EXPLORING HEAT AS INTERACTIVE EXPRESSIONS FOR KNITTED STRUCTURES

DELIA DUMITRESCU

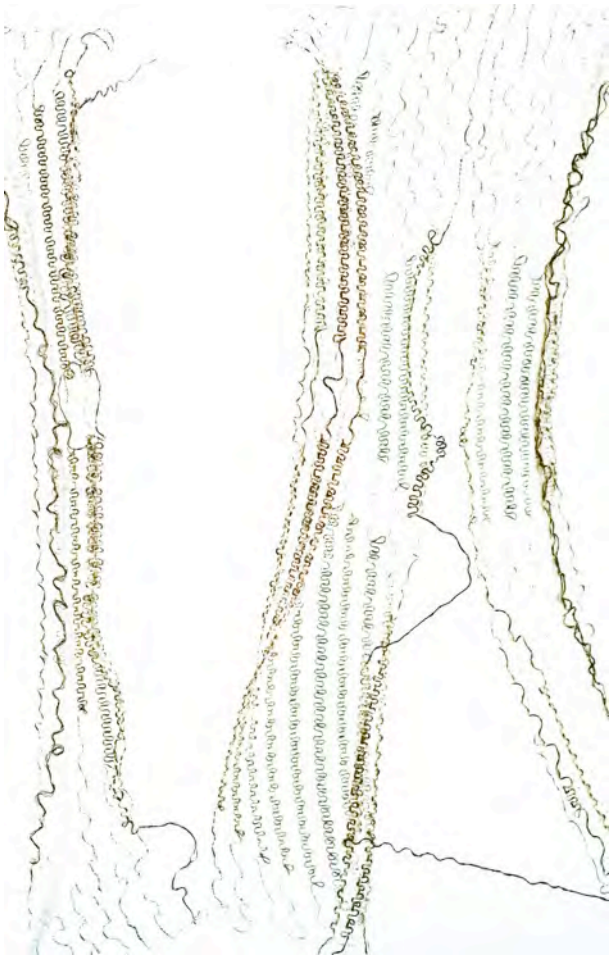
THE SWEDISH SCHOOL OF TEXTILES, UNIVERSITY OF BORÅS. DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING, CHALMERS UNIVERSITY OF TECHNOLOGY, GÖTEBORG

DELIA.DUMITRESCU@HB.SE

ANNA PERSSON

THE SWEDISH SCHOOL OF TEXTILES, UNIVERSITY OF BORÅS. DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING, CHALMERS UNIVERSITY OF TECHNOLOGY, GÖTEBORG

ANNA.PERSSON@HB.SE



ABSTRACT

This paper describes a practice-based research project in which design experiments were conducted to explore how knitted structures can be designed with particular emphasis on various interactive heat expressions. Several heat transformable structures, able to both sense and react to human touch, were developed in the textile collection *Knitted Heat*. The designed textiles serve as references to reflect further on the role of interactive textiles as materials for potential designs. Specific scenarios defined by *shrinking*, *breaking*, *stiffening*, *texturizing* and *warming* expressed by the textile transformations exemplify and discuss their potential as complementary for other design processes.

INTRODUCTION

The last few decades have shown an extreme development of the textile material as the area of interactive, or smart, textiles has influenced the fields of industrial design, architecture and of course, the textile industry (cf.[Berzowska and Coelho, 2005; Braddock Clarke and O´Mahoney, 2005; Colchester, 2007; McQuaid, 2005; Seymour, 2008; Ramsgaard Thomsen, 2007) etc). Compared to "non-interactive" textiles, the concept of smart textiles primarily describes textiles whose qualities have been enriched by technology. In this context, textiles can be defined as physical materials with transformable behaviors, the materials are "*augmented with the power of change and have the ability to perform or respond*" (Verbücken, 2003).

Due to technical developments within computer technology such as the miniaturization of electronic components, the possibility of integrating textiles and electronic components has been demonstrated through material research and development projects. As a sequel to the concept *Tangible bits* - the notion of seamlessly coupling the worlds of our physical environment with cyberspace (Ishii and Ullmer, 1997), soft material interfaces such as *Super Cilia Skin* (Raffle, et al., 2004), *Sprout I/O* (Coelho and Maes, 2008) and *Bosu* (Parker and Ishii, 2010) have been developed as alternatives to traditional screen-and-keyboard interfaces. By sensing and reacting to physical touch, these interfaces have a kinetic memory, are transformable and engage new sensibilities. Consequently, the interest to develop new design tools that help designers to relate virtual and physical media has emerged. Projects such as *Skin* (Saakes, Stappers, 2009), *Cabinet* (Keller et al., 2006) or *SandScape* (Ishii et al., 2004) open the interaction design field to novel creative processes.

The concept of smart textiles opens new discussions about the role of the material in the design process and the need for bridging various design disciplines. By introducing concepts such as interaction and transformation as essential features in textiles, the textile practice faces new challenges.

This paper describes *Knitted Heat*, a collection consisting of the previous projects *Touching Loops* (Dumitrescu and Persson, 2008) and *Designing with Heat* (Dumitrescu and Persson, 2009), with a particular emphasis on how interactivity can extend a textile's expressional properties as the use of conductive yarns in an advanced knitting design makes a textile become both sensitive and reactive to human touch. Knitted Heat explores possibilities to design for tactile and visual interaction as the textiles encourage a close and sensitive interaction with knitted textile material both by touching and sensing.

This project is made within the Smart Textile Design Lab at the Swedish School of Textiles and takes on an experimental approach in which design examples explore the aesthetics and emerging expressions of smart textiles rather than technical functionality (cf. [Redström et al. 2005; Worbin, 2010]).

KNITTED HEAT

Knitted Heat is a collection of several design experiments in the form of interactive textile samples, and unites two experimental projects, *Touching Loops* and *Designing with Heat*. Both projects uniquely explore the integration of heat as the focal point of the surface design.

TOUCHING LOOPS

In Touching Loops, heat is used to transform a textile surface's structure. The outcome is three different interactive textiles able to change structure both visually and tactilely. When one touches the textile by hand, the textile becomes hot and structure changes are made. The design examples show different kinds of structural changes in three different textile designs; *shrinkage, breakage and stiffening*. The following scenario refers to all three examples, with a difference in *how,* the structure is changing:

I touch the textile with my hand and it reacts immediately by shrinking (Structure 1) by breaking (Structure 2) or by stiffening (Structure 3) since it is programmed to generate heat as soon as it senses the presence of my skin. The textile reacts in the same area as it is being touched upon. Once it has been touched, the heat is on for 15 seconds which is considered to be enough time to make the surface react in a way that is perceivable.

Figure 1: detail -knitted pattern Structure 1

Touching Loops: Structure 1 (Fig. 1 and Fig. 2)

The surface is designed as a combination of two different tactile patterns. Its texture is based on the mix of a plain knit with a ridge pattern. Fine rows of conductive yarns separate the areas of the textile surface sensing and transmitting the information as heat.

When current is applied**,** the knitted patterns change size by *shrinking* in relation to the amount of heat and the surface area where heat appears.

Figure 2: detail -structure transformation Structure 1

Figure 3: detail -knitted pattern Structure 2

Figure 4: detail -structure transformation Structure 2

Touching Loops: Structure 2 (Fig. 3 and Fig. 4)

Rows of ridge patterns are interlaced on the surface design building its texture as a structural frame. In this case, the surface does not change texturally, as it did in the previous design experiment. Instead, applying heat through the conductive yarns on the material's ridges produces a transformation in the surface from soft to hard- by *stiffening* specific areas.

Figure 5: detail -knitted pattern Structure 3

Touching Loops: Structure 3 (see Fig. 5 and Fig. 6)

The pattern uses a Jaquard 2X2 net technique. The rows of Jaquard are separated in a computer program to control the placement and size of the breaks in the material. When exposed to heat, the transformable yarns melt, leaving the loops of conductive yarns. The rows of conductive yarns sustain the shape of the loops transforming the textural effect of the surface from a two dimensional to a three dimensional pattern by *breaking*.

Figure 6: detail -structure transformation Structure 3

DESIGNING WITH HEAT

Designing with Heat consists of two design examples

developed with a focus on heat changing properties. When someone touches the textiles with their hand, the surface becomes hot in a comforting way. The textiles show two different kinds of heat design, where temperature changes produce two types of tactile patterns.

Figure 7: shaping by heat various knitted pattern in Structure 4

Designing with Heat: Structure 4 (Fig. 7 and Fig 8)

This structure uses the same principles as the first design experiment but implements a different pattern design. The knitting technique in this design experiment is based on yarn inlays. The conductive yarn is inlayed in patterns instead of being knitted into the structure. Consequently, having less points of contact in between the conductive yarn and the shrinking yarn, produces a larger range of transformations in the surface design when heated. The effect appears both in shape and in size of the patterns by *texturizing*.

Figure 8: close up -structure transformation Structure 4

I touch the textile with my hand and it reacts by changing texture since it is programmed to generate heat as soon as it senses the presence of my skin. The textile reacts in the same area that it is being touched. Once it has been touched, the heat is on for 10 seconds which is considered to be enough time to make the surface react in a way that is perceivable.

Designing with Heat: Structure 5 (Fig. 9 and Fig. 10)

Figure 9: detail -knitted pattern Structure 5

The conductive yarns are partially knitted to form three-dimensional geometric shapes creating the texture of the surface. The conductive texture changes temperature. According to which area heat is activated and the planned time sequence of the change; new heat patterns can be created as a second layer of the surface by warming the hands.

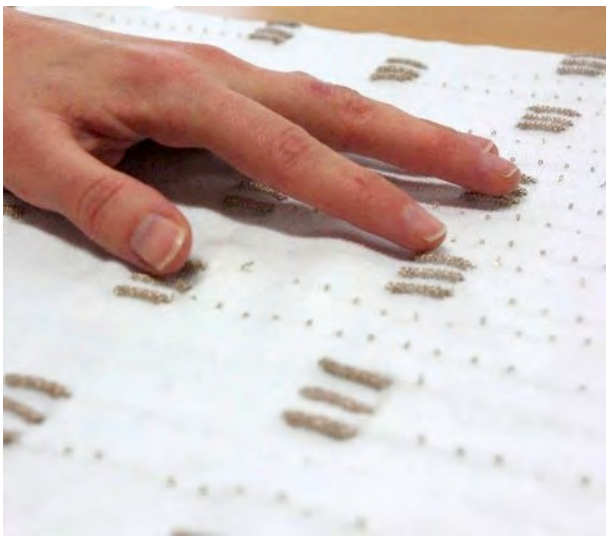


Figure 10: detail -structure transformation Structure 5

I put the palm of my hand on the textile surface and the textile reacts by becoming warm. The textile becomes heated in six different areas and the heat moves around to warm my hand. The textile senses the location of my hand, and heat is generated in areas around that spot.

The textile reacts kind of slow and once it has been touched, the heat is on for 5 seconds in each heating area. This keeps the heating areas from cooling down as long as my hand is still touching the textile.

KNITTED HEAT

In Knitted Heat, we talk about knitting in terms of structure and texture where both elements are expressed by aesthetic and tactile qualities of the knitted surface. The experimental projects resulted in the creation of various interactive knitted patterns where the design variables of the basic knitted surfaces were enriched by computation. The design of transformations in the surface and the interaction with the surface are relating in the subtle changes that appear as material design. The knitted surfaces in Designing with Heat and Touching Loops are complex textile constructions capable of embedding various layers of information, as they are able to both sense and react.

Heat is integrated into the textiles as a means to shape new patterns or to produce changes in the surface structure. The relationship between the amount of heat and the exposure time in the conductive yarns is the key factor in shaping the material design.

Various expressions of transformation are explored in the design of knitted surfaces. Each of the examples of textile surfaces represents a specific relationship between structural pattern and the placement of conductive and transformable yarns. The patterns, the texture and the shape of the textile surfaces are designed to allow further transformation of the knitted structures. According to the type of pattern used, the type of transformable yarn, the placement of the conductive yarn on the surface and the time settings in the computer program each of the structures allows for various states of transformation.

KNITTED HEAT AS DESIGN MATERIAL

Knitted Heat aims to advance upon new dialogues in the design process between designers and interactive textiles as material for design. That is to initiate a space where the textiles function as a meeting point between the virtual and physical design prototyping spaces. In Knitted Heat, the experiments by design combine the concreteness of the textile material with computation to create different types and scales of expression of physical and visual transformation- by *breaking*, *stiffening, shrinking, texturizing or warmin*g.

The expressions of heat transformation represent flexible relations in the textile surface relative to pattern, texture or shape leaving the knitted surface open for further change when placed as a material for various design processes. Accordingly, the examples are not an end design product; the result is a collection of knitted textiles whose changing behavior can be used as an open platform for surface explorations in knitted design.

Expressions of *shrinking*, *breaking*, s*tiffening*, *texturizing* or *warming* can be further enriched when the knitted textiles are supposed to be related to various products or scales of design. Therefore Knitted Heat opens the design parameters of the textile surface design**,** such as shape/texture/pattern**,** bridging shape to material exploration in one process.

The experiments show potential ways of exploring the relationship between surface/shape, pattern/shape, tactile/visual etc. in initial stages of the design process through the direct manipulation of the material when the scale of prototyping is the real world scale (that of the knitted material). In this context, Knitted Heat can be described as an expressive prototyping tool presented in real world scale.

re-texturizing
Structure 4 is an open knitted design that when placed in a 3D modeling context, allows the designer to play with the placement or scale of the pattern on the desired shape of the garment or object (Fig. 11). Through tactile interaction Structure 4 is able to express various types of patterns- opening possibilities for multiple relations in between its texture and form.

Figure 11: exploring pattern placement by physical manipulation of Structure 4.

On the right side, Structure 4 is a plain knitted surface. The conductive yarns are placed in fine layers on the wrong side to produce a transformation on the plain knitted side via heat. Depending on the location of touch and how the fingers are placed on the material the conductive yarn creates various types of tactile patterns on the right side of the material.

re-shaping
The knitted surface as in Structure 2 is shaped by

physical manipulation (Fig. 12). In this context, the physical manipulation of the surface and its transformation generates new relationships in between designing form using textiles and exploring the surface knitted materiality.

Figure 12: exploring surface shaping by physical manipulation

Due to heat and tactile interaction, the soft textile surfaces can change properties by stiffening. According to which conductive lines are pressed and how much the hands are pressing the material and on which areas, its surface can be three dimensionally shaped by varying its softness. The textile material in this example is seen as a means to transform a soft surface into hard shape and to explore them simultaneously by physical manipulation of the material.

re-scaling

Relating the experiments with heat patterns to larger scales of design, such as architectural design, various relations based on the relation between visual and tactile patterns can be created. The experiments with heat patterns expose the potential for new tactile expressions in space design. The textile surface in Structure 5 has a static visual pattern that relates to the dimension of space. The heat pattern is activated only in the near field when the textile surface is touched (Fig. 13).

Figure 13: Near-field scenario - exploring textiles as tactile expressions in architectural space, Structure 5

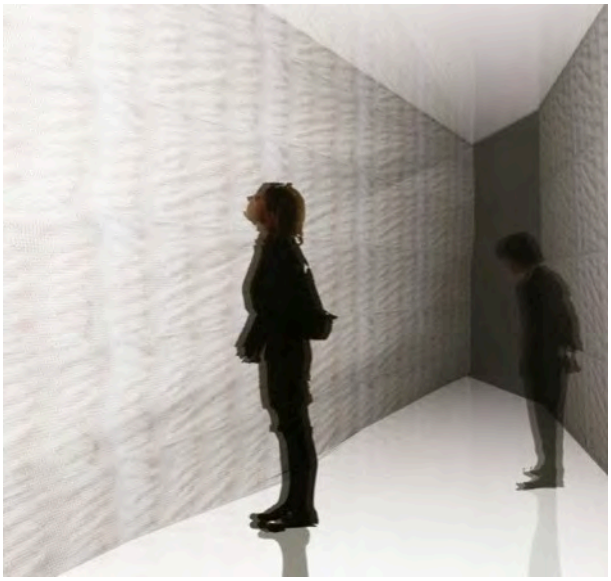


Figure 9: field scenario- exploring textiles as visual expressions in architectural space

New dynamic relationships in between textile scale and space design can be envisioned, where different scales of expression interact on one surface starting from the near field of the textile structure up to space. In this case the interactive tactile surfaces can complement the digital tools of prototyping by material exploration at real world scale, bridging new relationships between CAD applications and the concreteness of textile materiality.

By questioning the relation between human interaction and surface exploration in the design process of form making, Knitted Heat presents multidimensional forms that can be further transformed by the designer in form, texture, interaction, etc... This offers a new perspective in the context of interactive materials, providing open expressional tools for further designs, since textiles act as materials by and for design. The examples indicate various ways of exploring the surface's textural effects at different scales in the initial stages of prototyping, while retaining the textile as reference dimension.

The role of an interactive material for design, in this context, is to integrate various design processes leaving certain aspects open-ended for further experimentation with the textile texture.

By proposing alternatives to shaping, texturizing and scaling we aim to question the textile role in the design process for various fields and engage new dialogues where the textile and interaction can materialize design thinking. Consequently, the textile becomes both a tool and a material for design blurring clear distinctions in between material *by* design and *for* design; where the basic variables of design bridge various steps in the design process from material "*fabrication, application and appreciation*"(Doordan, 2003).

DESIGNING WITH INTERACTIVE TEXTILE EXPRESSIONS

Adding sensing and reacting properties to a textile extends its expressive possibilities and brings new challenges to the area of textile design. The relation between the textile material and the interaction can be seen as interactive textile expressions. A textile's interactive expressions should be seen or experienced in a textile over a period of time; they are both spatial and temporal in their nature (cf. [Hallnäs and Redström, 2006, 2008]). For example, examples of interactive textile expressions in the Knitted Heat collection are those of shrinkage, breakage and stiffening. The collection also shows examples of expressions that are purely tactile and in the form of temperature changes (as heat).

The two collections were designed with a focus on their interactive expressions, and are meant to exemplify ways of designing with these materials. They are meant to show the potential of how to reflect upon and understand the expressional tools these kinds of constructions and materials provide. This is made by both envisioning *specific* designs but also by opening up the design process to create new designs that use the same interactive expressions with another scenario.
A specific design example exemplifies *one* way of interacting with the textiles (as an example, see Structure 3). The scenario described is simple. Still, multiple choices have been made when designing this specific interactive expression. In this way, the design examples allow for further designs with the same materials (Fig. 15):
The specific example breaks in one area. The breakage occurs after I touch the textile, and is sustained for 15 seconds. The resulting expression is clear.


Figure 15: interaction scenario- breaking patterns in Structure 3

For further design, we can ask ourselves:

When touching the textile, *where* should it break

- On several areas or one area
- On the opposite side from where I touch or on the same spot
- As a whole stripe or as a part of a stripe
- Etc.

When touching the textile, *how* should it break

- Fast or slow
- In a subtle or clear way
- In a small or big area
- Etc.

When touching the textile, *when* should it break

- Directly or with a delay
- Once, or as a chain reaction
- As long as I touch it or within a range of time
- Etc.

All issues above are part of an interactive textile design and cannot be ignored. While issues considering *how* and *where* the textile should break are closely related to the material design, issues considering *when* to break are more related to the design of the computer program. The material design (the textile design, choice of yarns, electronic design etc.) and the design of the computer program function together and cannot be overlooked.

INTERACTIVE TEXTILES BY/FOR DESIGN

Through our design explorations, we were able to define knitted expressions for surface transformation on *shrinking, breaking, stiffening, texturizing and warming* when textile and interaction design form a common ground.

Describing design scenarios relating human interaction to surface exploration in the design process of form making, or extending the textural expressional registers of architectural space design with tactile patterns, we aimed to initiate new questions on textile materiality when placing Knitted Heat in the context of materials for design.

The design scenarios illustrate potentialities in a design space where the textile material is placed as a generative tool for new processes and expressions; a potential design space where textile materiality give computation a tangible dimension in the design process. Therefore the concept of interactive textiles for design uses the effects of heat as a prototyping method for object shaping or as a medium for interaction in the architectural space.

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