What and When Is the Textile? Extending the Reach of Computation through Textile Expression

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The authors of this article argue for 'making time appear' in computational materials and objects so that it can be used to help people become aware of their relation to their environments. [Hallnäs & Redström 2001] As more computational and responsive materials come into play when designing architectural spaces designers might consider opening up the dimension of time to 'make time appear' rather than disappear. [Hallnäs & Redström 2001] Computational materials are materials which transform expression and respond to inputs read by computer programs. Making time appear can have many uses particularly in applications where people can be helped by the awareness of unfolding of time, where the temporality is linked to transformative body experience rather than project efficiency or collapsing distance. If architects, designers, engineers and others could begin to consider and use time as a way to promote reflection then it would be possible to design materials which could expand human thinking through the material itself.

Keywords: Computational materials, Computational textiles, Aesthetics, Human computer interaction, Ubiquitous computing

INTRODUCTION

In the historic development of computational tools and the internet of things, computational objects have tended to disappear into our clothing, vehicles, homes, places of work etc. If designers can figure out ways of making time appear in many computational objects then reach of the computation can be expanded to include other complexities which critically relate humans to environments. These complexities include human emotion which is the way in which humans relate and communicate with environments, other people and animals. Emotion is as temporal and temporary as the weather [Picard 2000] and an important part of human intelligence, health and well-being. In this paper the authors present one project which is a group of four large scale responsive knitted tension textile structures. The authors frame a method of considering time in two interconnected ways. The first is to understand 'what' a computational material is, or in this case 'what' computational textiles are. The second is to understand 'when' a computational material is or in this case 'when' a computational textile is. These two issues open up a discussion which considers the temporality of ma-
BACKGROUND OR FRAMING TIME
To argue for making people aware of time or making time appear is to engage the problem of people's attention. With the proliferation of technological devices which demand people's immediate attention calm computing looks at ways in which using technology can produce calm and comfort as a human affect. [Weiser and Brown 1996, Ishii 2008] For and Weiser and Brown this means managing human attention in the design of computational artifacts. They argue calmness can be promoted in computational objects by using people's ability to move events or things between the foreground and periphery of their attention. Expanding a design's ability to operate on the periphery of people's attention can augment a person's ability to be aware of information but also heighten calmness. People can choose to bring that event into the foreground of their attention or not. Weiser and Brown build on Gibson's concept affordances which they see as typically describing only the surface of a design. However, if one looks at Gibson's writing affordance is really to be understood in relationship to all the senses a human possesses including, touch, smell, hearing, sight, motor capabilities and so on which goes beyond an idea of surface. [Gibson 1966] Ishii's ambient media and ambient low attention devices were designed to use the periphery of human attention. This low attention was garnered by using subtle engagements with the human senses to impart information. Sound, light, air flow, water movement made slow environmental transformations which could make people aware of important information by using a different level of sensing to make use of peripheral attention. [Ishii 2008]

Hallnäs and Redström in their work specifically use sound or hearing as one example of a basic sense to construct what they call a philosophy of slow technology in the field of human and computer interaction. Their emphasis for designing technological objects is on the "expression of functionality as such rather than its objectives" [Hallnäs and Redström 2001] They propose three ways to think about designing expressions for slow technology. These are reflective technology; time technology; and lastly amplified environments. In designing expression for reflective technology their philosophy is not so much about allocating a person's attention to the foreground or periphery, rather their idea stems from a plan to accommodate reflection on an experience which happens over time. An exemplary artifact of this thinking is a doorbell which plays different parts of a tune each time one rings it so that only by hearing it over many times does one get the entire tune by putting the tune together in one's mind. A second critical framework about slow technology expression is time technologies or technologies that make time appear where "use reveals a slow expression of present time." [Hallnäs and Redström 2001] They give the example of a musical instrument where the music produced makes time and it appears through the expression of the music. The last framework for thinking about slow technology expression resides in amplified environments which are expanded environments that amplify reality using computers and other technologies. [Falk, Redström and Bjork 1999]. Here Hallnäs and Redström give the example of a musical amplifier which makes it possible to share music in ways that are not possible without amplification. For them "The basic challenge is to design settings that amplify the expressions of a given environment in such a way that it in practice is enlarged in space or time." [Hallnäs and Redström 2001]

Löwgren and Stolterman describe digital technology as a medium which defines temporal and spatial structures in artifacts and enables a way of interacting with them; subsequently, time becomes a quintessential part when designing an artifact's experiential qualities. [Löwgren and Stolterman 2004]. For Löwgren and Stolterman working with digital technology, time is material. The way things are perceived relate time and space through different expressions that emerge according to how time pres-
ence is considered and exhibited by the changes in the materials used. Further, Lundren and Hultberg develop a framework illustrating different temporal themes to be used in the design process of interactive artifacts. Accordingly, two major placeholders appear here: one which refers to the closeness to the character of the real time-relating to the reality of use, and the other one which refers to the character of the defined time by the designer-relating to the level of control of the author [Lundgren and Hultberg 2009]. An important aspect to be discussed here is how the design of the temporal structure of the artifact is affected by the material choices. Let us get specific about a computational material or a computational textile for example to develop a framework of material in time.

'WHAT' IS A COMPUTATIONAL TEXTILE?

In Figure 1 'the material' of the computational textile is shown. For the purposes of exploration, let us say that 'the material' is a person, a heart monitor, a cell phone, the cloud to send and receive data, a laptop, an electronic power system to drive a knitted texture changing textile making up 'the material' of the textile and the surrounding environment. The material can vary, having different combinations of these elements depending upon a desired end result. Some elements may appear and disappear as the material develops and changes. The definition of the laptop, cell phone, heart monitor and the cloud as 'material' is a very similar exploration to Papert's and Vallgårda's & Redström's who see computers as materials. These materials are an 'object to think with', to use the language of Papert's Mindstorms, "one that can build a sense of science as inquiry, exploration, and investigation rather than as answers."[Papert 1980, Vallgårda & Redström 2007]

In fact working with textiles as materials proposes a different method of work in HCI because with textiles the designer does not necessarily have a predetermined use for the material. Design ideas can come from play with the material, the material is an interface for thought and connection rather than serving as a means to an end. [Ingold 2010, Jung et. al. 2010, Wiberg 2014] Computational textiles as technological materials can offer a similar expansion of the space of design opportunities and invention. [Redstrom 2005] Keeping the relationships open between all the parts in a technological material can help create new ideas for use or ways of using that material. [Redstrom 2005] If technological materials are developed like the material-in-flow formation model Ingold describes then play with technological material is critical to understanding what it may be used for and invention of new uses.

If computational materials themselves can be things to think with through play then the act of making the computational material is tied to its expression. The making of computational materials or textiles is critical to understanding 'what' is a computational material or textile. The invention and free speculation in computational textiles is found through play across different domains of craft and abstract knowledge calling for compositing as a model of making. [Vallgårda and Redström 2007] If one looks at the different models or ways in which people make computational textiles it runs from individual exploration to large teams. Smaller less complicated computational textiles can be made by one person, however this person then must possess the skills to author work in several different domains, knitting or sewing, electronics and programming for example to develop the material. A more common situation whether or not
the textile itself is handmade requires several minds
at work with the material, so that any discussion of
making is about collaborative making necessitating
communication between the people who are work-
ing on different elements of the material such as knitt-
ing and programming the phone, heart monitor or
organizing an power system for the material. Ulti-
mately this collaborative act of making is part of the
expression of the material.

'WHEN' IS A COMPUTATIONAL TEXTILE?
One of the most important issues to figure out as a
designer of computational materials is when a mate-
rial takes on a particular state. [Kennedy 2011] What
initiates a state change and how long does that hap-
pen? If a designer is thinking about time with re-
spect to material transformation intended to com-
municate some affect to people then the material is a
real time nexus connecting the environment to peo-
ple. There is a difference between the time we think
about when using transforming material expression
to communicate affect and change a person’s emo-
tion through vision and touch for example compared
with a temporality one might use in a textile to shut
out light when the sun is too bright to make our
spaces more energy efficient. One technology the
authors will call fast technology and the other slow
technology. [Hallnäs & Redström 2001] "What is im-
portant to note here is that the distinction between
fast and slow technology is not a distinction in terms
of time perception; it is a metaphorical distinction
that has to do with time presence. When we use a
thing as an efficient tool, time disappears, i.e. we get
things done. Accepting an invitation for reflection in-
herent in the design means on the other hand that
time will appear, i.e. we open up for time presence."
[Hallnäs & Redström 2001] 'When is a textile' relates
to states of the material in specific circumstances that
allow time to appear.

Bergström et. al. call this potentiality of ma-
terial becoming material which is a material in con-
stant and continuous negotiation with its environ-
ment. [Bergström et. al. 2010] This becoming is
also a characteristic of humans relating their bodies
to the environment. Moment to moment each per-
son’s body changes to adjust and respond to events
in place, indeed an elemental definition of emotions
is the adjustment of the body to its environment or
change in bodily expression which is necessary to
survival. [Damasio 2000, Darwin 1872/1998, Gibson
1966, Picard 2000] When people see, feel or touch
a material they are already interconnected with that
material, it is communicating to them through their
senses and their senses give a feedback about that
experience. Bergström’s term becoming may be seen
as human becoming, for perception and material-
ity are connected together. Textility as described by
Ingold weaves the forces of material formation and
shaping with the senses of the body to make ma-
terial expression. [Ingold 2010] Textility is an inter-
weaving of bodily and material transformation which
reads and creates expression. Emotion felt or com-
municated through interaction with material is a tex-
tility of emotion which reads and creates emotions.
[Davis 2015] Creating the 'when' for reflection, affect
or emotion requires understanding this reading and
creation of expression though people.

When making computational materials which
use skills found in multiple disciplines designers of-
ten use the idea of a script to understand the pos-
sibilities of transforming materials in advance of de-
ployment. [Bergström et. al. 2010] The script is an
informal written or rough sketches on paper by a per-
son or lead group who has an idea. The script in
one way could be considered as an abstract imposi-
tion of form onto material, however it is difficult to
even make a script without having had some feed-
back from the material about how it could behave
and affect people before making the script. Finding
out when the textile will respond is dependent upon
lots of experimentation, play and reflection. 'What'
and 'when' is a textile frames computational textile
expression as a linked human/material transforma-
tion in time.
FOUR TEXTILE TENSION STRUCTURES

As an example of these two concepts about material in time for reflection the author presents 4 knitted tension tubes which respond to presence. As examples the knitted textile tension tubes operate as artistic exploration of material expression which can be used for making time appear. The materials in this paper were developed as an experiment to understand what transforming material expression could do. The 4 tubes were done as a collaboration between the two authors at the Swedish School of Textiles in Boras, Sweden and presented in an exhibition tilted Patterning with Heat at MIT Keller Gallery. [Davis and Dumitrescu 2013] Photographs of the exhibition can be seen in Figure 2. Three core design areas set up the field of potential for how the textile tubes functioned and how time perception was controlled. These areas included the material/chemical composition of the yarns and the structural design of the knit, the electronic design controlling current through the yarns and lastly the programming which controls timing. Each of the 4 tubular structures showed one of two material responses which were activated by an electrical current. This current irreversibly changed the pattern and surface appearance of the material.

The first typology of material developed was pixelated, designed with yarn that melts at high temperature; accordingly, the fabric opens or breaks when it receives current. The opening allows designers flexibility to experiment with see through effects on the fabric, or to 'write' upon the fabric making apertures, collecting foreground and background through the qualities of the material. The second material has been designed with yarn that shrinks or closes into solid lines in the fabric when it receives current. The shrinking reveals a more opaque patterning in the textile closing parts of that textile off, transforming the material and the quality of space framed by that material. Figure 3 shows the opening yarn on the left and shrinking yarn on the right.

Both breaking and shrinking yarns were knitted into four different architectural tension structures for the exhibition. These tubes were The Pixelated Reveal Tube, The Radiant Daisy Tube, The Stainless Steel Tube and Tube in Tube. Two of the tension tubes in the exhibition, The Pixelated Reveal and The Radiant Daisy structures were designed and wired to register people’s presence in space using proximity sensors. A
signal sent by the sensor to the fabric then triggered an opening or closing response on these two tubes. Two tubes, *The Pixelated Reveal* and *The Radiant Daisy* will be discussed in detail in this paper. The remaining two tubes were left unwired and were to show the different types of material that could be made responsive employing the opening or closing yarn technique. These remaining tubes will not be discussed in detail in this paper.

The material for the tension tubes in the exhibit was designed on two different industrial knitting machines at the Swedish School for Textiles, University of Boras, in Boras Sweden. The authors had the skilled help of two technicians to test our yarn selections and knit structures on these machines. The first machine used was a circular knitting machine that could produce tubular shapes that had the same diameter along its length. This machine was capable of knitting with quite stiff stainless steel and metal yarns to make our tubes conductive. The second machine used was a double needle bed flat knitting machine that could make tubes by knitting the two sides together. This machine was developed for knitting socks, gloves and pants therefore it was able to vary the diameter of the tube along its length. This machine was also capable of making closed knitted shapes, in addition to being capable of knitting with metallic yarns.

During the fabric manufacture the authors tested two yarns in combination with conductive yarns to develop materials that either opened up the fabric or closed and became opaque. These yarns were Grillon VLT which when heated to 60C breaks, and Pemotex ®, which shrunk 40% when heated to 90C. Patterns were made in materials that included these two yarns by sending current in conductive yarns to specific areas along the knitted structure that activated these two yarns.

**Pixelated Reveal Textile**

*The Pixelated Reveal* tension structure was made on the circular knitting machine with the opening yarn. The material was designed with small stripes of melting yarn to create what we called ‘pixels’ which opened when heated by current. The fabric was designed so that many different designers could make their own patterns with these pixels. In addition, the material was designed so that if all the pixels were open there was still knitted material between the pixels to hold the structure in tension. Please see Figures 4 and 5.

![Figure 4](image1.png)  
**Figure 4**  
Pixelated Reveal Knit Fabric

![Figure 5](image2.png)  
**Figure 5**  
Close up of Pixelated Reveal fabric pixels open left, pixels closed right.

This geometric structure is made up of conductive yarn and melting yarn using a tubular Jersey structure. The pattern is formed of 4 courses of texturized polyester yarn, monofilament, 1 course of melting yarn or GRILLON VLT ® and 1 of conductive yarn. The two courses made by the conductive yarn and melting yarn are knitted every 4 stitches which leaves floats on the textile reverse side. Thus, when the melting yarn is heated it disappears from the area...
where it is stitched in the textile structure. This structure may be seen in Figure 6.

The Pixelated Reveal structure was wired to open a small 10 cm area of pixels at a time in a spiraling fashion up the tube. Each 10 cm line of pixels was given current through a microcontroller via a positive or negative cable at either end. The conductive yarn was continuous and circular in the tube and had to be cut at each end of the reactive area to ensure that the current only went to that area. Figure 7 shows the fabric of the tube unrolled. The material was connected to a proximity sensor in the exhibition, but the authors discovered it was very difficult to control the response with many people in the room in an exhibition situation and could only get a small sample to operate.

The programming for *Pixelated Reveal* was designed to receive a signal from the proximity sensor and then send current to open up one 10 cm area of pixels. Each time a person was sensed near the tube, the next line of 10 cm pixels would open until the entire pattern was revealed. Once a person was sensed, 10 cm of pixels opened up over 8 seconds. Figure 8 shows the set up for the Pixelated Reveal Tube in the gallery space.

**Time in the Pixelated Reveal**
The intention in *The Pixelated Reveal* tube design is to make time appear via both rapid and slow changes in the texture. The rapid change in the fabric appears dramatically because 5 pixels are activated at once in an interval of 10 seconds. Figure 7 shows the author’s choreographic drawing which helped them as designers understand the different possibilities of expression in time with this material, however this drawing could only be done after playing with or testing smaller material samples which had different numbers of knitting stitches for conductive and melting yarn. Supporting this rapid change are yarns which react instantly to heat transformation the geometry of which the authors experimented with. The two sensors placed on the top of the piece activate every 5 pixels of the helix at every movement. The sensors are activated by a person standing at approximately 30 cm or fairly close to the tube. Figure 8 shows this set up. The changes in expression are dependent upon real-time movement in space by a person around the textile tube. In *The Pixelated Reveal* tube the pixels can open in a faster rhythm due to the fact that they can be activated by two or more persons moving simultaneously. The changes in the textile pattern accumulate in time due to the irreversible character of the yarns. Over time the intention of the reveal, was a registration of presence of people which
would result in a lengthening of the tube in height, and reduction of the opacity of the tube as the pixels opened stitches. It is this slower accumulation of smaller rapid changes that makes time appear in the textile.

**Radiant Daisy Textile**

*The Radiant Daisy* tension structure was knitted on the circular knitting machine with Pemotex or the shrinking yarn which made patterns by making fabric areas opaque. This material starts out as a transparent volume which when activated by heat closes the cells defined along horizontal bands in the structure. The textile when patterned can be used to create closed areas in a surface. The structure is formed by 5 courses of Pemotex yarn using a tuck pattern and a stainless steel yarn knitted as single jersey every 6th course. The Pemotex® shrinks 40% at 90°C, which is the maximum heat put onto it. Figures 9 and 10 show the fabric of the Radiant Daisy tube.

The pattern we selected to show was a large daisy on the tension tube. The conductive stainless steel yarn, which was continuous in the knit cylinder, was cut to make the daisy pattern. Current was run to activate these cut areas using positive and negative cables attached to a microcontroller. The microcontroller received signals from a proximity sensor. When a person was near by the tube, the sensor sent a signal to the material via the microcontroller and heated up one petal of the daisy. Figure 11 shows the choreographic drawing for the Radiant Daisy pattern.

This specific textile structure had much higher resistance compared to the Pixelated Reveal material. The pattern was constructed with a parallel circuit, because it was a higher resistance material. The ends conductive line defining the daisy petal had to be sewn to its neighbor by hand with conductive thread, taking much more preparation time than *The Pixe*
lated Reveal.

After tension was applied to the material the resistance went up and we were not able to activate the tube hanging in the exhibition space. Smaller samples laid upon a table were able to respond, however it is possible that this particular knit and structure has a maximum tension limit to perform.

Figure 11
Radiant Daisy Choreography drawing

The programming for *The Radiant Daisy* was written so that the microcontroller received a signal from the proximity sensor and then sent current to make one petal of the daisy opaque. Each time a person was sensed near the tube the next petal would become opaque until the entire daisy pattern was revealed through opacity. Figure 12 shows the set up for the *Radiant Daisy* tube in the space.

Figure 12
Set up of the Radiant Daisy Fabric

*Time in the Radiant Daisy*

*The Radiant Daisy* is designed with time as expression of reflection, once the sensor on the wall senses people’s presence close to the textile piece; the pattern starts to grow by slowly activating each line within 12 seconds. Figure 12 shows a choreographic drawing which helped the author’s design the temporal interactions for this material. The programming is done so each line activates in 12 seconds and then stops until another movement occurs to activate the next line. The change in the textile is discrete so one needs to stop to visualize the change. The dynamic of the textile expression depends upon the real-time spatial interactions which occur in a natural order. The changes in the textile pattern accumulate in time due to the irreversible character of the yarns.

**CONTRIBUTIONS**

The contributions made by the authors of this paper are a framework for considering the temporality related to designing computational materials which make time appear. The authors have identified 2 interrelated concepts about time ‘what’ and ‘when’ is a textile frame computational textile expression as a linked human/material transformation in time. The authors have presented work from an exhibition titled *Patterning by Heat: Four Responsive Tension Structures* as an example of these 2 temporal concepts. More specifically they have presented the process of making and designing these computational textiles to show how material selection, the structural design of the knit, electronic design and programming, present different gradations of time which can be used to make time appear in human interaction with the computational textile.

The authors would like to thank Mika Satomi for her assistance with programming the textiles and master knitters, Tommy Martinsson and Christian Rodby at the Swedish School of Textiles in Boras Sweden.

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