EXPLORING THE RELATION BETWEEN TIME-BASED TEXTILE PATTERNS AND DIGITAL ENVIRONMENTS

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Abstract

Presently, digital sketching environments have come to be used as a complement to the traditional manufacturing techniques for textiles; the research presented here looks into the area of time-based patterns and their relation to digital tools and textile structural techniques. Thus, the aim of this work is to expand on the existing methods used by designers, and to explore ways for capturing and expressing the complexity and temporality of pattern changes in textiles. Furthermore, our result sketches a method for using dynamic colors to design complex surface patterns for textiles by utilizing methods that facilitate the hiding and/or revealing of multiple colors and shapes on the printed surface of the textile; this method is discussed in connection to the different expressions that can be achieved by using knitting as media for print.

Keywords: leuco-dye based thermochromic inks, dynamic surface design, time-based textile patterns

1 Introduction

In textile design, the relationship between the material and the graphical drawing is quintessential to the definition of the surface pattern. The design of surface patterns for textiles has traditionally been supported by a range of manufacturing techniques, e.g. screen-printing or structural techniques such as Jacquard knitting or weaving; thus, the material itself has come to play an important role in the definition of the expression together with colors and forms. Accordingly, these established methods have allowed the designer to explore the synergy between the surface pattern and the character of the material texture in the design process.

As computer software has come to be used as a complement to the traditional manufacturing techniques in the design process for knits and weaves, a wide range of digital environments that support the design process of surface patterns has emerged. These environments are capable of creating either static (e.g. Adobe Photoshop and Corel Draw) or dynamic forms (e.g. Processing and Java). It is possible that digital tools may not just introduce new aesthetics but a different way of sketching complex patterns by introducing digital elements such as pixels and vectors as design fundamentals [1]. In structural techniques for the design of surface patterns, i.e. Jacquard weaving and knitting, bitmap images have become mediators between the digital environment and the physical world, facilitating the translation of digital images into textile constructions; thus, the manner in which digital elements, such as the pixel, are defined become fundamental to the translation of the depth of the pattern expression. Compared to the solid, monochromatic fields produced by screen printing, the ability to define the properties of individual pixels in digital printing allows for the creation of a different kind of surface expressions, which are based on gradation and an unlimited range of colors. Examples of artistic works explore the design potential of digital pattern design and which proposes ways to manipulate a surface expression in order to create illusions in the perception of the surface pattern in space are, or enhance the sensuality of the material by creating an illusion of depth and volume[2, 3].

Moreover, the research presented here looks into the area of time-based patterns and their relation to digital tools and textile manufacturing techniques, aiming to explore methods for capturing and expressing the complexity and temporality of pattern changes in textiles. In so doing, a new area for textile design explorations is framed.
2 Designing dynamic surface patterns for textiles

In addition to existing digital methods for surface design, new techniques for coloring textiles, such as printing with thermochromic inks, contribute with rich variables to the design of dynamic expressions in physical space. Compared to conventional textile materials, which have static expressions, thermochromic inks are able to change between multiple states, thus providing a range of different expressions in textiles. Leuco dye-based thermochromic inks have the ability to change color in response to temperature variations; these changes are reversible, which allows for repeated changes from state A to state B and then back to state A again [4]. In the search of a conductive textile medium on which to print thermochromic inks, some research projects have taken to exploring different ways of combining structural textile techniques, such as weaving, with the aim of finding a method for controlling and composing with the temporal and spatial activation of the dynamic printed patterns. Dynamic Double Weave[5] and Shimmering Flower[6] are two experimental projects which investigate the interactive potential of printing with leuco dye-based thermochromic ink on textiles; the inks were used in combination with woven electronic circuitry in the design of color-changing textiles which posed a challenge to the user’s perception of surface patterns. In a related experimental design research project, Recurring Patterns, the leuco-dye based thermochromic inks were printed on a double woven surface, and as the textile was heated by the running of an electrical current through the conductive yarns on the backside of its surface, the patterns changed color. This project discusses the complexity of designing dynamic surface patterns and proposes a method for relating the gradual changes in temperature to the changes in color and shades when designing time-based expressions for textiles [cf. 7].

The research projects mentioned above consider weaving only in the role as a structural fabrication technique for conductive textile materials to print the patterns on, and as no other printing methods besides conventional screen-printing were used, however, these methods are limiting the depth that can be achieved in the surface expressions by using dynamic colors. Although the contributions made by these research projects improve on the understanding of the aesthetic qualities achievable through the use of leuco dye-based thermochromic inks in combination with heat-profiling circuitry, a great deal of work remains to be done on the aesthetical possibilities inherent in textile structural techniques and how to relating them to the printing process, i.e. proposing methods in which the conductive textile structure is considered as part of the design process and in which the depth of the printed pattern is included in the sketching. The research project presented here takes as its point of departure the vast complexity of the surface patterns possible to design using digital printing techniques, and focuses on exploring mixed methods as synergies between physical and digital media i.e. to create new ways to design dynamic textiles. Thus, the aim of this work is to expand on the existing methods used by designers to translate complex time-based patterns into textile surface expressions by utilizing methods that facilitate the hiding and/or revealing of multiple colors and shapes on the printed surface of the textile. Furthermore, our result sketches a method for using dynamic colors to design complex surface patterns for textiles, which will be discussed in connection to the different expressions that can be achieved by using knitting as media for print.

3 Methods

Since the project explores the relation between programmable textiles (supporting and activating media) and thermochromic prints (reactive media), the design experiments presented here involved three layers of exploration:

1. methods of knitting patterns which allow the conductive circuits to be hidden from the surface of the textile, based on inlay techniques and knitted on a single or double bed machine;
2. a method of forming temperature sensitive color mixtures using leuco dye-based thermochromic inks;
3. a method of printing a dynamic surface-pattern on textiles using Offset method of printing with temperature sensitive color mixtures;

In this research project, reversible and water-based leuco dye-based thermochromic inks, with an activation temperature of 31°C, were used. A recipe consisting of 25% ink and 75% binder was selected [8] in order to provide a good textile-printing effect with maximum color intensity at the ambient temperature. The printing method used was traditional hand silk screen printing, and the size of the silk-screen mesh was 43 threads per centimeter. For the first series of experiments, black thermochromic ink was mixed with orange textile pigment paste.

1. Methods of knitting patterns which allow the conductive circuits to be hidden from the surface of the textile, based on inlay techniques and knitted on a single or double bed machine;

Printing was explored in relation to three different types of knitted structures:

1. 1. Single bed knit: The first structure was a single jersey cotton fabric with conductive yarn inserted into every sixth wale using loops and floats as shown in the picture below. As the textile was heated, the first visible change appeared after 5 seconds as the loops created a clear shape on the printed layer. After 20 seconds of heating, the floats on the
back of the textile structure became visible, changing the color of the whole print, as the shape of the wale was mirrored by the pattern created by the heat. After 30 seconds maximum diffusion of the pattern was achieved in the shape of the conductive wale (see Figure 1).

![Figure 1](image1.png)

**Figure 1** Single Jersey structure showing (from left to right) the colour change after 5, 20 and 30 seconds

1.2 Double bed rib: The second structure was a full rib knitted in cotton with the conductive yarn knitted in every sixth loop on the front bed and as a tuck stitch in every third loop on the back bed. When the textile was heated, the first visible change took place after five seconds as the loops became visible as diffuse dots on the printed face. After 20 seconds of heating, the floats between the beds became visible, changing the color of the whole print, as the shape of the conductive wale was mirrored by the pattern created by the heat. After 30 seconds the conductive wale was fully heated mirroring the tuck stiches from the back bed to the printed front of the surface, at which point the pattern took on the diffuse form of a straight line (see Figure 2).

![Figure 2](image2.png)

**Figure 2** Double bed rib structure showing (from left to right) the colour change after 5, 20 and 30 seconds

1.3 Jacquard net structure (1X2): This type of structure allowed the conductive threads to be embedded only in the front side of the knitted fabric, thus enabling the textile material to be heated so as to form specific patterns, and by adjusting the density of the conductive loops in specific places in these patterns it was also possible to vary the textures of the material. After 5 seconds of heating, the shapes of the pattern became visible, and after 20 seconds, the floats between these shapes became visible as the heat changes the color of the whole print; in this way, the textile surface is divided into areas with different visual textures. After 30 seconds of heating maximum diffusion of the pattern was achieved, at which point the printed layer displayed the diffuse form of a straight line (see Figure 3).

![Figure 3](image3.png)

**Figure 3** Double bed rib structure showing (from left to right) the colour change after 5, 20 and 30 seconds

During the conducting of these experiments, it was observed that the area around the interface between the knitted material and the printed layer reacted to the heat emitted by the conductive yarn. The shape of this area was circular due to the shape of the stitches, and its radius depended on the length of the stitches; the color change introduced an offset radius of up to 4 millimeters around each stitch. The precision with which the surface pattern embedded in surface of the knitted fabric was translated by the heat depended on the distance between the loops of conductive yarn which came in direct contact with the printed layer, and also on the amount of heat applied. In order to achieve a pixelated expression, the heat has to be planned so as to turn on/off at five second intervals, and for an organized expression, the distance between the loops has to exceed the size of the offset circle around each stitch. For the exact shape of a whole wale of knit to be transferred to the printed surface by the heat, the conductive threads have to stay activated for 20 seconds; if the activation time exceeds 30 seconds, the knitted line becomes completely diffused. The times stated here are primarily included to facilitate comparisons between the examples, as the exact times vary with the amount of current used.

2. **A method of forming temperature sensitive color mixtures using leuco dye-based thermochromic inks.**

The results of the experiments presented above highlight the need to expand on designers’ possibilities to create more innovative dynamic surface patterns than offered by existing methods, and to do so by utilizing a technique where multiple colors and patterns are hidden and/or revealed. Thus, further experiments were conducted to accomplish this.

In order to hide and reveal more than one latent color of the surface pattern, there was a need of forming temperature sensitive color mixtures. For hiding and revealing each color, temperature sensitive color mixtures had to be prepared. The first of five temperature sensitive color mixture was made by mixing magenta, yellow, orange and black leuco dye-based thermochromic inks with a cyan textile pigment paste, resulting in a dark grey below 31°C and cyan at or above this temperature. The second mixture was formed by mixing cyan, yellow, orange and black leuco
dye-based thermochromic inks with magenta textile pigment paste, giving dark grey below 31°C and magenta at or above and so on. All five temperature-sensitive color compositions looked similar at or below 31°C, and produce five different color transitions above 31°C.

The work illustrates the possibilities of having one common background color below the activation temperature of inks, which if heated, generates a multi-colored background at equal or above the activation temperature of the inks. In contrast to the existing methods available to designers, in which thermochromic inks are used to provide multi-colored patterns which become transparent when heated, the examples in this paper illustrate how to design dynamic patterns which display a single color at temperatures below the activation temperature, and a multi-colored at higher temperatures (see Figure 4).

![Figure 4](image)

**Figure 4** Pictures showing one common background color below the activation temperature of inks, which if heated, generates a multi-colored background


In the paper printing industry, the offset litho printing method is one of the most commonly flat printing techniques used for printing full-color images or photos; it is performed in a series of steps starting with process of color separation, during which the image is decomposed into the four process colors (CMYK), and translating each color layer to halftone. A Persian inspired, full-color surface pattern was digitally designed and prepared for four-color printing in Photoshop using the Channels window; this included creating four halftones by selecting each channel in turn and exporting the result as a bitmap image. Based on the principles of CMYK color separation, four temperature-sensitive color mixtures were prepared. The four temperature-sensitive color mixture resulted in a gray- brownish color below 31°C and cyan, magenta, yellow, and black above 31°C. The layers were printed in succession from light to dark colors, which means the temperature sensitive color mixture made by black pigment was printed last, i.e. over all the others (see Figure 5).

![Figure 5](image)

**Figure 5** Pictures showing (from left to right) the printed pattern on white plain cotton-weave at ambient temperature (20°C) and the effect of heating

When trying to find the lower limits of printable details, an experiment was made several times on a knit without a successful result, i.e. when the prints were heated up the color changes did not turn out as planned. When trying out the same print on a more compact weave, it was not only clear that the more compact textile gave a higher resolution when it came to details in terms of millimeters and inches, which one can assume; the weave also gave a higher resolution in the color changes. In fig 6, for instance, one can see a difference in color of the two fighting animals, whereas there is no difference of the animals color in the less compact knit. The reason was that an accurate overlapping of print on knitted layer was not possible to be achieved with a looser knitted structure (see Figure 6).
Figure 6 Pictures showing (from left to right) the result of heating the printed pattern on a knitted and a woven fabric

4 Expressions

The complexity of a design process of a printed pattern increases when time is added as a design variable. Colors are no longer static or limited to binary changes between A to B to A; rather, in our design experiments, they change from A to Z and then back to A again with any number of steps in between, and the speed of these changes vary as it is determined by whether the conductive yarn is heating up or cooling down. The complexity increases even further when these parameters are taken together with those representing material properties, to the point where it becomes exceedingly difficult to predict the exact outcome of a design process [7]. Thus, the conducted experiments take into consideration all variables relevant to the understanding of the final pattern expression, even those representing material properties such as the character of the yarns, stitch length, and the structural properties of the textile material. Three overlapping layers of information, i.e. knit, ink, and print, have been identified, and the method is discussed in relation to the basic expressions that can be achieved by using knitted materials as printing media. Consequently, two types of surface pattern expressions are presented. In the first type, the expression of the knitted material defines the foreground of the dynamic surface pattern, with the printed area as the background; the surface reveals a visual textural expression based on knitted forms as the one of the printed layer transforms as the result of exposure to heat. Thus, the structure of the knitted material adds to the expression of the printed layer, and the diffusion of heat over time creates the possibility to design new time-based expressions, e.g. revealing the knitted structure in order to create the illusion of a three-dimensional texture or the emergence of an unexpected textural pattern of colors (see Figure 7).

Figure 7 The expression of the knit defines the foreground

For the second type of surface pattern expressions, the expression of the print defines the foreground, creating a complex pattern, and the knitted structure forms the background; as the knitted structure is heated, the surface reveals multiple colors and shapes within the initial pattern (see Figure 8).

Figure 8 The expression of the print defines the foreground
5 Discussion
The increased involvement of computation in the design process brings two questions to mind: How does it influence the textile expressions designers create? Is it even fruitful to consider the idea that it may give rise to certain aesthetics? Digitally printed textiles or three-dimensionally printed garments do in fact materialize intricate design expressions, based on complex design variables and the relationships between them; these expressions carry a distinct depth, sharpness, and accuracy regarding details which result from the digital parts of the design process. As figures 7 and 8 illustrate, textiles add to the digital a strong material expression based on the structural techniques used. Consequently, the introduction of computational properties may also be regarded from different angle; for example, the same raster principle used to enhance the expression of depth in digital printing can be applied to hand silk screen printing with thermochromic inks (a type of ink which is still incompatible with digital printers). In the same manner, a knitted structure can be regarded as a set of pixels, although the type of stitch used is not a binary parameter as there is also a third possibility: the tuck. Moreover, a textile material knitted on a flat bed or double bed machine and printed with thermochromic inks is able to alter between multiple colors and visual textures; thus, such a “pixel” would not only need to contain information about the surface structure of the material but color values as well. When combining two layers, e.g. a printed layer (with variables such as color changes and printing method) and a knitted material (type of structure) they will together define the qualities of the digital unit (see Figure 9).

The digital environment may be a meeting point between different design methods where the pixel becomes the fundamental unit for the communication of the pattern design, and from which the pixel takes the step into the physical space in the form of a stitch. In this perspective, the smallest element used to design a pattern intended for printing does not only contain information about color, but also about the conductive structure of the textile material; thus, it becomes the bearer of the very idea that determines the visual appearance and the dynamics of the final product.

Figure 9 A drawing unit combining printing and knitting in the design of the time-based pattern

Future works may consider the fact that dynamic digital sketching environments, e.g., Processing and Java, introduce another intriguing aspect into the field of textile design as they allow the elaboration of time-based form processes. In addition to exploring the expressive potential in the use of these environments to design textiles, it may also be fruitful to explore methods for capturing the complexity of digital generative form processes and the accurate translation of them into a material environment as dynamic patterns. Subsequently, in a digital environment a surface containing information not only about color but also about the dynamic possibilities could be mapped to any object: flat ones as well as three dimensional ones; through the use of tools, e.g., Processing and Java, the temporal aspects could be included, substantially increasing the designers possibilities of sketching time-based textile patterns in three dimensional objects.

References