaving, sewing and embroidery have been developed to construct simple electronic components. This is a very time-intensive and delicate process.
2. I developed the underlying technology for Shimmering Flower at International Fashion Machines, which I co-founded in 2001. A first example (called "electric Plaid") was shown at The National Design Triennial: Inside Design Now at the Cooper-Hewitt National Design Museum in New York in April 2003.
3. A significant problem for electronic textiles is the power source. Electrical infrastructure is something we take for granted and we often forget that electronic textiles would need portable power sources. Batteries are heavy and expensive. Rechargeable batteries need to be removed and plugged in at night. There are no easy answers. One of the alternatives is research into parasitic power, to collect the energy that is wasted in our daily movements and interactions with the world. As power requirements for microelectronics decrease, environmental energy sources can begin to replace batteries in certain wearable subsystems. Projects such as the Parasitic Power Shoes by Joe Paradiso examine devices that harvest excess energy from each step and use it for generating electrical power while walking. Nothing comes for free, however, and the Parasitic Shoes need to sacrifice comfort in order to allow energy harvesting.

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