Transformative Textiles: Integrating material and information in the design of sonified textiles

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Abstract

Digital technologies are now deeply embedded in our everyday lives, becoming seamlessly integrated with objects and materials that we engage with routinely. Digital information is no longer confined to screens as "painted bits", but is spilling into our environments creating a seamless extension of the physical affordances of objects into the digital domain. This seamless integration is enabling information to be explored through new modes of interaction, utilizing interactive materials that can be manipulated, accessed, and programmed. The progressive, ubiquitous nature of computing is creating a need to re-evaluate the ways in which new technological emergences affect how we relate to and understand the world around us.

A key area of material technologies development contributing to this seamlessness is "interactive textiles", also known as smart textiles or "e-textiles". These materials are the amalgamation of digital technologies and textiles, allowing materials the ability to sense, react, and display. This utilization of digital media within our materiality is producing textiles that are no longer mute, but are responsive, amplified through a number of outputs, including light and sound. This transformation of materials from passive to responsive is being driven by the informational capacity of embedded technologies. Küchler (2008) describes e-textiles as existing not simply as material but also informational. This material-informational duality highlights a need to understand the way in which we relate to material in our changing technological world, and a closer consideration of our "dual citizenships" between our physical (material) and digital (informational) spaces.

Through a practice-led investigation, utilizing the processes of the creation, prototyping and performance of sonified textiles, this paper presents current research into the relationship between textile as material and information and the way in which these

dimensions may be aligned successfully through design. It also draws on key theoretical texts and the work of other designers. Considering closely this transformation of textiles, this investigation intends to understand the evolving relationship between material and information; the physical and the digital.

Keywords: digital technologies, interactive textiles, e-textiles, sonified textiles

Introduction

Digital information has saturated our lives, interlaced with objects that we routinely engage with. No longer are we simply considered physical, but our "posthuman" bodies are becoming "material-informational entities", as stated by cybernetics theorist N. Katherine Hayles (2008, p. 3). Bodies, now seen as an amalgamation of not purely physical but also digital parts, are treated "as an assemblage of human-computer-communications networks" (Cleland, 2010, p. 74). This informational augmentation is extending us beyond what once was considered our boundary; the skin. The physical-digital transformation of our bodies is driven by the assimilation of digital information into objects and materials existing within our physical environments. For this reason it is important that our designers, architects and computer scientists understand the way in which we might consider and design for our "dual citizenship" (Ishii & Ullmer, 1997, p. 1) between the physical and digital domains. Doing so means being mindful when forging relationships between bits (digital information) and atoms (physical material) (Wiberg & Robles, 2010, p. 1).

One of the leading areas of material-digital integration is the development of smart materials. Materials, such as textiles, have made the transformation from "being" materials to "doing" materials (Bergström, Clark, Frigo, Mazé, Redström, &Vallgarda, 2010, p. 155). Increasingly important is not just our understanding of what a material is, but also what it does (Bergström et al., 2014). These smart materials are "blurring the seams between mechanism and material" (Küchler, 2008, p. 3). They are the union of digital and physical, with the capacity to sense, react, and display. This utilization of digital media within our materiality is producing materials that are no longer mute, but are responsive, and amplified through a number of outputs, including light and sound.

The purpose of this research is to engage with and explore ideas around the transforming relationship between bits and atoms, digital information and physical material, through creation of a knitted, sonified smart textile.

Background

Understanding information and material

Digital information is becoming increasingly pivotal to our everyday lives, and on the surface it almost appears to take standing over our materiality. Tasks that were once done physically are now translated into our digital domain; spaces, such as supermarkets, that once could exist without the abstraction of digital information can no longer (Kitchin & Dodge, 2011, p. 17). These environments rely on a myriad of computer systems and networks, utilizing unseen but necessary digital information and databases that keep these spaces in operation. The prominence of our physical-material world has seemingly waned, creating a hierarchy where information reigns. It has been proposed that our society should now be considered the "information society" or perhaps the "networked society" (Dourish & Mazmanian, 2013, p. 94). In this vein, digital information is seen as "dematerialized", appearing to have "lost its body"; (Hayles, 1999, p. 2) occurring through the employment of virtual interfaces, shaking off the materiality that had been previously seemed so significant.

It can be argued however that this is only partly the case. It is important to consider the origin of digital information, and how it came to exist. While it can be perceived as being disembodied, information relies on the physicality that it appears to reject. Digital information, or bits, in its most fundamental form is physical. It is a pattern of electrical signals, created through the interaction of physical materials. This reliance of digital information on physicality presents itself when technology refuses to work; (Dourish & Mazmanian, 2013, p. 94) when the weather causes a power cut or when a scratch on the DVD causes it to skip. With this in mind, it seems impractical, or purely impossible to isolate information from material, and vice versa. If we consider the basic level of digital information being purely simple patterns occurring physically, we can begin to consider

the importance of the material instantiation of that "dematerialized" digital translation to its realization.

While digital information could be seen as a material in itself, with computers being used as design material in the same manner as paper or cardboard (Wiberg & Robles, 2010, p. 67), Vallgarda and Redström (2007) believe that digital information exists rather as a "computational composite" exploited not in isolation, but within its relationship to another material. In the case of e-textiles, digital information is exploited in its relationship to textile materials, inheriting and utilizing the properties and characteristics of that textile. While digital information may only be in its rawest form a simple pattern, its union with another material allows it a full expression that moves beyond being a stream of ones and zeros. This seats digital information relationally next to materiality, existing in a way that isn't concrete, but also not entirely disembodied.

One of the characteristics of information that allows it to be seen as being "immaterial" is its temporal nature; computational information is not fixed but transforms over both space and time (Sundström, Taylor, Grufberg, Wirström, Solsona Belenguer, & Lundén, 2011), constantly in motion. While physical material can be perceived statically, captured in a single moment, digital information characteristically is fluid, and can only be perceived and understood in the course of time.

Designing with information and material

Wiberg and Robles, in their work *Computational Compositions: Aesthetic Materials and Interaction Design* (2010), perhaps contrary to the idea of information "losing its body", infer that digital information is still very much reliant and dominated by physicality in our modern human-computer interfaces. Traditional design methods have pushed bits and atoms into differing categories. Bits simply mock the physical world by means of metaphors, as in the case of Graphical User Interfaces, or further still bits disappear into physicality as the result of Ubiquitous Computing. While digital information is very much vital to the organization of our environments, many ways of designing user interfaces appear to simply camouflage digital information, making bits disappear behind atoms.

Tangible User Interfaces, known as TUIs, Wiberg and Robles assert to be the most successful way of bringing together the physical and the digital. These interfaces "augment the real physical world by coupling digital information to everyday physical objects and environments" (Ishii & Ullmer, 1997, p. 2). Doing so allows digital information to be palpably handled and controlled creating greater relationally between the digital information and physical materiality of the designed object. However, while Tangible User Interfaces move away from a hierarchal view of the relationship between bits and atoms, the method of designing still concerns a categorical distinction between bits and atoms (Wiberg & Robles, 2010, p. 68). In order to respond to and overcome the categorical distinction between bits and atoms, Wiberg and Robles advocate a new way of talking and thinking about the way we design. They highlight the importance of creating a relational vocabulary as a step towards thinking of bits and atoms compositionally.

While Wiberg and Robles believe that physical materiality is being emphasized in the design of human-computer interfaces, particularly by means of TUIs, it is debatable whether it is done with an appreciation of the physical materials that these interfaces utilize. Previous research has considered the importance of the physical qualities and characteristics of the material at hand, understanding not simply how a material might create a seamless and invisible interface, but rather how the material affords interaction and digital information creation. In this way the research allows the materials to "talk back" to the designers (Wiberg, 2013; Sundström et al., 2011).

Empowering Materiality (2011), by Schmid, Rümelin and Richter, is a body of work that seeks to understand the rich cultural and physical affordances of glass objects, and how these objects might lend their expression to the formation and representation of digital information. The work flips the typical design process: rather than simply applying information to the glass surface or using typical user interface tools such as the mouse or keyboard, the materiality of glass was considered, understanding how an interface might be designed around the physical constraints, affordances and cultural understandings.

Similarly, Sundström et al. (2011) see the need to work within the constraints of the design materials at hand. However, unlike Schmid, Rümelin and Richter who initiated the design process with the physical material, they departed from the digital information. In doing so they looked to understand the constraints and quirks of the computational technology, "allowing the properties of technology to play a stronger role in shaping the outcome" of the final work (Sundström et al., 2011, p. 1562). The designers explored Bluetooth as a design material, working with the technology in a way that offered intimacy with the digital information. In the same way *Empowering Materiality* sought to create familiarity with the physical materiality, *Inspirational Bits* (2011) pursued generating a greater intimacy between designer and digital information, allowing the technology to be explored and experienced. Both of these works reiterate the importance of not simply engaging with the functionality of a material, but also understanding the characteristics of that material. While perhaps in contradiction to our understanding of smart materials becoming "doing" materials, we need to start at the beginning, asking what qualities a material has before we can understand what it might do.

Not only is it important to understand the characteristics of a material in order to understand what it might do, it is also important to understand what it might do, or what functionality it has, in order to understand what the material "is" and what characteristics it has (Hallnäs & Redström, 2002). While the characteristics of the things we design often become secondary to functionality, these characteristics can be important to understanding the multitude of ways in which materials and objects might be used. On the other hand, functionality can be used to explain and understand qualities of the material. In their work *Abstract Information Appliances* (2002), Hallnäs and Redström propose using cyclic exercises, moving from the "expression" of a material or object to its functionality, as *Empowering Materiality* and *Inspirational Bits* both did, and in turn moving from functionality to expression. This is done in order "to discover functionality in expressions and rediscover the hidden aesthetical choices in the expressiveness of things in use" (Hallnäs & Redström, 2002, p. 3).

Design and exploration of sonified textiles

E-textiles as a platform for the exploration of bits and atoms

E-textiles, or interactive textiles, serve as an appropriate and useful platform when attempting to understand the relationship between bits and atoms. This research understands the term "e-textiles" to be distinct from "wearable technologies", as it does not refer to all technologies worn on the body. Rather, it implies an intricate fusion between electronic and non-electronic materials. While "wearables" often refer to technologies that do not integrate the digital technology and product fully, but rather "tack" the electronic components on to the surface of the garment, e-textiles incorporate the electronic material into their very fabric. This then blurs the divide between the digital and non-digital characteristics of the textile.

This research employs a knitted textile constructed on the Sheima Seiki WHOLEGARMENT™ machine using both conductive and nonconductive yarns, embedding a sensing mechanism directly into the structure of the textile. As the structure is deformed and manipulated, the degree of resistance flowing through the yarns is altered. This can be interpreted by a micro-controller and transmitted to a computer for analysis. There is a direct relationship between the manipulation of the textile and the resulting digital information. The extent of electrical current flowing through the fabric is altered as the fibre's physical relationship changes; this then is translated into digital information, flowing and transforming with the physical textile, coupling digital information tightly to materiality.

Sonification and textile

There has been much research into the way in which information should be presented to the body by being moved away from screens and placed into our environment. "Ambient displays" is a term used to describe displays that no longer rely on the screen for explicit expression, but are expressed implicitly via other modes of perception, making use of an entire physical space and the entire human body. Sonification, or the expression of information through sound, was used in this research as a way of

expressing the digital information created through the movement and manipulation of the textile. Initially, the digital information shaped by the textile was reported back to the researcher using a minimal onscreen graphical display. The meaningfulness of the information was lost, and the screen posed itself as a distraction by diverting attention away from the textile and its manipulation, to a seemingly trivial stream of numbers. Sound, and the sonification of the resulting digital information, became a fundamental tool in connecting the digital information directly to the movement and manipulation of the textile. If we consider the screen as being an interface to digital information, then in this way we can understand the textile in a way became the screen itself.

As mentioned earlier, digital information has a number of interesting characteristics, including its seemingly immaterial nature, its way of speaking about the relationship between physical objects and its temporality and fluidity. Interestingly, sound also holds these traits, and can be used as a "malleable" and "intangible" representation of digital information (Ishii, 2008, p. xvii). Sound can be considered as the expression of the relationship between objects: sounds are "events" of thing, rather than things themselves (Connor, 2004, p. 157). This means that, like digital information, sound is a physical pattern, perceived not as a substantial material in its own right, but as a dematerialized representation. Sound cannot be pointed at, rather it is seen to "radiate and diffuse evenly in all directions, like a gas" (Connor, 2004, p. 158).

Like digital information, sound is omnipresent, existing in the spaces between objects and unable to be captured in a single moment. However, unlike digital information, sound does not disappear, but makes itself apparent, becoming a useful way of bringing bits into the foreground. The consideration of these parallels between sound and digital information allowed an insight into the textile's physical materiality, and its relationship to its informational qualities. The sound became an amplification of the structure of the material, its movement and its interaction with the body.

Process

The initial research stages took a hands-on approach to exploring the relationship between bits and atoms. Understanding how a knitted structure might lend its

characteristics to the formation of digital information meant understanding that structure; this was done by means of hand knitting. Using craft as a way of "thinking through materials" is not a new method in interaction and human-computer interface design (Wiberg, 2014, p. 627), as can be seen in the work of research groups such as MIT Media Lab's Hi Lo Tech group. This integration of craft materials and practices in electronic development "expands the material landscape of technologies" (Buechley & Perner-Wilson, 2012, p. 13) and allows intimacy between creator and creation. This approach opened a dialogue with the materials; understanding of the relationship between the digital and physical aspects of the work arose through interaction and engagement with the materials. Such as in the works of Sundström et al., and Schmid, Rümelin and Richter, this work sought to understand the expressions and the characteristics of the design materials, through a process of crafting.

It is important to highlight the means in which the materials were explored and the ways in which bits and atoms were brought together in the crafting process. The Arduino micro-controller is the *brain* of the knitted prototypes, enabling physical real world information to be translated into the digital and vice versa.[1] Arduino communicates between hardware and software, material and information, hard and soft. It is through this tool (and its communication with software such as Processing[2] and MaxMSP[3]) that this research was not only able to explore the informational characteristics of a textile, but to also express these characteristics.

While these handknitted prototypes were important in the understanding of the expression and potential functionality of the textiles and the way in which they might facilitate and speak about a relationship between bits and atoms, they were also largely useful in the communication of these ideas and knowledge. These prototypes allowed ideas and intentions to be conveyed to others, becoming tools sitting on the boundary between disciplines, thus enabling the accessibility of ideas to researchers in other

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[1] Arduino is open source hardware, allowing electronic fabrication to be accessible to everyone. Arduino.cc
[2] processing.org
[3] cycling74.com

fields as seen in the next stages of research, working with a knit designer to utilize the WHOLEGARMENT™ machines. These initial works prompt and enable conversation regardless of discipline, which is vital in design activity which seeks to consolidate the physical and digital. Bringing bits and atoms together means bringing together disiciplines, establishing and facilitating conversation amongst those not only in harder engineering-based disciplines, such as computer science and materials engineering, but those too in softer arts-based disciplines such as interior and product design.

Figure 1. Manipulating the sonified textile.

Figure 2. Interaction with the body.

Figure 3. Final, full scale prototypes.

The two final large-scale prototypes exist in two configurations. The first resembles a squab cushion, made to be interacted with through means of compression; hitting, sitting, squashing, flattening. The other is a frame covered with the knit material placed upright against a wall, intended to be interacted with through stretch; leaning, pressing, distorting, straining. The simplistic forms emphasize experience of the tangible and auditory qualities of the work. The pieces each have three sensitive areas, accented with colour in order to evoke interaction. The interaction of bodies with these sensors is expressed through sound, evolving as the materials are transformed, exploited and manipulated by the body. These sounds trace and amplify the relationships between bits and atoms, the digital and the physical.

Discussion

The development of these works highlights the importance of the body. For while we speak about designing *objects* that facilitate a healthy relationship between bits and atoms, why is this important? It is our *bodies* that are in need of focus; we need to design these objects so that our bodies can experience digital and physical spaces in ways that are appropriate and inspiring. This research initially assumed that a healthy relationship between bits and atoms was equated with the idea of seamlessness; a relationship that exists between bits and atoms in a way that bodies can no longer perceive where digital information starts and physicality ends. Rather than placing bits and atoms into obvious and differing categories, there would be no clear difference between the two. It is the body and its sensory interface that collects and organizes information, so the implications of the way in which we design the informational aspects of objects needs to be directly related to our bodies.

In a way Cleland's statement, "the human subject is increasingly constituted as an assemblage of human-computer-communications networks" (2010) rings true in this research. The designed objects are not isolated from the body, but can be viewed as informational prostheses, turning bodies into "material-informational" entities. The expression of the body implicitly through sound creates a blurring of boundaries between the body's materiality and immateriality. The expression of the body through

sound spatially distributes information, making it difficult to distinguish where the body starts and ends. The bits and atoms of the body become interrelated and indistinguishable. While it is important to understand the relationship between bits and atoms, it is also important to trace this relationship alongside the relationship between the bodies immaterial and material aspects, and how these technologies involve and transform our understanding of bodies.

While seamlessness appeared to be the goal and allowed the body to be thought about in an expansive sense, the work can also be read from another perspective. Initially the sound was designed as a pure representation of the digital information. If the textiles were manipulated, the sound was composed to represent the exact movement, creating an apparently seamless response; for example, "if I manipulate this textile in x way, it will make x sound." However, it became interesting not only to simply exactly represent the movement but also to explore the digital information as a more complex material, beyond seeing it as a passive "composite" and to compose something unique and thought provoking from it. While sound has been paralleled ontologically to digital information in the way in which it exists as the pattern of the relationship between physical objects, the fundamental difference between sound and digital information is that digital information can be manipulated and played with in isolation from the event that triggered it – unless of course that sound is translated into digital information. The computer in this case becomes a extra tool in the exploration of bits and atoms.

Digital information was collected and manipulated, exploring the relationships between different parts. The sound no longer represented the exact movement occuring in that exact moment, but rather represented relationships between movements, moments, and bodies. This made the work more reflective and thought provoking; however, also losing an element of seamlessness. The relationship between movement and sound felt somewhat strange. While digital information can be seen as the seamless extention of the body, should we also understand the way in which we might be able to bring bits and its relationship to atoms into the foreground through a method of defamiliarization? Defamiliarization can "be used as a method which calls into question our usual interpretations of everyday objects" (Bell, Blythe & Sengers, 2005, p. 154), by making

strange. By creating responses that are unexpected or strange brings the familiar into perspective and can be used as a tool to highlight the relationship between bits and atoms and how we consider and think about them and how we might confront and challenge these familiar understandings.

Perhaps we might abandon simply considering the material charactaristics of the things we design in our quest to understand the importance of the relationship between bits and atoms. Understanding bodily perspectives of the relationship between our physical and digital spaces is important. Both seamlessness and defamiliarization can be perspectives navigated and shifted between by designers as a means of thinking through the relationship between bits and atoms, and the impact these have on bodies. Do we want bits and atoms to be glided between seamlessly, or should there be a seam between the two that our bodies are made aware of? What part *then* do our materials play in this relationship? It becomes a choice of how we want to experience our digital and physical spaces, and how we envisage our "posthuman" bodies of the future.

Beyond this, the work also highlighted the multitude of "parts" needing to be assembled in design processes concerning the digital and physical; this work represents a discourse between not only bits and atoms, but bodies and technologies, hardware and software, theory and practice, and hard and soft disciplines. How do we start bringing all these together? More and more design practice is not simply about creating objects, but about assembling and forging relationships, about crafting the spaces between; between people, between objects, between moments in time and between materials. Our consideration of sound and information as the spaces between objects supports this insight – it is not simply enough to ask "what is it?" or "what does it do?" but now also "what are the spaces between?"

Conclusion

This research exists as an exploration of the evolving relationships between bits and atoms gained through practice-led research. Rather than simply considering the importance of the material characteristics and expressions of the things we design, as iterated in works such as *Empowering Materiality* and *Inspirational Bits,* this research

takes a step further, by considering the bodies central role in defining and forging relationships between bits and atoms. It presents a construct in which relationships are never stable; through the continuous development of technologies and our changing cultural and social understandings of our bodies and technologies, this relationship is seen as constantly being defined and redefined. However, this research is highlighting the need for new frameworks and methods of exploration of alternate perspectives. This research re-examines the role of individual judgement in determining how technologies are experienced and judged. It highlights a need to think about not just the assembly of bits and atoms, but also a range of dichotomies. Using our understanding of sound and digital information existing in the spaces between bits and atoms, it suggests that experiences should be prioritized in the things we design. It is no longer enough to ask "what is it?", or "what does it do?" but also "how does it feel?"

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