Drapely-o-lightment

Citation for published version (APA):

DOI:
10.1162/LEON_a_00913

Document status and date:
Published: 01/06/2015

Document Version:
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

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Download date: 06. Sep. 2019
The field of techno fashion is developing rapidly. The contributions come from fashion designers such as Hussein Chalayan [1], who use the technology to translate their views on fashion or even on society, but developments are also driven by needs in sports [2] and medical research [3-5], supported by progress in electronics, materials, and tools. There are also interesting developments in textile multi-modal interfaces [6, 7]. We refer to [8, 9] for overviews. In [7], the concept of embodied computing is studied in the context of “invisible computing”. Schiphorst [7] develops examples illustrating how our own body data can be used to create and share awareness in an intimate way in a social space – and we consider this worth exploring.

Most of the technological research on sensor networks and on-body networks seems motivated by medical objectives: monitoring for heart patients [3], unobtrusive monitoring for at-risk babies [4], seizure detection for epilepsy [5], and so on. Technically it becomes easier and easier to measure all kinds of body signals. Although the medical objectives are very worthwhile, we also want to bring the idea of self-expression to the attention of the technology developers. Traditional garments are not only used for functional reasons (warmth and protection), but they also allow a person to convey messages about his/her identity, state of mind, social status, etc. The covering and exhibiting of more or less intimate body areas is an important issue both in the fashion world and at a personal level for each user. Similarly, the possibility of showing or sharing new body signals such as breathing, Thecla Schiphorst’s exhale [7], muscle-tone in Philips’ fractal ([10] p.27), or heartbeat in Drapely-o-lightment will become important possibilities worthy of exploration. In Drapely-o-lightment, interactivity is added to give the garment a kind of soul; it detects approaches, not only in exhibitions, but also when a person wears it. This almost gives the skirt its own will, which makes it more interesting and valuable.

Our work fits in with the vision put forward by Linda Worbin [11], that nowadays combinations of textiles and computational technology are usually tools for design and for speeding up production; but that in the near future the computational technology will be an active part even after production - it will be a part of the fabric during use. This is the case in our project, where the special Voronoi algorithm and the laser cutter were essential for design and production, and the Arduino and the OLEDs are also active computational technology during use. The result of our explorations is the skirt shown in Figure 1.

Drapely-o-lightment was shown at various opportunities in the Netherlands, and at Pretty Smart Textiles at Textiles Open Innovation Centre TIO3 in Ronse, Belgium [12]. In this article we describe the background, the design process, the result, and the lessons learned. The article targets readers in fashion innovation, and also designers and technologists developing new sensors and actuators to be used close to the human body.

Loe Feijs and Marina Toeters

Fig. 1. Drapely-o-lightment, the OLED skirt. Photo Brian Smeulders, model Stephanie Samson. (© Marina Toeters)
TECHNO SQUARES

At present and in the near future we are faced with discrete components to be embedded locally in limited numbers in mote-of-a-kind conventional fabrics. Many of these traditional components are manufactured as squares or rectangles. Important examples are OLEDs (organic light emitting diodes), solar cells, QR codes, PCBs (printed circuit boards), and magnets, a few examples of which are shown in Figure 2. In theory these could be manufactured in other forms, but in practice they are most often just squares. We call them techno-squares.

The design challenge we wanted to explore was the integration and interplay of the textiles (with their inherently soft nature), and the techno-squares (with their typically hard nature). At present, the electronics industry is offering square OLEDs of increasing size, giving rise to the important question of how these can be embedded. In the future, perhaps in ten years, the industry may produce very soft, lightweight, and flexible wireless PCBs, which will give rise to new design questions. The challenges of embedding techno-squares are twofold. The first challenge is to visually integrate the techno-square into the fabric so that it appears to belong there, rather than being an island or alien body. The second challenge is to maintain the drapability of the fabric / patches combination. The key properties in which textiles and techno-squares differ are: color, form, weight, and flexibility. Accepting the fact that techno-squares are not easily changed, as in our case where the OLEDs are given, we decided to work by adapting the color and structure of the textiles. The color was the easiest part (see the next section). For the structure, an important design decision was to make the textile less flexible in order to mimic the material properties of the techno-squares, but in a way that still made it both soft and drapable. We added a segmented type of stiffness to the fabric by working with a top layer of patches. Of course this influences drapability, which became a main theme of the work.

COLOR AND MATERIAL

We looked at the organic light emitting diodes in various states and under various conditions, searching for color / fabric combinations that appear visually similar to the OLEDs. Each OLED can be in several states: bright, off, or any brightness level in between (dimmed). When off, an OLED appears as a small mirror, so it may be light or dark depending on what is reflected. Because of the metal components in the OLEDs, we decided to pick fabrics with a metallic look. We took four colors that are close to the colors of the OLEDs at different intensities (Figure 3). The basic skirt itself (a silver colored substrate) is 100% polyester, weight 87 grams/m2. The patches are one layer of polyester glued on a stiff cotton interlining.

FROM TRIANGLES TO SQUARES

If we were not to impose any conditions, there would be an infinite number of ways of making the transition from triangles to squares. This means that there is some freedom of choice for the designer, and we propose a specific way of implementing the transitions. Both natural animal skins and mathematics inspire it. These turn out to be connect- ing in the theory of Voronoi diagrams, which describes certain cell structures in two dimensions. Our proposition is to have a structure of patches, some of which are squares, and most of which are triangular. The triangles provide for good drapability whereas the squares can be used to embed the techno-squares. In the next two sections we discuss animal prints, and then Voronoi diagrams and their connection to certain animal prints.

ANIMAL PRINTS

Prints inspired by animal skins are a favorite theme in contemporary fashion. For an overview of the history and the meanings of animal prints we refer to Tanya Wilson’s text on Animal Print [13]. The meanings include evoking the power of the animal, respecting the prey, associating their wearer with “the wild”, and having status (because real animal skin was precious). But Tanya Wilson also notices that, with the advent of new production processes, the meaning of animal prints tends to shift from wealth and status to a message that comes across as witty, playful, and bold.

When exploring the design options for Drapely-o-lightment, we felt that a loose and implicit reference to animal skin would make the pattern more interesting than a random pattern or a purely technical solution. And at the same time we felt that a link to nature would somehow counterbalance the technical and future-oriented meanings carried by the OLEDs, the metallic colors, the presence of a microcontroller, and the pure geometry of triangles and squares.

At a more abstract level we are happy to think our design fits in with the trend described by Li Edelkoort [14]:

“our relationship with the natural world will need to become symbiotic; if we intend to survive as a species, and by learning lessons from nature, we will be able to mimic its evolved forms, its mastered techniques and benefit from its proven knowledge. Our archaic roots will be transformed into contemporary ways of living, and in animistic fashion, we will connect with animals on entirely different levels. Mankind is after all a part of the animal kingdom.”

VORONOI DIAGRAMS

In mathematics, a Voronoi diagram is a way of dividing space into a number of regions. A set of points (seeds) is specified beforehand, and for each seed there will be a corresponding region consisting of all points closer to that seed than to any other. The regions are called Voronoi cells (Figure 6).

Voronoi diagrams are related to animal skin prints in a practical sense: many graphical designers and artists use Voronoi-based algorithms and tools to generate effects that resemble animal skin. A popular way of doing this is using the Filter > Texture > Stained Glass option of Adobe Photoshop. An example of this effect is shown in Figure 7.
In computer graphics this resemblance is exploited in special algorithms for generating animal skins for animation purposes. For example, Marcello Walter did this for the skins of various species of giraffes in his Ph.D. thesis in 1986 [15]. The computer graphics work is inspired by biological research into how skin develops in real animals. One theory is the Clonal Mosaic Model (Walters [15]).

Designing the pattern
The main layout of the skirt was made in Adobe Illustrator by the straightforward tailoring of a standard skirt pattern for the basic skirt substrate. The size was 36 (European measures). For the patches, a copy of this pattern was subdivided into the patches by laser cutting. The patches were separated by borders of about 3 mm. The pattern was shifted in the four colors and cut out with four different Illustrator files.

The pattern of patches was created with a special algorithm programmed in Processing (an open source Java-based platform also used for teaching in TU/e Industrial Design). After some puzzling we noted that it takes a regular and symmetric hexagonal point grid for a Voronoi algorithm to produce equilateral triangular cells, and that it takes a square point grid for it to produce square cells. We had to find a way to make a smooth transition from a hexagonal point grid to a square point grid, details of which are presented in the next section. Using this we combined things to get a large pattern consisting of triangles, except for 17 areas around a square. In total there are about 2500 patches, mostly triangles, and 17 squares. Around each square there are about 30 irregular polygons. Six of these squares actually contain an OLED, whereas ten are there for pattern consistency and prevent the upper skirt area becoming boring. Figure 9 shows the pattern. The original pattern has all its triangles of the same size, and, by means of a subsequent straightforward geometric transformation, was texture-mapped to the layout of the basic skirt.

REALIZATION
The total of about 2500 patches were transferred manually from the four laser-cut fabrics to the skirt. The fabric was fixed by cotton interlining carrying a glue layer, and then when this had to be activated by hot ironing. This was a very labor intensive process. The exact positioning was done with the help of a template: the network of 3 mm borders left over from one of the cuts.

We also discussed and played with various design options regarding the behavior of the light. We implemented two behaviors. The first behavior is a scanning behavior: the six OLEDs go on and off, with smooth transitions, in a low frequency rhythm of 0.3 Hz. The lights are not fully synchronous, but follow each other with a 0.5 second delay between adjacent OLEDs, similar to the effects of breathing. The second behavior is a heartbeat pattern. This pattern is a double-blink, similar to the pulse pattern picked up by a PPG sensor or felt when feeling a person’s heartbeat. For the heartbeat behavior, all OLEDs work synchronously (so the effect is more pronounced, and draws attention). It is technically possible to show the real heartbeat of the woman wearing the skirt, for example using a PPG or ECG sensor, but for demonstration purposes we implemented only a simulated heartbeat of about 70 beats per second. The main reason is that we were aware that the skirt would be shown at various exhibition purposes. For example, Marcello Walter did this for the skins of various species of giraffes in his Ph.D. thesis in 1986 [15]. The computer graphics work is inspired by biological research into how skin develops in real animals. One theory is the Clonal Mosaic Model (Walters [15]).

The possibility of interactivity also had to be part of the demonstration: there is a sensor to detect movement in the environment, so there is interaction even with a static dummy: visitors to the exhibit trigger heartbeat and pulse patterns. Technically it works with two LDRs (light dependent resistors) and an Arduino LilyPad (a microcontroller intended for textile applications). The Arduino calculates a moving average light intensity level, and uses that to detect fast changes in intensity. The LDRs are put in a Voltage divider circuit with distinct resistor values so that the detector mechanism works under both dim and bright conditions. In practice it is quite robust and will trigger the heartbeat when a visitor gets nearer than 0.5 meter. After about eight seconds of heartbeat operation the skirt returns to scanning mode. The Arduino was hidden inside the skirt, near the lower seam, and a small pocket was made to contain the rechargeable battery (900 mAh Lithium). The skirt functions for about two days and nights before recharging is needed.

Our efforts on the drapability of the patches have paid off, as shown by the photo in Figure 10. The effect is not the traditional draping of smooth bias-grain garments, but it resembles the wrinkling effect often seen in architecture in modified goodie-sic domes (such as the “blob” building by Massimiliano Fuxas in Eindhoven, see Figure 11) and in design (such as Mathieu Lehanneur’s ottoman called “bucky’s nightmare”).

The skirt is designed to be comfortable in wear. The wearer can sit, walk, and dance without practical problems. The OLEDs are clearly visible during normal in-house conditions, also when daylight enters through the windows. However, in bright sunlight, the intensity of the OLEDs is simply not enough. Note that it is an essential point in this design that the effect of the lights is subtle (and not screaming “this is an LED skirt”). The dynamic effects of the breathing rhythm and the heartbeat certainly have aesthetic qualities (but these are hard to show in this paper - we shall provide a movie or a simulation as supplementary material for the readers of the electronic Leonardo).
Woods in Hussein Chalayan’s Autumn/Winter (19). LED dresses were a main theme of our innovative laser-cut fractal designs being exhausted (see also, for example, interesting: its possibilities are far from printing is interesting, but we also be-

in the context of the epistemological theory of K. Kraft [24], who argues that beyond the possibility that patterns are deployed as carriers of ornamental cultural values, there is the important perspective that all kinds of symmetries arise during the production process (knitting, plaiting, weaving etc.). We envisage new textiles that do have very interesting symmetries, but where the story told by the symmetries is a more complex mixture of computer-aided design, laser-cutter-aided production, functional require-


LOOkiNg bAck

In retrospect we are glad that the Escher-style tilings were not so drappable because the present reference to nature is much more subtle. The point is that stiffened textiles with non-straight edges tend to interlock rather than fold nicely at the edges. Before doing the experi-

ments we had an impractical intuition that perhaps any tessellation would improve drappability, but then we found that the chosen triangular pattern outperformed all others (and certainly the Escher-like pattern).

At a higher level, we draw several conclusions about the process. We found that computer-driven laser cutting is a very valuable innovation, and that its creative possibilities are far from ex-
hausted, although nowadays 3D printing seems to get more attention. We found that the embedding of techno-squares in subtle ways is an important contempo-

rary design challenge. We found that the Escher-project was a way of sharing something intimate.

Appendix: Details of the Algorithm

After having discovered that it takes a regular and symmetrical hexagonal point grid to get a standard Voronoi algo-

rithm to produce equilateral triangular cells, and that it takes a square point grid to get it to produce square cells, the next question is this: “How can we make a smooth transition from a hexagonal point grid to a square point grid?”

We took inspiration from De Bruijn’s pentagrids [29], but here the situation is much simpler since we need only a “duogrid”. A duogrid is a set of verti-

cal strips j = 0, 1, 2, etc. and a set of horizontal strips j = 0, 1, 2, etc. A duogrid can be used to produce the (x, y) coordinates of a hexagonal point grid, and it can also be used to produce the (x, y) coordinates of a square grid, as shown in figure 12.

The trick is to turn to algebra, as De Bruijn did, and, in our case to construct a formula-pair which gives the (x, y) co-

ordinates for the hexagonal grid: x = ½(1 + odd(j-i)) : 0

y = ½(1). We combine the formula-pairs into one formula-pair:

x = ½(1 + odd(j-i)) : 0

y = ½(1). This produces a hex point grid for k = 1 and σ = 0 and which produces a square point grid for k = 0 and σ = 1. For most (i, j) we take k = 1 and σ = 0. And if we want to put one or a few squares near a
target point A with indices i = iA, j = jA then we gradually change λ to 0 and σ to 1, locally near (iA, jA). A point grid then modified (and the resulting Voronoi diagram) is the one already shown as page 6. To convert the point set into a set of polygons we used Lee’s Processing mesh library [28]. The pol-

gons were drawn in Processing using the PDF export library with commands such as beginRecord() and endRecord().

References


Related Work

The use of Voronoi diagrams, and struc-
tures resembling them, is not uncom-

on in architecture and design. In ar-

chitecture these structures usually arise on curved surfaces. An example is the “emergent architecture” Summer Pavil-

ion in Novosibirsk, Russia by Tom Wis-

combe [22].

In fashion, the Dutch company Free-
dom of Creation (FOC) creates “tex-

tion in Novosibirsk, Russia by Tom Wis-

combe (2007).

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