Functional Styling - Exploring a textile design space

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INTRODUCTION

As interactive materials enter the world of textile design, a new area is defined. From an interaction design perspective, interactive (or smart) textiles obviously differ from, for example, a computer game or a word processing program in various ways. One difference is that interactive textiles are experienced as physical materials and are not pixels changing colour on a computer display. But the main difference lies in the diverse aesthetical values; computer software and hardware are related to advanced technology, hard material and functionality whereas textiles are familiar, tactile, flexible and touchable. Still, textiles can build on of advanced technology.

Functional aspects of interactive textiles have been thoroughly explored through for example health-monitoring devices (cf. for example [Lysteris and De Rossi, 2004]) and wearable electronics (cf. for example [Tao, 2005]). Other research includes interactive textile interfaces such as Super Celia Skin [Raffle, et al., 2004] and Sprout I/O. [Coelho and Maes, 2008]. The Smart Carpet is a large-area sensor network integrated into a carpet able to, for example, detect if someone has fallen on the floor [Glaser, et al., 2005]. Similar carpets, capable of detecting footsteps and the presence of a person, are available on the market [Future Shape, 2010].

To be able to understand the full potential of interactive textiles, we need to consider them as something new, designed in the intersection between textile design and interaction design. The experimental approach taken in the Functional Styling project is inspired by the work made at the Interactive Institute within the IT+textiles design program [Redström, et al., 2005;
Worbin, 2010] where a series of experiments and design examples were made in the field of interactive textiles, exploring the aesthetics and emerging expressions of smart textiles rather than technical functionality (cf. [Hallnäs and Redström, 2006, 2008]).

This paper reports on a collaboration between the Smart Textiles Design Lab at the Swedish School of Textiles, University of Borås, and designers and technicians at Kasthall, a company with a long tradition in producing hand tufted and woven high-class quality carpets [Kasthall, 2010].

By taking the approach of a practise-based design research method, experiments and design examples are meant to explore the expressive potential of interactive textiles. The aim of this paper is to describe the Functional Styling project where three full-scale interactive carpets have been designed. The carpets are meant to exemplify various interactive textile expressions and could serve as inspiration for designers that aim to work within the field of expressive sensing and reacting textiles.

The main part of the paper describes the results and design processes of the carpets Spår (Traces), Dimma (Foggy) and Glöd (Spark) – design examples of carpets with dynamic textile patterns. Secondly, the paper discusses how the making of the carpets is a way to explore a new design space in the intersection of textile design and interaction design. The paper also discusses how the carpets can serve as inspirational examples for textile designers and how interactive textile design brings new challenges to the area of textile design.

THREE DESIGN EXAMPLES

The three carpets serve as design examples of interactive textiles with heat, light, colour-changing and sensing properties. They are experimental, designed in the intersection of textile and interaction design, with inherent flexible properties manifesting themselves as dynamic patterns. As the environment changes, the carpets respond and react by changes in patterns. In what way and how much environmental conditions affect the carpets’ expressions, differ in the three examples. Following pages describe the result and the design processes of the three design examples respectively.
As a person walks on Spår, the footsteps leave traces as white and turquoise light stripes in the carpet. Spår looks like an ordinary woven carpet but is able to show that someone is, or has been, walking by lately.
Result, Spår

Spår is a woven carpet able to light up in a certain way as a person walks on it. Together with wool yarns, light threads (electroluminescent wire) are weaved into the carpet. The light threads light up in a white and turquoise striped pattern where a footstep is placed. Three light threads light up by a footstep, and as a person walks by the carpet the light stripes turn off with a delay, one at a time behind him/her. In this way, Spår is able to give information that a person recently has passed by; the light pattern has both a decorative and functional meaning.

The size of Spår is 90 x 200 cm. It is provided with five different sensing areas within the range of a footstep. The five sensing areas are provided with pure conductive yarn, knitted as meshes and embroidered on the back of the carpet. Six capacitive integrated circuits, capable of detecting near-proximity and touch, are each connected to the conductive areas so that the carpet is able to sense where a person places his/her foot. The electronics connected to Spår are placed a meter beside the carpet. In this way, Spår looks like a “traditional” woven carpet. The “traces” from a person’s footsteps, visualized as light stripes, are only seen as a person passes by.

Design Process, Spår

For practical reasons, Kasthall’s existing warps, facilities and yarn qualities were used in the making of Spår. First, several woven samples were made to try out different colours (black and white), and materials (wool and reflective lurex). Also different materials for light emitting were evaluated. Trying out both electroluminescent wire and optical fibres as weft, the electroluminescent wire showed to be most suitable to use. Compared to optical fibres, the electroluminescent wires showed a more distinct pattern in the textile structure, and it also meant that no external light source was needed.

Try-outs for weaving the electroluminescent wires and optical fibres at Kasthall

White wool was used as weft combined with two different electroluminescent wires changing colours from pink (when the light is off) to white light and from white (when the light is off) to blue-green light respectively. The expression of Spår is similar to that of a traditional Swedish woven rag-rug carpet which makes the light-pattern “hidden” as long as no one walks on it. The overall design choices aimed for a simple design to make the pattern-change distinct as to enhance the dynamic textile pattern.
In parallel processes, different pressure sensing principles for Spår were explored. The requirements included that the carpet should be able to sense both when and where a person stands or walks on it. First, a resistive sensing principle was explored, a construction of two layers of conductive textiles with a non-conductive layer in-between.

Testing sensing properties with layers and conductive knitted material

This technique failed to be reliable since the glue that were used for the different layers seemed to insulate the conductive yarns. A capacitive sensing principle showed to be much more promising. Instead of using the weight of a person to mechanically press the conductive layers together, the capacitive sensing principle detects the near-proximity of a person. For this purpose, QT113 proximity sensors from Atmel [Atmel, 2010] were used.

Spår has five sensing areas and the size in-between them is based on the size of a small step, \(\frac{1}{2}\) meter. Each step makes three electroluminescent wires light up at the same time and when the foot is lifted they fade away behind you, one at a time.

The electroluminescent wires were all inserted by hand and had to be individually connected by wires to the electronics external to the carpet. When this was done, several ways of programming the relation between the input-signals (the footsteps) and the output-signals (the light pattern) could be explored. Different scenarios were designed such as; all light threads
light up at the same time as someone steps anywhere on the carpet, light threads on the opposite side from where someone stands light up, etc.

The proximity sensors and the electroluminescent wires are controlled by a BX-24 programmable microcontroller [BasicX, 2010]. The electronics are placed approximately one meter from Spår and are connected to the carpet with wires. To detect signals from the carpet, the wires are connected to the five knitted conductive yarn meshes embroidered on the back of Spår. Wires are also connected to the electroluminescent wires to provide electricity. Spår runs on 9 Volts.

*Soldering and connecting the electronic circuits for Spår*
Dimma is a tufted carpet combined with light sources. Due to surrounding light conditions, Dimma's light-pattern is able to change into three different states. The intensity of the surrounding light influences the ambience of the pattern into a range of different expressions.

Result, Dimma

Dimma is an example of a tufted textile structure combined with an under-layer of electroluminescent films. Connected to a light sensor, the carpet is programmed to express three different modes corresponding to light conditions in a room at day, dawn/evening and night. Twenty-five rectangular light films are individually turned on and off which makes the pattern change over time. The light films are placed as a layer and shine through the tufted structure. Two different colours of light have been used, white and turquoise.
Mode 1: During daytime, the carpet changes between two interactive expressions so that a chess-pattern is pending between a white-light checked pattern and a turquoise-light checked pattern.

Mode 2: At dawn and in the evening, three electroluminescent films light up at a time, forming a pattern that slowly moves around the carpet. As one light film is turned on, another one is turned off, making the pattern constantly change.

Mode 3: At night, a calmer pattern is created, as just one light film is turned on at a time. After some seconds the light film is turned off and a neighbouring light film is turned on.

Design Process, Dimma
To explore how tufted textiles could be combined with light sources in a carpet, the work started by using already existing black and white coloured tufted samples from the Kasthall tufted range. As a first experiment, electroluminescent light films were placed under several tufted samples with cut out holes, to explore the expression of light shining through the tufted materials.

After the first experimental exploration, some new qualities designed especially for certain light requirements, were made using special hand tufting machines. For example, samples with circular shaped holes for the light film to shine through were made together with thinner, more transparent qualities. Also after-glow yarns and optical fibres were tried out, but the material was too stiff to use in the tuft machines, so some of the yarns were instead stitched in by hand.

Tufted holes and the light film shining through
To be able to turn the whole carpet into a potential light source, thinner and more transparent qualities were chosen. A range of thin samples in different sizes and qualities were tufted, both by using different amounts of material and different kinds of materials. The quality used in Dimma consists of rows of thick tuft combined with rows of no tuft at all, creating a slightly striped pattern that diffuses the light that shines through.

In parallel, an external under-layer of electroluminescent light films were constructed. The layer was made of twenty-five electroluminescent light films, taped together into the same size as the final tufted carpet, 140 x 200 cm. Two different colours of light were used,
turquoise and white. The films were positioned next to each other in horizontal and vertical rows so that the two colours are arranged as a chess-pattern.

Just like in Spår, a BX-24 programmable microcontroller is used for interaction. The electronics and power supply for Dimma are placed in a box beside the carpet. Compared to Spår, Dimma requires relatively high electricity (around 40 V) due to the twenty-five light films. For safety reasons, the box is closed (but transparent) and each light film is connected to the box with a wire and can be switched on and off individually. In this way it is possible to design for a very large range of different patterns.

The thinner tufted structure used for Dimma

Trying out programming possibilities with four electroluminescent films. The box with electronics is seen behind the light films.
GLÖD (SPARK)

Glöd is a carpet functioning as a mobile heat-source for heating up cold floorings. The carpet changes pattern due to the amount of heat-elements turned on at the moment.
Result, *Glöd*

Glöd is a woven carpet printed with pink thermo-chromatic pigments. In a second layer, placed under the woven carpet, eighteen individually controlled heat-elements are integrated.

The dynamic textile pattern visualizes the temperature generated from the carpet; when Glöd is striped (pink and red stripes) it means that it is “cold”. As the stripes dissolve into a pink and white checked pattern, heat is generated.

There is no microcontroller used for Glöd, the heat elements are turned on and off by hand so that the pattern can change from striped to checked, symmetrical or asymmetrical in a range of variations. Each white rectangle that appears in the pink printed area, indicates that a certain heat element has been turned on.

Each heat-element is connected to a box, placed beside the carpet, by a wire. The box is equipped with eighteen switches so that each heat-element is manually regulated and able to be turned on or off by hand. Glöd is meant to be used as a mobile carpet able to heat, for example, a cottage or a basement.

**Design Process, Glöd**

Glöd is based on the carpet "Polka", an existing white and red striped woven carpet from Kasthall’s range [Kasthall, 2010]. To enhance the carpet with a dynamic pattern when exposed to heat, the carpet was screen-printed with thermo-chromatic pigments.

By placing different cut out papers on top of the carpet to visualise colour and form before printing, full-scale sketches could be made directly on Polka.

To achieve the same red colour used as weft in Polka, the possibility to mix a red thermo-chromatic colour was considered. But to achieve the same red intensity for the thermo-chromatic pigments showed to be impossible. Instead, other colour combinations were tried out. The first printing test was made with a turquoise thermo-chromatic pigment printed as squares on the white parts of the carpet. The thermo-chromatic pigments are supposed to be completely transparent when heated, and the plan was that only the warm red colour of Polka would show. But instead of disappearing completely, the turquoise pigment left a dull grey shade.
To be able to sketch with full-scale colour-changes directly on Polka, cut out papers in different shapes were placed on top of the carpet.

To avoid the difference in shade due to the combination of unprinted white parts next to the thermo chromatic printing, stripes (instead of squares) were printed on the white areas.

Before the final print was made, three different test prints were made on the back of the carpet to try out the pigment, the printing technique, the colours and at what temperature the print reacts.

Parallel to the printing experiments, different ways of generating heat in textiles were explored. Both methods for integrating heat directly into a textile structure and to use heat elements as separate layers, were considered. As a first experiment, knitted structures constructed of wool and Bekaert HT steel yarn [Bekaert, 2010] printed with grey thermo-chromatic pigments were made. By parallel-connections, the structures were connected to a power source to generate heat. The heat made the print gradually dissolve, first into stripes and then it became completely transparent.

It turned out to be hard to achieve a stable temperature in the knitted heat-elements over a longer period of time. Following the device of the Functional Styling project - to make design examples that show new possibilities rather than solving technical details, special designed heat-elements were custom made. Eighteen heat-elements were made in a size and shape to fit Glöd. The heat elements were fastened in an under-carpet to generate and direct the heat to the printed carpet on top. Due to the rather high power (40 Volts) needed for the heat-elements, it was also convenient for safety reasons to place the heat-elements insulated as an external under-layer.
When connected to a power supply, the thermo-chromatic print on the knitted fabric becomes warm as the heat is spreading through the fine lines of conductive yarn.

Before printing the electroluminescent pigments, the group had a look Linda’s colour maps, made in a previous project
EXPLORING A NEW DESIGN SPACE

By exemplifying and pointing out new expressions, functions and use for carpets, the design examples are meant to serve as openings towards further interactive textile design. With the ability to sense and react on external stimuli, the examples open for new possible use for carpets, where decorative aspects are part of how they behave and express themselves over time.

Programming a dynamic textile pattern

Textile designers are used to work with advanced textile technologies, maybe even to program weaving- or knitting machines. The process of designing a dynamic textile pattern might still be unfamiliar to him/her since it includes the programming of a pattern that changes over time. To program a microcontroller that controls an interactive textile pattern is to design the expression of the textile. The programming code is in this way not an objective line of numbers and letters only used for adding functions. On the contrary, the code is highly expressive and defines the textile’s expression.

When working with Spår and Dimma, the programming code was written quite late in the design process, a fact that might have influenced the outcome since the coding opens for a huge range of design variables. Still, even late in the design process, there were plenty of options of how to program the carpets. The programming code dictates the expression of the interactive patterns, and the carpet can easily be reprogrammed. For example, it is easy to imagine how Spår could be reprogrammed to be used to show a visitor the way inside a complex building, a carpet for children to play hopscotch on, or to a carpet that could add some mystery in an office building by leaving traces of persons etc. In this way, the expression can be redesigned after a textile is produced, both with respect to functionality and with respect to aesthetics.

Dealing with electronics

Another issue that textile designers normally do not have to deal with, is electronic components and power supplies. For pedagogic reasons, the electronics designed for the design examples were deliberately exposed. The differences in size of the electronic parts vary for each design example; in Spår the electronics are not even mounted in a box, the rather small circuit board is placed right beside the carpet and is driven by a 9 Volts battery. In Dimma and Glöd, the electronics were mounted inside boxes for safety reasons since both Dimma and Glöd requires relatively high current. For the electronics connected to Dimma, a transparent box was used so that the electronic parts are seen through the plexiglass. For Glöd, the electronics are put inside a box equipped with switches to manually turn the heat-elements on or off.

New Possibilities

The project shows three carpets, designed in specific ways. The interactive expression of Dimma is programmed and designed so that the carpet responds to different light conditions in a room, and a specific series of pattern-changes are visualised. Dimma exemplify one way of using a textile layer combined with a programmable under-layer which in this case consists
of light films. By using another textile structure, another programming code, other kind of light sources and other types of input (for example sound-sensors, movement-detectors, etc.), the principle used for Dimma opens up for a huge number of new possibilities for designing interactive carpets in other forms and shapes. Also the principle of letting the proximity of a person build a dynamic pattern, (as in Spår), point out new use and new carpet expressions as the carpet is able to give information, show a direction or to give a clue about previous events.

Handicraft Vs. Industrial methods
 Functional Styling deals with how to transform an experimental-craft process to fit production requirements within the textile industry. When bringing new materials into the textile design industry, both handicraft methods and industrial machines can be used. For example, by using old style weaving machines with shuttles, optical fibres and the electroluminescent wires in various sizes could be inserted as weft inlays, something that would be real hard to do with modern weaving machines since they cut the edges. Still, the machine had to be stopped during the weaving to make some inlays by hand in a process that can be considered a kind of industrial-crafts process.

Since some of the tufting work at Kasthall already is made by hand, it was easy to manually test several materials in the hand tufting machines. Examples of materials that were tried out were different conductive yarns, optical fibres and glow-in-the-dark yarns, all combined with yarns already used at Kasthall. Stiff and strong materials, such as the conductive yarns and optical fibres, did not work in the hand-tufting machines since the machines were not able to cut them properly and it also led to wearing out the machine components.

In one way, this project meant to take one step back to be able to take two steps forward when dealing with new interactive material, not yet adjusted to an industrial process.

DESIGN CHALLENGES

As the carpet pattern is not static anymore it means that more, or at least other, design decisions related to how textiles express themselves over a period of time have to be considered. When interaction design and textile design start to merge, the appearance of a textile is the sum of all inherent building materials and constructions and in what way external environmental stimuli are able to influence its appearance (such as the presence of a person, light conditions in a room etc.). Through their physical form and temporal expression, the carpets are manifesting the expressive and subjective art of inherent physical materials and software.

The dynamic pattern-expressions of Spår and Dimma are partly designed in the program code written for the microcontrollers connected to the carpets. In Glöd, the dynamic pattern-expressions are mechanical and controlled by a person switching changeable elements on and off. The appearance of the carpets at a certain moment is strongly related to the interaction between the carpets and their surroundings; in Glöd, the pattern corresponds to the action of turning the heat elements on and off by hand while the pattern-change in Spår corresponds to someone walking on the carpet and Dimma’s interactive pattern responds to light conditions.
The changeable elements in the carpets (such as the light threads in Spår, the light films in Dimma) are, apart from the programming, of course also designed with physical materials. But, the change doesn’t manifest itself until the environment behaves in a certain way. This means, hypothetically, that a certain carpet pattern (in terms of a certain combination of changeable elements appearing at the same time and in a certain order) might never appear. We are able to design the physical material and the computer program, but the behaviour of the surrounding is often harder to predict. The design is in this sense open.

A certain appearance of a carpet is affected both by properties inherent in the physical material and software, and also by external stimuli such as user interaction. The relation between the two varies. For example: when crossing the carpet Spår, at a specific moment a certain number of light threads light up as I put my foot down, creating a certain carpet expression. This specific appearance shows only when my body is near the carpet and I behave in a certain way. The light threads, electronics and computer program are all inside the carpet all the time, designed for potentially lighting up. However, they do not show their full potential until someone crosses the carpet.

EXPRESSION DIAGRAMS

As an attempt to explore the relationship between how a certain interactive expression is created through internal (material, design and programming) and external (user interaction) properties, “expression diagrams” have been introduced [Persson 2009].

When reading the expression diagram, the notions of function and interaction and actions and reactions (cf. [Hallnäs 2004, Hallnäs and Redström 2006]) are essential. In this context, function refers to what a given thing does when we use it, whereas interaction refers to what a user does when using the given thing. Actions and reactions refer to the chain of actions-reactions that occur when an interactive expression (in this case dynamic textile pattern) appears. The chain of actions-reactions is depending on each other, and the degree of actions-reactions is directly related to a textile’s changing properties.

Example: A person approaches Spår and step on the carpet → the sensor detects the near-proximity of a person → the microcontroller reads the signal → the microcontroller sends a signal so that three light threads are turned on → the foot is lifted from the area → the sensor detects no near-proximity of a person → the microcontroller sends a signal to the power supply and the light threads are turned off one at a time etc., etc.

In the expression diagram, a textile’s initial design is seen at the lower left corner where the axes of the system intersect (the origin).
Expression diagram where given initial design describes:
- The degree of functional actions and reactions
- The degree of interactional actions and reactions

Expression A shows a specific expression appearing at a certain time due to the influence of a person. Expression B shows a specific expression appearing at a certain time due to the influence of the material, construction and programming.

Following diagram shows some possible interactive expressions able to appear in Spår:

Expression A: The initial design: no light threads are turned on
Expression B: All light threads are turned on
Expression C: Three light threads on each side of the carpet are turned on
Expression D: The light threads turn off one by one
Expression E: The colours of the light are white and turquoise
For expression B to appear, someone might have run really fast over the carpet so that all light 
threads are turned on. Another possibility is that that several persons are standing on the 
carpet at the same time. Either way, expression B is related to one or several persons’ 
influence. The same goes for expression C, where either a person has taken a leap on the 
carpet, or two persons are standing on each side of the carpet. Hence, both the expressions are 
placed close to the interactional-axis.

Expression D and E are closely related to the material, construction and programming design. 
Therefore, the expressions are placed close to the function-axis in the diagram. But for the 
light to appear at all, a person has to interact in some way. Hence, the expressions can not be 
placed directly on the function-axis, but a little bit upwards.

Following diagram shows some possible interactive expressions able to appear in Glöd:

<table>
<thead>
<tr>
<th>Actions</th>
<th>Reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expression C</td>
<td></td>
</tr>
<tr>
<td>Expression B</td>
<td></td>
</tr>
<tr>
<td>Expression A</td>
<td></td>
</tr>
<tr>
<td>Expression D and E</td>
<td></td>
</tr>
</tbody>
</table>

Expression A: The initial design: the carpet is all striped
Expression B: One pink area has partly turned white
Expression C: All pink areas have dissolved into pink and white checks
Expression D: The colours of the checks are pink and white
Expression E: The shape of a check is rectangular

For expression B to be seen, a person has just turned one switch on. The corresponding heat- 
element heats a pink area that gradually changes colour into white. Expression C appears as 
all switches on the box are turned on. Both expressions relate to the action of a person.

Expression D and E relate to the material, textile construction and programming design and 
are placed close to the function-axis.
Designing an interactive textile means to work with both passive material (here meaning material such as cotton, wool etc.) and active material (here meaning material such as conductive yarns, light threads, thermo-chromic colours, etc.). As in all designs, it is hard to foresee the outcome of a design process, and by adding interactive features, such as software, the final design is even more difficult to predict.

Smart textiles in general tend to be more associated to functional rather than to aesthetical issues, and the expressive possibilities of software design are sometimes overlooked. Just like any other design decision, decisions related to software need to be carefully considered.

The integration of computer technology brings new design possibilities to the area of textile design. By enhancing a textile with sensing and reacting qualities, a textile’s expressional properties are extended. Computer enhanced textiles need to be seen as something new, that brings new aesthetical values to textile design.

Expression diagrams could be a help to structure and control the design process in relation to a desired outcome. By visualizing relations of function-interaction and actions-reactions, the expression diagrams were developed as a tool to be able to foresee possible interactive textile expressions. By providing a language to describe and pinpoint a certain interactive expression, the diagrams can be used to explicitly map out a new design space located in the intersection of textile design and interaction design.

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REFERENCES


