Chapter 19

Felted Terrain: Interactive Textile Landscape; Transforming the Experience of Knitted Textile with Computation and Soft Electronics

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Additional information is available at the end of the chapter

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Abstract

This paper presents Felted Terrain, an interactive textile with embedded soft electronics, that creates a sensorial experience with tactility, sound, and esthetics. The project takes the traditional craft of knitting and applies computation at different points of processes, from pattern generation with parametric scripting to integration of conductive and flexible electronics for creating user interactivity. With digital design and fabrication tools, the sensor-embedded textile is produced to be experienced at the spatial level of the interior. The paper discusses the design processes of the project and the potentials of embedding unexpected interactivity to the everyday object of the knitted fabric to provide opportunities for multi-sensorial experiences.

Keywords: Interaction design, design methodology, computation design, esthetics of interaction, tangible interaction, haptic interaction, sensible interface, flexible electronics, soft computation

1. Introduction

Knitting, creating fabric from weaving of worsted fibers, has been with us since the old days. As a material at the scale of our body, we are familiar with its touch, use, and experience. Textiles have also been used at the scale of the interior as wall tapestries and affect our experience with the space through esthetics. Through its interlaced yarn and colors, textile wall hangings were important elements of story-telling, communicating stories to the inhabitants of the space [6].

With the advent of soft electronics, there is an opportunity to take the experience of the textiles to the next level of multi-sensoriality. This project aims to explore two aspects of 'craft research' in interactive textiles; the generative design/craft process of textile and creation of spatial experience through public exhibition (reflective-on-action). The first part discusses the production process of an interactive textile using embedded soft electronics, computation, and generative design that “focus on aesthetics, personal expression, and the idea of play, as opposed to the prevalent utilitarian focus of wearable technology design on universal connectivity and productivity applications” [2]. The slow-paced craft process of the felted textile embraces the practice of ‘reflective-in-action’, where final interaction design of the project was continuously designed and iterated throughout the process of making [11]. The second part of the project focuses on the experience of interactive textile in a spatial (exhibition) setting where it becomes a mediator of experiential elements, that transforms an everyday space into a multi-sensorial ‘practice space’ [5]. The combination of haptic, visual, and auditory experience that is placed throughout the exhibition space provides users to ‘reflect-on-action’ [11] and discover the various interactive elements of the textile.

2. Design, computation, and production of Felted Terrain: an interactive non-woven textile

Felted Terrain attempts to subvert the notion of primitive handcraft in knitted/felted textile through its integration of soft electronics, computation design, and fabrication method. Using traditional textile techniques such as knitting, embroidery, and felting, the project aims to create textile of an ‘ambient display’ [14] that sense, transmit data, and create spatial sensory effect by presenting information within a space through subtle changes in the background of awareness (in this case, sound) (**Figure 1**).

There are two parts to the creation of ‘Felted Terrain’—designing of knit pattern to create three-dimensional knit structures with parametric computation design tools, and making of the electronic textile “that incorporates capabilities for sensing, communication, and interconnection technology” [2] with soft computation. Felted Terrain is a result of this two-part process and aims to present a seamless integration of technology and interactive experience in a knitted woven textile. As a handcraft process, the slow pace of the design and production of the textile enables ‘reflection-in-action’ [11], to continuously reflect on the project as a whole and also at every stage of the process to ensure the integration of design, craft, and intended user interaction in the production of the interactive textile. The following documents every step of the design and making process, that involves both digital and manual methods.

Figure 1. Felted Terrain—an interactive sensorial textile that generates sound and visual graphics upon touch.

2.1. Creating the pattern

2.1.1. Generating dynamic three-dimensional knit patterns with computation

As the initial inspiration from the project came from the rolling mossy landscape of Iceland (**Figure 2**), creating a three-dimensional pattern to express the soft terrain was the first step in the process. To generate pattern, a circle packing Grasshopper script for Rhino 3D was used. The size of the circles varied from large to small (which corresponds to the pitch of the musical notes). The script also allowed easy planning in mapping of conductive areas, as shown in **Figure 3** (the red circles indicate where the conductive thread will be added to create a capacitive sensor tips). The parametrically generated pattern was then overlaid on a grid to translated these into a knitting pattern. The pattern used in this project was one of many iterations generated from the computational design tool, which opened up a wide possibility to quickly generate variations for different visual effects.

2.1.2. Designing soft circuitry embroidery patterns

Using the same pattern, a soft circuit diagram was made to plan out the embroidery of conductive circuits on felted textile. The curved lines indicated the circuit that links all of the conductive tips (gray-shaded area) to the Lilypad microcontroller (**Figure 3**). Soft circuits were

Figure 2. Interpreting the mossy terrain of Iceland to a knitted pattern.

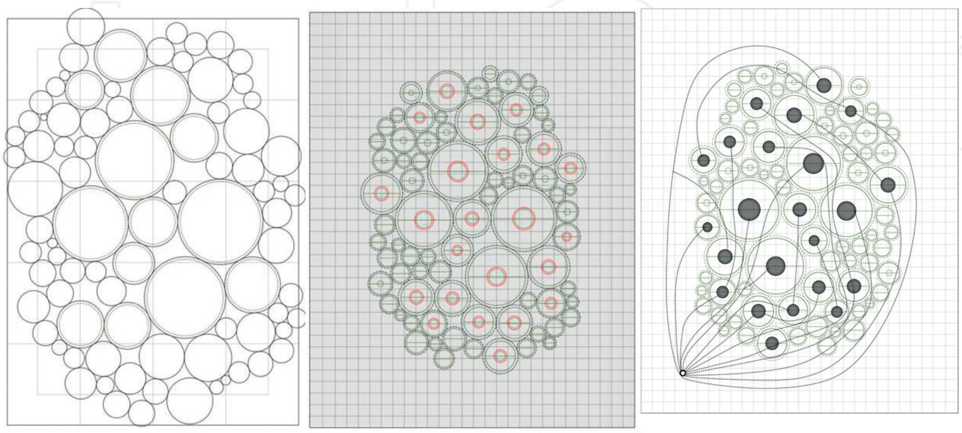

Figure 3. (Left) Circle-packing pattern generated from parametric scripts. (Center) The pattern was overlaid on a grid to create a knitting pattern, and red circles indicate where the conductive thread should be added during the knitting process to create capacitive sensor tips. (Right) Gray-shaded area indicates the conductive tips, with circuit path showing its connection to the central microcontroller placed on the bottom left corner.

embroidered along the designated pattern using conductive stainless steel thread. The Lilypad microcontroller and x-Bee wireless modules were also hand sewn using conductive thread, creating a full e-textile.

2.2. Embedding conductivity to knitted textiles

2.2.1. Knitting with two types of fibers

The knitting process involved using two different types of yarn, a regular wool yarn and a conductive stainless steel yarn. As seen in **Figure 4**, stainless steel yarn was knitted together at the tips of the bumps to give “electro-mechanical properties” that will enable the fabrication of complex textile with interactivity [1]. This allowed integration of flexible sensors to build electronic circuits on soft substrates, and enables a move away from traditional electronics, of using PCB boards and hard materials, to an exploration of emergent flexible materials to create interactive physical designs [2]. When connected to the microcontroller, these tips can be programmed to become touch sensitive through capacitance. In this project, a low-profile stainless steel yarn was used instead of visible silver or gold metallic threads in creating soft circuits, so it could be blended in with the wool fiber and create a seamless look, paving its way for unexpected interaction in the final stage.

To produce a textile at the scale of the interior, yet using a domestic scale of the knitting machine, the project was made in small size patches of 1 m × 1 m as shown in **Figure 5**. Knitted patches were stitched together to create a large wall-sized piece woven textile with three-dimensional ‘bump’ forms. The process produced a loosely knit woven textile with areas of embedded conductivity where stainless steel yarn was added to the wool yarn during the knitting process. Hand stitched seams and stainless steel yarn at tips of the three-dimensional bumps were still visible at this stage—in order to create a seamless esthetics of a non-woven textile, the completed knit textile went through the multi-step process of wet-felting.

Figure 4. Knitting with two different types of yarn to create a conductive 3D structure knit. Conductive fibers are embedded in each tip of the three-dimensional forms.

Figure 5. Knitting in 1 m × 1 m patches to produce a spatial-scale of knitted textile.

2.2.2. Transforming woven textile to non-woven: felting

Wet felting shrinks the knitted textile by 30–40% from its original size (**Figure 6**). The felting process is a result of the 'tangling of wool fibers', due to the reptile-like scales on the surface of individual fibers. These scales are the main reasons in giving traditional wool its abrasive texture. When washed with hot water, these scales interlock and become lighter and tighter causing shrinkage, becoming a non-woven felted textile (**Figure 7**). Using this natural mechanism, the above knitted textile went through the wet-felting process, where it was agitated multiple times in the washing machine with hot water and soap, until the knitted structure was no longer visible and became a homogenous texture of felted fabric. Afterwards the entire piece was formed, flattened and then air dried to retain the shape of the bumps.

2.3. Actuating sound and visual interactivity

The previous section explored the use of computation as a tool to generate design for the three-dimensional pattern of the knitted textile. Computation can go beyond the role of design tool, and become 'part of the designed things themselves' [12].

Figure 6. Felting process shrinks the woven wool textile by 30–40%. Felting transforms a woven knitted fabric into a seamless non-woven fabric.

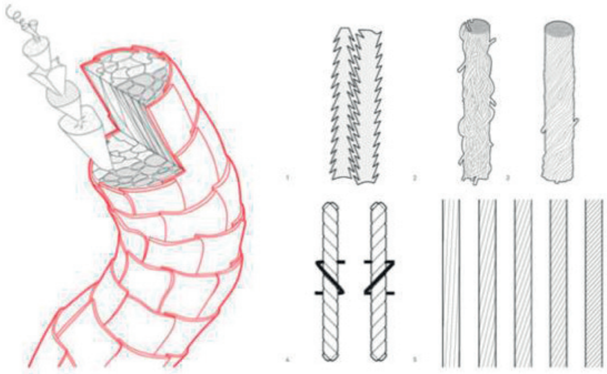

Figure 7. Diagram of wool fibers and the interlocking mechanism of wool scales in felting.

The three-dimensional form of the felted textile is designed with an intention to draw users touch, squeeze, and stroke each of the bumps. In addition to the apparent visual and tactile experience of the textile, auditory experience was programmed to the textile as an output of the touch interaction. In this project, a Lilypad microcontroller, an Arduino variant that is designed to be easily integrated with flexible circuits on textiles through sewing with conductive threads, was used along with a wireless x-Bee module to transform the experience of the everyday textile into an interactive e-textile.

2.3.1. Creating intuitive interaction: textile keyboard

The interaction had two parts to the design. First was leveraging on the expected behavior of people with textiles (especially since the bumpy form intrigued users to touch) and second was designing an interaction that is intuitive for users to find out the rules of the game after a short engagement. In this project, a simple music notes were assigned to selected bumps on the felted textile. The size of the bumps corresponded to the pitch of the notes, for example, large

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bump played a lower octave note, and the note/pitch of the sound would go up the scale as the bump sizes get smaller (**Figures 8** and **9**).

2.3.2. Real-time visual feedback of sound and touch

In order to enable the textile as a simple sound keyboard, Lilypad microcontroller was loaded with a modified Capsense Arduino Code. The received serial data was then transferred to a

Figure 8. Lilypad microcontroller was sewn onto the felted fabric along with x-Bee module for wireless transmission of data to the main computer.

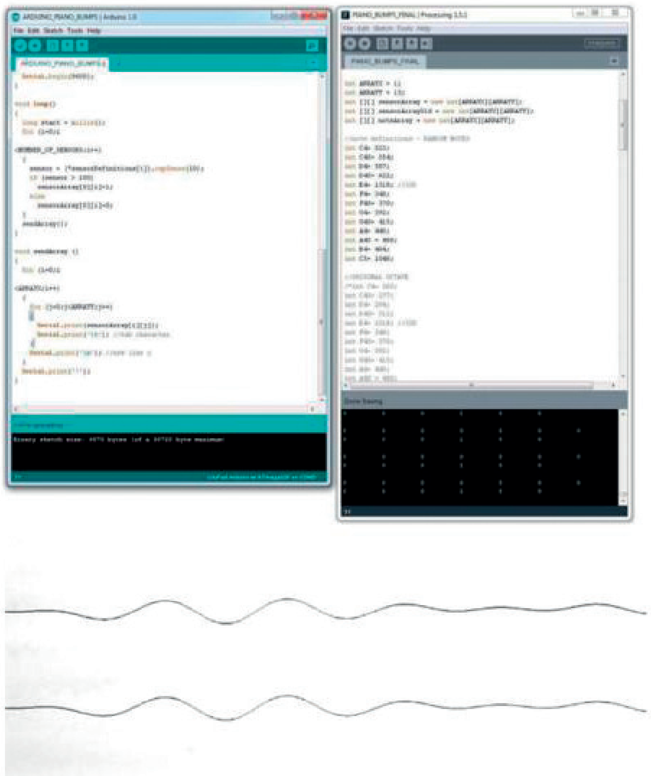

Figure 9. Using Arduino and Processing, touching of the conductive felted tips produced individual sound of piano notes, at the same time visualizing the pitch through real-time projection of the sine wave curve on the wall.

Processing script (adapted from MIT Media Lab High-Low Tech Group's Piano Code). With these codes each touch on the tips were translated into a sound, which was then played through a speaker placed in the room. To create a visual connection to the sound the textile was producing, a real-time projection of the sound pitch was projected on the wall, in a form of a sine curve. Through this tri-part experience, a tactile touch could be both felt acoustically and visually.

3. Interactive textile as mediator of experience: creating opportunities for 'practiced space' through exhibition

Felted Terrain was installed at the MIT Keller Gallery for open interaction with visitors and passersby. The exhibition context could influence how one experiences the material of the exhibit [9]. With the design of the layout, the exhibitor can guide the visitor to engage with the material in a specific way and order, adding additional interaction element to the whole experience (**Figure 10**).

The exhibition was designed to invite visitors to reflect-on-action [11], to unveil the experiences of the interactive textile by engaging with it step by step. The square felted textile was placed on a clear table with a spotlight providing visual focus. A circular shiny mirrored film was placed beneath the table to enlarge the presence of the felted textile as well as providing additional view of the textile (negative space of the three-dimensional pattern). Upon entry, the three-dimensional form and fuzzy texture of the felted textile lures users to engage in touch. Each touch of the capacitive sensor tips, produced different musical notes, which was played through embedded sound system in the gallery space. By touching various sized tips, users could gradually understand the connection between bump sizes and sound notes, where the pitches of the notes correspond to the size of the bumps. Over time, one could make the parallel analogy of the textile as musical keyboard, and many of the users started to play a tune with the felted textile bumps. Various touch gestures were observed during the exhibition—in addition to lightly tapping the bumps, other gestures such as stroking, squeezing, pressing, and pulling of the bumps were made. Regardless of the types of gestures, in this version of the

Figure 10. Exhibition of the textile—it was placed on a custom designed clear table with reflective film on floor.

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Figure 11. The tactility and three-dimensional design of the textile invites users to touch, which generates sounds and visualizes the pitch of the sound on a nearby wall.

textile, the touch was accompanied by real-time visualization of the sounds, which was a wall projection of a sine wave curve.

The interactive textile also became mediator of experiential elements, and as a result it created an opportunity for a 'practiced space' by bringing meaning to a static space [5], where one's actions and engagement with the textile produced different perception of space (from space of sound, space of visual movement, and space of tacility). The interactive textile influenced how people experience their surroundings (**Figure 11**).

4. Potentials/future applications

The Felted Terrain project explored the creation of different sensorial experiences to the everyday surface of textile through computation-based design and integration of soft electronics. The exploration described in this paper is just the beginning, as many variations, effects and experiences can be created. For simplification, there are three components to the project for further exploration. First is in the design of the esthetics through pattern making. Through generative computation design, many dynamic and diverse designs can be made for application on textile. When combined with traditional techniques in knitting (such as creating "bumps" in this project by adding and decreasing stitches) the parametric design tool can quickly generate iterations of design forms.

Second, design of the interaction can be explored further. The project engaged few sensorial experiences, from auditory to visual, however, multitudes of combinations of experiences can be designed. The sensorial output from the touching of felted bumps are unlimited; further exploration can be made to produce other outputs such as changes in lighting of the space, temperature, haptic vibration, etc. Interaction modes are another part of the interaction design that can be modified. Additional touch behaviors on fabrics, such as stroking, squeezing, pushing can be studied to embed actuating sensors (conductive areas) to encourage other modes of engagement with the textile.

Lastly, the scale of the textile experience can be varied, from a scale of the body to the scale of the interior and building, to produce different emotional effects and affect understanding of the space. Other production methods and tools, such as thermo-forming of non-woven textile on digitally produced forms (CNC milled form base as an example), or using an industrial scale knitting machine to scale up and automate the process can produce the soft, responsive, sculptural textile surface at a scale of the interior. The e-textile surface can also be modularized in a form of e-textile for application on larger surface. The placement of tiles can produce different overall visual patterns as well as sensory outputs (**Figure 12**).

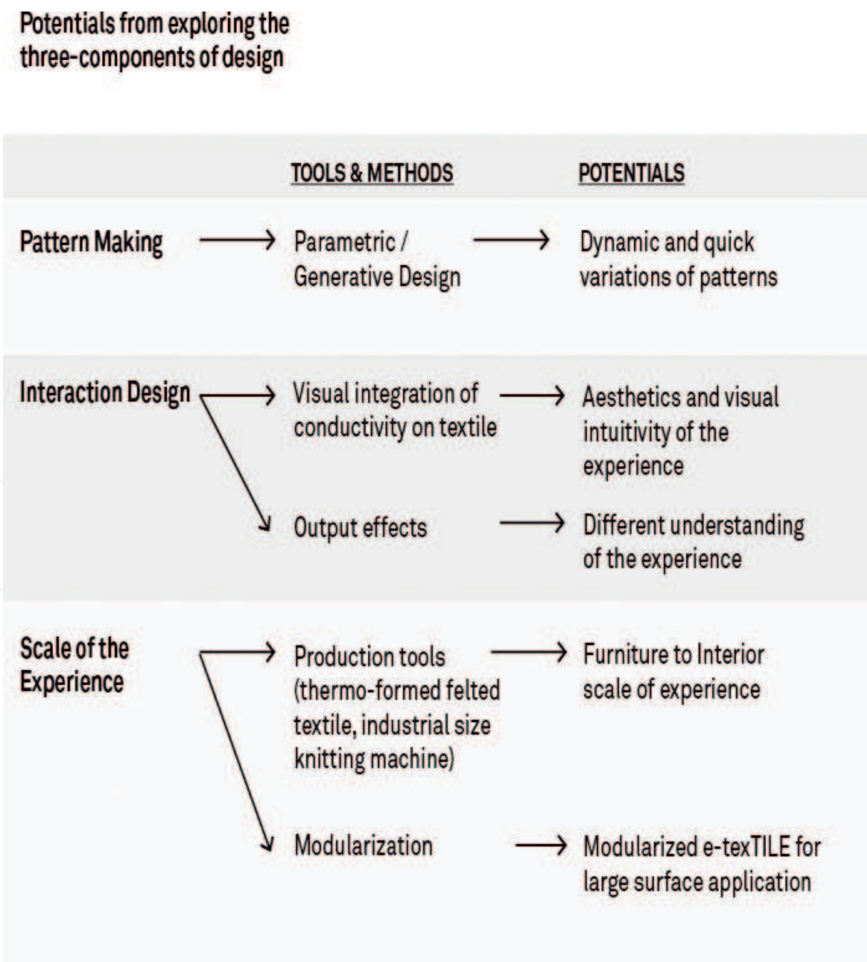

Figure 12. Diagram of components to be further explored.

5. Conclusion

The Felted Terrain project is an exploration of creating a soft textile surface that creates rich interaction and activities between people, computer, and the physical space to be expressive, unexpected, and enjoyable.

The slow crafting process of designing and making the interactive multi-sensorial textile provided many moments of 'reflection-in-action' [9], where the designer-maker can reflect in each action of the process to inform the experience of the whole and design decisions of parts. The exhibition context provided opportunities for 'reflection-on-action' [9], by allowing visitors to unveil layers of experiences and figuring out the pattern (rule) of interaction by reflecting on past experiences, knowledge and actions.

Textiles have a "uniquely intimate relationship with the human body" [1]. We wear them as clothing and also live around them as interior furnishing. We are naturally drawn to touching and feeling the tactility of the textile. What further explorations can be made to create soft surfaces that intuitively draw people to feel, respond, and interact? Would production at various scales, from the body-scale wearable to the level of interior and building produce different experiential effect of the interactive textile surface?

Textiles, whether knit or woven, worn on body or hung in space, is ubiquitous in our lives. The everyday presence of textile surfaces and its application to create soft, fabric-based computers embody Mark Weiser's vision of ubiquitous computing [13]: providing functionality while disappearing discreetly into the soft surface of the 'textiled' space. The esthetics, material qualities, and flexibility of the textiles present large possibility for embedded computation [4], or as a medium to form 'computational composite' [9] to create a pervasive, playful, and theatrical interactive experience for all.

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