Memory Rich Clothing: Second Skins that Communicate Physical Memory

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ABSTRACT
This paper examines the development of wearable technologies that display a garment's history of use and communicate physical memory. We explore how trends in digital technologies and conventional wearable research contrast the ways our bodies and clothing register memory at a personal and social level. Our research concentrates on the production of garments that take into consideration aspects of playfulness and that reflect more subtle or poetic aspects of our identity and embodied history. The pieces described here are part of a larger series called Memory Rich Clothing and employ several soft computation techniques developed in our labs.

Author Keywords
Reactive garments, wearable computing, electronic textiles, history of use, physical memory.

ACM Classification Keywords
J.9.e Wearable computers and body area networks

INTRODUCTION

Clothing is one of the most intimate things that we interact with in our daily lives. Because of its extremely close relationship to our body, our (non-digital) clothing is able to witness some of our most intimate interactions; it is able to record our fear and excitement, our stress and our strain, through the collection of sweat, skin cells, stains, and tears. It becomes worn over time and carries the evidence of our identity and our history.

Digital technologies allow us to shape and edit that evidence to reflect more subtle – or more poetic – aspects of our identity and our history. Patterns of touch, stress, and bending within garments (the subtle wrinkles of time and use) can be quantified digitally and utilized to reconfigure physical patterns and additional characteristics of those garments. Gestures and personal history can, in this way, be perceived, manipulated, and represented on displays integrated into the fabric. Collectively, these digitally-augmented garments change and modulate social interactions.

This paper will describe our research and the development of several reactive garments that display their history of use. Some of the early conceptual and technical prototypes examine how embodied memory can be communicated through our clothing. A variety of input and output methodologies are explored to sense and display traces of physical memory, raising the question of what exactly do we want to remember.

LIFE CACHING

The miniaturization and reduction in cost of digital memory (hard drives, recordable DVDs, and flash cards), digital cameras, personal digital assistants, and other digital accessories enable us to capture and store a constantly growing amount of personal data. Whether this data takes the form of text, photos, video, or audio, its collection has contributed to the emergence of several trends, such as web logging (or blogging), in the last few years. The term "life caching" describes the process of compulsively photographing, annotating and saving photos to document moments in everyday life. [1] Coupled with growing access to wireless communication and internet access, these moments can be uploaded, saved, annotated and catalogued. Moreover, while a traditional paper-based diary is a very intimate and personal account of someone's life, a blog is free and open for anyone to read. Life caching would not have the same social implications if it didn't create a new space for human interaction, a space where anonymity can easily co-exist with surveillance.

The term "memory industry" is being used to describe western society's growing interest in various gadgets that help commit to computerized memory all of the things that we otherwise might forget, such as appointments, commitments, and other important life details. One of the proclaimed goals of pervasive computing research is to develop invisible distributed sensor networks to record various aspects our activities. Wearable computing research

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Figure 1. Intimate Memory shirt shows the time elapsed since the intimacy event occurred, by turning off LEDs one by one.

is similarly concerned with questions of memory. The Remembrance Agent, for instance, 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. [2]

The more traditional research in wearable technology deals with memory under a framework of efficiency and physical enhancement. Many of these researchers are actually suspicious of the body, and tend to ignore its importance in how we accumulate memories. They talk of wearable technology as an exoskeleton, or a protective building built for a single inhabitant, as opposed to thinking of it as a revealing, expressive artifact that facilitates our communications with others.

Although these technologies are portable/wearable, they often ignore the presence of the body when registering memories. The data makes its way through physically intimate personal devices, but these devices only capture a very objective sort of user experience. The technology mediates people's relationships without taking into account corporeal or embodied ideas of intimacy, and ignores the body as an instrument for communication.

CONCEPTS OF MEMORY

We need to clarify the distinction between concepts of human memory versus computer memory. Computer scientists started using the term memory to refer to hard drives and RAM as analogous to the way that humans remember facts. But computer memory is distinctly different from human memory insofar as it acts more as a dumping group for data, as opposed to the rich, contextual space that makes up human memory. Computers do not forget things in the same way that humans forget. At the same time, a computer can store images with great accuracy but cannot identify one image as being similar to another, which humans can do quite easily.

Once the term "memory" became established in computer science, computer-based definition of memory infiltrated our discussions of human memory. The "memory industry" thus defines the concept of memory in a very objective and impersonal way. Photos and video register memory as events in time instead of stored experiences. Memory-rich research, on the other hand, deals with memory as it relates to the body and the interaction between people through the use of their bodies.

MEMORY RICH CLOTHING

Memory Rich Clothing is an ongoing Extra Soft Labs (or XS Labs) project that focuses on the research and development of reactive garments that display their physical memory, or "history of use". We employ a variety of simple input and output methodologies to sense and display traces of physical memory on clothing. Our primary objective is to produce costumes that can show personal memory data, such as where and when they have last been touched, including subtle evidence of intimate contact. This work has resonances with psychological investigations into the affect of experience on physiological substrates.

The term "physical memory" is used to describe spatial and tactile memory inherent in experiencing things through the body in activities such as playing an instrument. Here, we refer to the fact that the garments build up physical memory insofar as they retain some traces of presence of the user, through the ability to sense and record a history of interaction that can be communicated visually. By placing these memories directly on the body, we question assumptions about the ways that the body remembers. If the way that the body is perceived or used changes, then the way we build our memories can also change.

We want to question how objects can have "memory". How are objects altered through interaction? What kind of interactions will be necessary to give physical memory to a wearable object? What is the difference between passive and active interaction (manipulation versus sensing)? How can the emotional content of memories be displayed? The longer term objectives are to develop an extensive body of technical and conceptual prototypes that explore how physical memory can be communicated through our clothing. Emphasis will be placed on poetic and personal interpretations of history and memory. This project is developing in parallel to the XS Labs' Squirrel Tails project, which focuses on the research and development of visually animated textiles that will enable the construction of soft reactive addressable displays. By focusing on aesthetics and the idea of play, this project can enhance the natural expressive language of the body by encasing it in visually animated reactive cloth.

INTIMATE MEMORY

Intimate Memory was our first experiment in the construction of reactive garments that display their history of use. We developed an outfit, consisting of a shirt and a skirt, which employs two different kinds of input and output methodologies to sense and display traces of physical memory on clothing. These garments record acts of physical intimacy and indicate time elapsed since the "intimacy events" have occurred.

Figure 2. The Intimate Memory shirt records the intensity of breath on the neck of the user.

The shirt is embedded with a sensitive microphone in the collar and a series of illuminating elements that follow a curved line across the front. When a friend or partner whispers something into the wearer's ear, the microphone records this event and the shirt lights up, showing that an "intimacy event" has occurred. The number of lights represents the intensity of the intimacy event, similar to the volume indicator on a stereo. Over time, the lights progressively turn off, one by one, to show how long it has been since the intimacy event took place.

The skirt incorporates soft switches (the simplest of touch sensors) into its design. These switches are sewn out of metallic silk organza, and connected to a small analog circuit. When those areas are groped, they trigger high intensity LEDs that register the intimacy event and display traces of physical memory. In a similar fashion to how our skin registers touch, the LEDs fade over time to indicate the time elapsed since the event. The LEDs not only register intensity but also how this event unfolds over time. Do things that mark us intensely last longer in our memories?

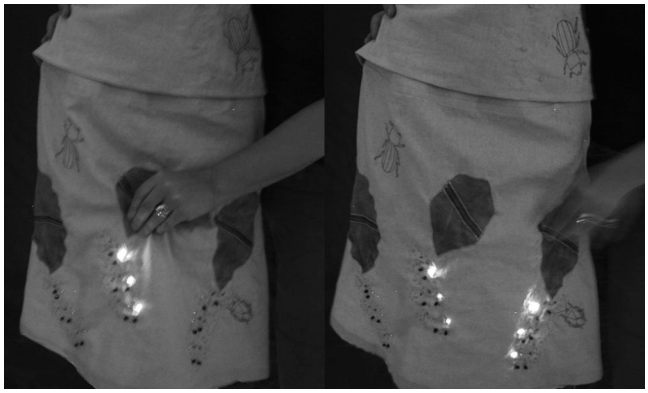

Figure 3. The Intimate Memory skirt records how hard – and how long – you were groped.

Because of the overtly sexual nature of groping someone's thighs, this garment highlight the fact that many memory technologies are invasive. Most people remark that they would not want their partners to see that they had been groped by someone else. They claim that this information, and this physical memory, is a private one, it is a memory that they might not want to share with others. This piece reveals ways in which our actions and our personal histories can be recorded, stored, and displayed. It highlights aspects of surveillance that we are often happy to forget when dealing with more conventional wearable technologies. Many people do not question issues of surveillance and loss of privacy implicit in the deployment of wearable technologies, whatever they may be.

Technical details

The shirt uses a microcontroller to analyze the microphone input and determine the state, intensity and duration of the illumination of each LED. The electronics for the skirt are much simpler. The circuit is completely analog and uses capacitors, a kind of electrical device used for storing

electric charge, to control the amount of time it takes for the LEDs to fade. Transistors are used to avoid discharging the capacitors too fast.

Figure 4.The soft circuit sewn into the Intimate Memory skirt

A strong element of this project is the use of soft computation to incorporate the circuit as an aesthetic element on a wearable substrate. All the research that shares a common interest in electronic textiles faces similar technical and manufacturing challenges when making the transition from printed circuit boards and wires to fabric and conductive yarns. Soft computation precludes the use of "hard materials" (PCBs and insulated wire) and traditional electronic techniques (soldering), in benefit of a design approach that borrows from a textile tradition and that can naturally suit the body.

Analog design often affords a richer symbolic terrain than design that relies exclusively on traditional binary digital techniques. Soft computation methodologies more accurately reflect the fluidity and permeability of life events. As the Intimate Memory display changes, it follows a cascade of capacitive discharge in an organic way suggestive of the patterns of information accumulation and dissipation generated in biological cognitive processes.

A series of methods are being developed by our research group to construct simple electronic components with techniques such as weaving, sewing, embroidering and tying knots. In the manufacturing of the Intimate Memory skirt, for example, the resistors, transistors, and capacitors are sewn into the fabric as if they were small beads, and their leads are glued with conductive epoxy or tied together by braided conductive yarns. This is a very time-intensive and delicate process, which opens space for problems such as durability and strength.

In conventional electronic design, a prototype goes from a breadboard to a printed circuit board, and both share a very similar layout and arrangement. However, in wearable technology, after the prototyping stage, the components need to be completely rearranged to separate the conductive yarns and avoid short-circuits. This demand brings aesthetic considerations to the circuit level, since the components become an integral and visible part of the piece.

The circuit design becomes an aesthetic component of the garment design. The shapes created can be decorative as well as functional, especially when using highly conductive yarns. Together with the use of traditional materials and components for garment making (integrating snaps, rivets, zippers, beading techniques etc…) we can create simple circuits that fit into the aesthetics of fashion and that can be manufactured in similar ways.

Figure 5. Stitching conductive thread into the Intimate Memory shirt

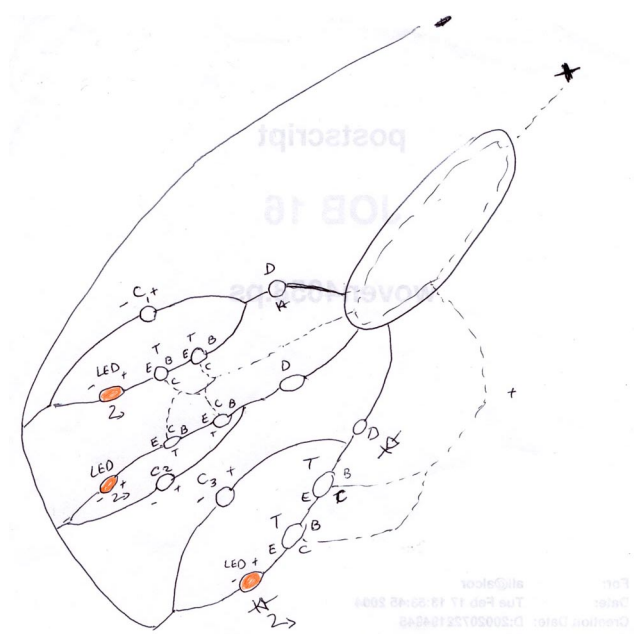

Figure 6. The schematic for the soft circuit. The circuit itself becomes a decorative element on the skirt.

PURE PLAY

Pure Play is a project that takes a purely aesthetic and playful approach to the design of wearable technology. It is a tunic decorated with a dynamically changing color element along the neckline. Functioning as a simple non-emissive animated display, the tunic's neckline is overprinted with thermochromic ink, which changes color with a change in temperature. The neckline incorporates several Peltier junctions, which can activate the color change electronically. In addition, portions of the neckline do not contain Peltier junctions, and the change in color is simply triggered by the changing temperature of human skin. Alternating color blocks employ electronic components and body heat to create the shifts in temperature necessary to change the color of the neckline.

Figure 7. The neckline detail on the Pure Play tunic changes color over time.

The changing pattern thus reveals the interplay between body heat and heat-emitting electronics to create a visual conversation between physiological and computational input. This emphasizes the differences and the tensions between voluntary and involuntary, or active and passive control. The physical memory in this case is illustrated through the interpolation of color variations generated by the electronics together with the accumulated changes naturally created by body heat. The final outcome is a piece that focuses on the wearer's body, complementing and enhancing it in a very personal way.

Technical Details

As an alternative to the resistive heating techniques used in Squirrel Tails, the Peltier junctions have the advantage of providing a higher refresh rate, as well as the additional ability to cool down the surrounding fabric. Peltier junctions are electronic devices capable of converting electrical energy into a temperature gradient. They are constructed from an array of two semiconductors connected by metallic conductors and arranged between two ceramic plates. Electrons in the two materials have different potential energies and, to move from one to the other, they absorb heat on one side of the ceramic plate, and release it at the other. By inverting the current, it is possible to quickly switch from a heating to a cooling state, and vice-versa. The ability to invert current and regulate the voltage drop across a junction allows for a finer electronic control of the fabric temperature.

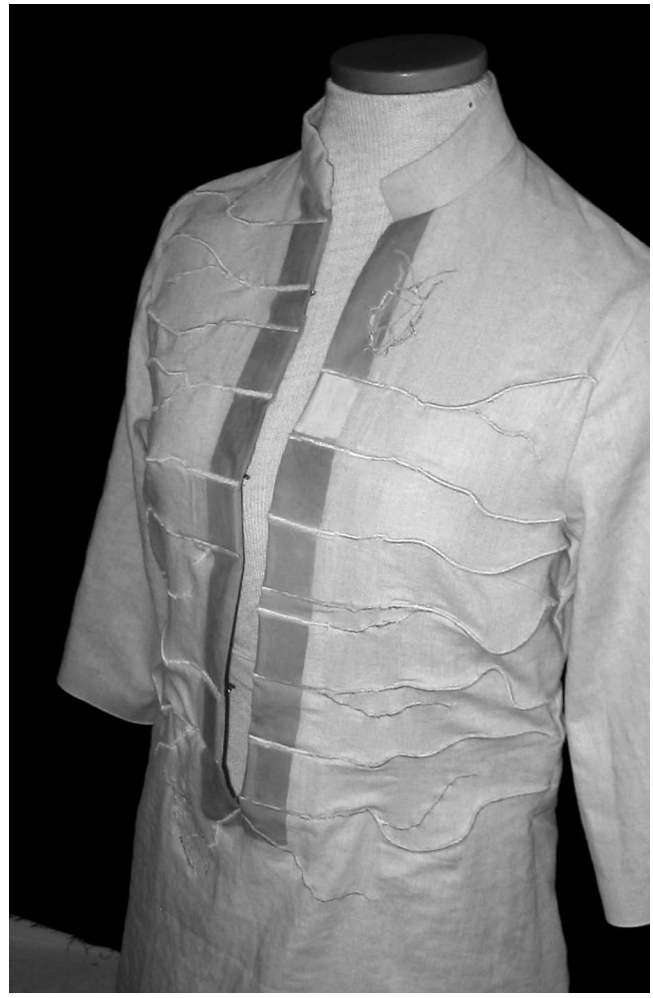

Figure 8. The Pure Play dress with thermochromic ink, Peltier junctions and stitched connections.

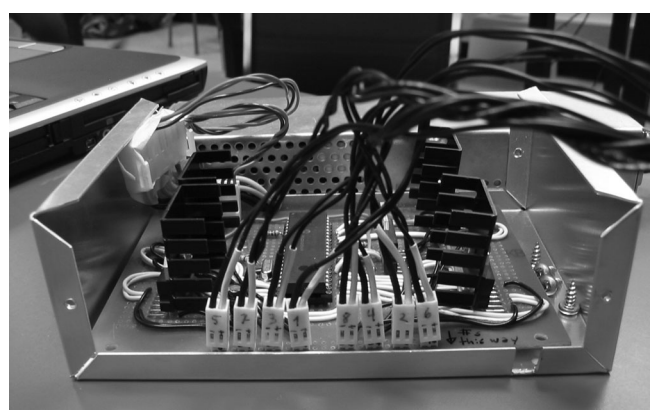

Figure 9. The Pure Play dress control electronics with large heat syncs to absorb heat generated by the circuit.

Aesthetically, the wiring for the junctions guides the focus of attention to the visual changes happening in the collar and creates a seamless transition between the textile and the electronic components. The wires are stitched into the fabric, moving from the back towards the front of the tunic. Instead of being concealed from view, they reinforce the asymmetric disposition of the junctions and help to break away from the visual aesthetics of standard grid displaying techniques.

Asymmetry also influenced the programming of the Pure Play dress. A conscious attempt was made to develop a less predictable visual pattern. A microcontroller switches eight Peltier junctions in an apparently random fashion over a ten minute heating and cooling cycle. The alternating sequence make it difficult for viewers to predict where the color changes will appear, blurring the lines between the natural print left on the garment by body heat and the electronically manipulated changes.

Figure 10. The dress is tethered to its power source.

Power Consumption

A significant problem for electronic textiles concerns the power source, specifically when dealing with heating components. Electrical infrastructure is something we take for granted and we often forget that electronic textiles need portable power supplies. Pure Play was programmed to have a maximum of 2 junctions running simultaneously at 5V and drawing an average of 0.7A. This constraint forces the tunic to be constantly tethered to a power supply and prevents it from being a wearable garment. Batteries for this kind of demand are heavy and expensive, while rechargeable batteries need to be removed and plugged in at night. There are no easy answers.

As power requirements for microelectronics decrease, environmental energy sources can begin to replace batteries in certain wearable subsystems. An attractive alternative is the promise of "parasitic power," based on the idea that we can harness energy wasted through walking or other physical movement. 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.

TOUCH MEMORY

A recent XS Labs experiment in memory rich garments consists of two sets of three dresses that explore touch, embodied intimacy, and the technical implementation and construction of visually reactive substrates for manipulating use data on textiles.

The conceptual framework consists of the gathering and displaying of intimate touch events but also explores social choreographies that emerge when three bodies actively inhabit three identical reactive costumes. Instead of displaying a demo reactive garment, a single instance, on a model or on a hanger, we decided to deploy three identical but distinct garments on human bodies.

Figure 11. Three Dancers wearing the feathery dresses, developing a choreography of touch.

We found that there is a considerable qualitative difference that emerges from manufacturing three instances of a reactive garment versus manufacturing a single one. Many wearable technologies are displayed (and this was the case with the Intimate Memory and Pure Play) in a gallery or science show context, away from the body. When the garments are actually worn, and especially when they are worn by more than two persons, social patterns of interaction start to appear that could not have been anticipated when interacting with one instance of the garment. The social patterns that emerge, especially when the costumes invite touch and give visual feedback in a playful way, are quite interesting.

Figure 12. Three dancers wearing the Spotty dresses, touching each other to make their camouflage disappear.

Whereas many other reactive outfits define interaction in terms of one participant acting upon another, these sets of three dresses stimulated social choreographies of touch that brought the dancers closer physically, instead of bringing them closer together virtually, which is what many other wearable (wireless) technologies do.

Spotty Dresses

The first set of three dresses is called Spotty. The dresses are constructed out of thin, light cotton, overprinted with an irregular pattern of thermochromic spots. The dress design is a simple A-line shape, quite loose and airy to facilitate dance movements as well as an easy flow of air to cool the fabric and the body of the dancers. The spots form an irregular pattern that hints at symmetry, based on animal camouflage patterns. The spots allow the dancers to act out social choreographies based on animal behavior.

There is a very immediate and literal aspect to the interaction. The direct touch memory is displayed when one user touches another and affects the color of the spots using body heat. There is an immediate and very direct effect on the visual patterns displayed on the dresses. Since the dresses display a camouflage pattern, body contact – whether touching, rubbing, pressing the fabric against their bodies or the bodies of other – makes the inks change color and effectively disappear. Increased physical intimacy makes their spots blend into your skin, it erases their camouflage patterns. They become nude, revealed.

These dresses invite a very playful attitude. They are intimate, fun artifacts that invite physical contact, communication and play. With these dresses, we explore the idea of transforming the body so as to challenge common cultural perceptions of the body, especially in terms of intimacy as defined in relation to touch and physical contact.

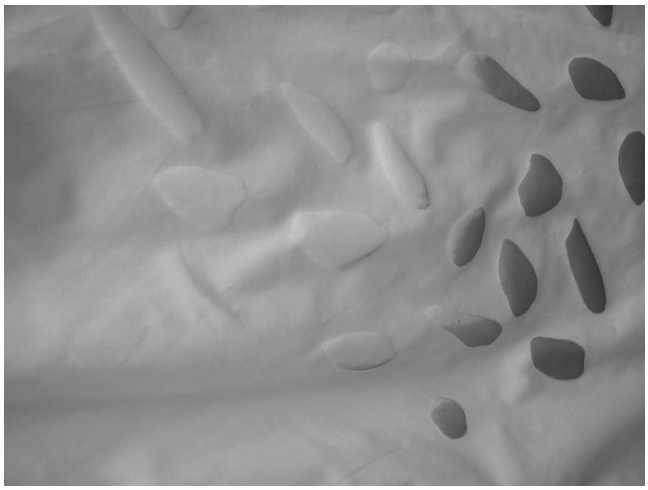

Figure 13. Thermochromic ink switching from red to yellow and blending into the fabric of the dress.

These dresses remember traces of presence, similar to the idea of hit counters on web pages, to show when and where the users have been touched. The user is thus exposed. Because the spots fade from a distinct color to the color of the fabric, the camouflage capabilities of the spots disappear. Because of physical intimacy, the user comes out of hiding. This simple interaction paradigm highlights the dichotomy between privacy and intimacy and how we happily relinquish one in exchange for the other.

Figure 14. Mapping out intimacy zones on the body using the Feathery Touch Memory dresses.

Wearable artifacts, by virtue of the fact that they are worn on the body, are a very intimate technology. Social and cultural changes are implicit in any new technology. These dresses explore the idea of wearable technologies that encourage physical touch and contribute to create embodied as opposed to virtual proximity between people. This embodied aspect is a central focus of the XS labs, which can also be seen as the cultural transduction of very abstract notions of memory and information into tactile artifacts capable of enhancing and promoting spontaneous contact.

FEATHERY DRESSES

The feathery dresses deploy similar technology to that used in the Intimate Memory skirt, but replace the analog circuit with a microcontroller, so as to better control the feathery illumination and the behavior of the LED-enhanced feathers embroidered onto the front of the dresses.

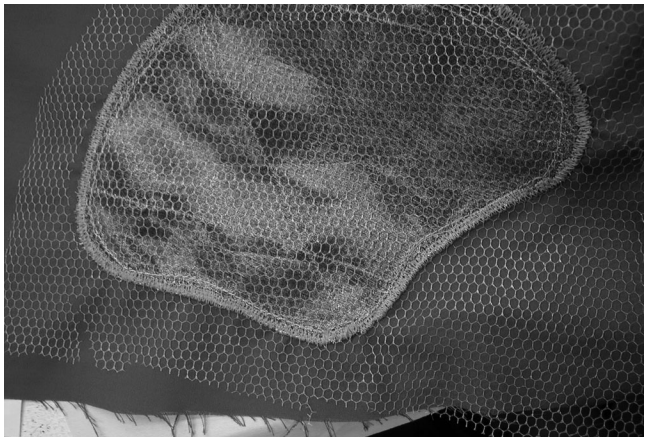

Figure 15. Insulated layer of a touch sensor, constructed with metallic silk organza and conductive thread.

The touch memory is based on the idea of intimacy maps on the body. There are three touch sensors (soft, conductive textile switches) that record touch events on the body. These events act as input into the simple program running to the microcontroller, and the touch event is displayed through a pattern of illuminated feathers embroidered on the dress. The use of a microcontroller allows us to use much less conductive material in the body of the dresses and reduces failure rates due to broken connection.

Figure 16. Light Emitting Diodes (LEDs) sewn into the feather surface with conductive yarns.

RECORDING USE DATA

Human use can have an impact on the integrity of digitally-augmented objects. Drawing upon previous work in "history enriched digital objects" [3], the memory-rich experiments layer a “history of use” on a variety of digitally-augmented clothing. The primary purpose of these

augmented layers of information is to inform, involve and unite, to create a feeling a social presence in textured history, and assign value and identity. [4] Collecting use-data interests computer scientists who see possibilities in leveraging people's simple behaviors in order to assist others and develop more collaborative practices.

Many traditional Human Computer Interaction (HCI) or Ubiquitous Computing (UbiComp) research projects that record history of use are predicated on data analysis and user modeling. The assumption is that use data is recorded in order to provide useful information. How we define this, away from a purely utilitarian context, is an interesting question. These dresses could be theorized as such use-history artifacts. They could be used to show how often the wearer has come into contact with other people or objects. In the evening, the dresses could display a history of its daily physical contact. But they are not! None of this data is saved. This is meaningful because it creates a different kind of paradigm.

Figure 17. Playful and physically intimate interactions facilitated by the Spotty Touch Memory dresses.

It is a paradigm where context and evanescence both contribute to emergent meanings as they evolve between people. As the illumination fades, so do the memories; as the body carries marks of time, so do these garments. In this paradigm, data is impermanent and perpetually contextualized within interpersonal relationships.

CONCLUSION

It is important to develop wearable technologies that challenge social structures and assumptions in relation to embodied interaction (or concepts of knowledge). These interactions have developed under specific cultural, historical and social contexts.

Much of current wearable and portable technologies (such as cell phones and personal digital assistants) contribute to increasing physical distance between people. Mobile technologies developed today favor the use of verbal communication at the detriment of communication that makes use of the whole body. By bringing people closer together through remote presence applications and universal connectivity, physical detachment is amplified.

The garments produced in this research treat memory data differently from other digital technologies in several ways. Electronic devices, like PDAs and digital cameras, store data in a memory space that can be randomly accessed and retrieved at any time in the future. Memory becomes limited to the amount of storage space available and, once that limit is reached, we are obliged to delete or erase old memories that are not as important or relevant.

In contrast, the garments we develop build their new memories upon the previous ones, overlapping social interactions that took place at different points in time. The result is a history of use that does not go through a conscious selection process and thus resembles more the memories naturally captured by our clothing such as stains and sweat. It is not necessary to forget certain things to remember others. This can happen because the events we register in the clothing fade over long periods of time. It is an analog form of output, where the colors and LEDs scan through different kinds of intensity, instead of simply being binary or displaying a certain color/transparency.

In future work, XS Labs will continue to expand upon these research initiatives to find hybrid forms which incorporate technology in an organic and intuitive way appropriate to the body.

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