# THE MUSIC SLEEVE: FABRIC AS AN ELECTRONIC INTERFACE MEDIUM


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## ABSTRACT

In the area of fabric interaction, (also known as wearables or smart textiles), innovation often comes from technological advances. Interface designers, on the other hand, take the role of exploring fabric as a medium for interaction. In this paper, we will describe and analyse the design of the 'Music Sleeve' – a fabric controller for a music player on a mobile phone. The development of the Music Sleeve was an experiment in open-ended design approaches. As a case study, it represents an interface solution that emphasizes the functional fabric qualities in the interaction, complementary to other, either more expressive or more pragmatically designed interfaces. In the paper, we will therefore not only describe the design process, but also reflect on our insights: How the fabric properties guided the development of fabric interface elements; how the functions associated with the interactions were guided by the form of the final prototype; and how concept development and prototyping were closely intertwined in the process. We conclude with a reflection about how aesthetics and function interrelate in the fabric interface.


## INTRODUCTION

Conductive fabric and thread are a new interface technology that spread from medical and military products into the consumer market. Hence, wearable technology is becoming more common and for interaction designers, under the labels of smart textiles, e-Textiles or wearable computers. At the beginning, developers have often referred to existing interface solutions used for electronic devices. When doing so they also often adopted the common and familiar user interfaces such as control buttons and symbols from music players. Therefore the potential of the fabric to

Figure 1: Music Sleeve and phone

provide new interactions has seldom been explored. Although these products were often cutting-edge technologies, they did not create new experiences for the users.

More recent research has matured. For example, works like E. R. Post's master thesis on an embroidered jacket interface (1999) and an interactive tablecloth (2000) represent early works on appropriating fabric production techniques for electronics. Similar to the use of embroidery, J. Berzowska experimented with jacquard weaving technique to produce complex fabric circuits (2005) and investigates the incorporation of fibered electronic materials, such as nitinol, in interactive garments (2008). While these projects mean to appropriate fabric as displays and kinetic surfaces, L. Buechley's works demonstrate various detailed investigations on gracefully integrating electronic components into the fabric (2009). Similarly, H. Perner-Wilson developed a large number of low-fi textile sensors from scratch (2010).

The important achievement of those works is to regard textiles and electronics equally as technologies to be mixed and appropriated for each other. By revealing their 'technical' qualities once again, the aforementioned researchers find a compelling and surprising way of creating new functional and expressive meanings for both electronics and fabrics. They also investigate electronic fabrics in an experimental and open-ended way.

In this study, we follow a similar direction as these researchers, but investigate fabric physical properties as sources for new interactions with electronics instead of focusing on innovative production of electronic fabric. We will describe and analyze the design of the 'Music Sleeve' – a fabric controller for a music player on a mobile phone.

We will describe the design process, as well as reflecting on a number of questions arising from the study: How did the physical properties guide the development of the fabric interface elements? How the specific functions associated with the interface elements in turn were guided by the form of the final prototype? How were concept development and prototyping intertwined in the process?

Through these reflections, we learned that opposing qualities between fabric and electronics hold the most potential for new modes of interaction and user experience.

## FABRIC AS AN INTERFACE MEDIUM FOR ELECTRONICS

The Music Sleeve was designed and implemented in three months as a part of a doctoral dissertation on experimental interface design in fall 2010. We first give an overview of the Music Sleeve, its design and workings. Then we continue by explaining how the Music Sleeve was profoundly influenced by material and physical qualities.

## THE PROTOTYPE

The Music Sleeve is a wearable controller for playing music on a smartphone. Shaped as a knitted closed tube that can be slung across one's shoulders, it functions as a music controller when one puts a handful of coins in it.

The Sleeve can be moved around the shoulder to shuffle the coins inside, which will always fall to the bottom due to gravity. It has four pull strings on the outside, dividing it in four equal sections. When tied together, the strings block the coins inside or lock them in a particular section of the sleeve. The location of the coins in the tube and the combination of strings trigger a

Figure 2: a) An opening that allows coins to be dropped into the sleeve. b) The sleeve is worn across one's shoulders. c) Rotating the sleeve moves the coins within. d) The movement of the coins can be obstructed by tying the string.

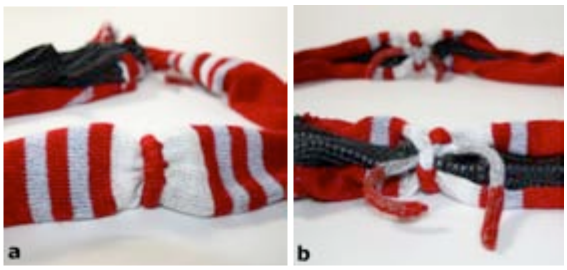

Figure 3. Active zones a) White areas act as the location switches. Grey lines are direction indicators. b) A closed string switch.

function (see figure 4). The different states of the sleeve (off, pause, play, shuffle mode, volume mode, skip tracks) are transmitted to the mobile phone via a Bluetooth module on a Lilypad microcontroller, and interpreted by an Amarino application on the phone. The four pairs of knitted-in 'location switches', located on each side of the pull strings, consist of two oppositely charged parallel rows of conductive yarn knitted on the inside wall of the sleeve. When coins pass through, they activate a switch. The strings, the second kind of switch, can be pulled and tied in particular combinations to access different functional modes. They will also lock the coins in certain regions of the sleeve.

Tying all strings will switch the music off, opening all of them will switch it on; blocking half of it will activate the shuffle mode, blocking a quarter triggers the volume control, and blocking one single switch with coins on both sides will pause the music (see figure 4). The switches and strings are distinguished by colour as 'active zones'. Different numbers of stripes at each switch hint to how the sleeve behaves in action. E.g., when all the coins are locked within one quarter section of the sleeve, the switch with one line will decrease the volume of the music; the switch with two lines will increase it.

We propose that the Music Sleeve interface is an

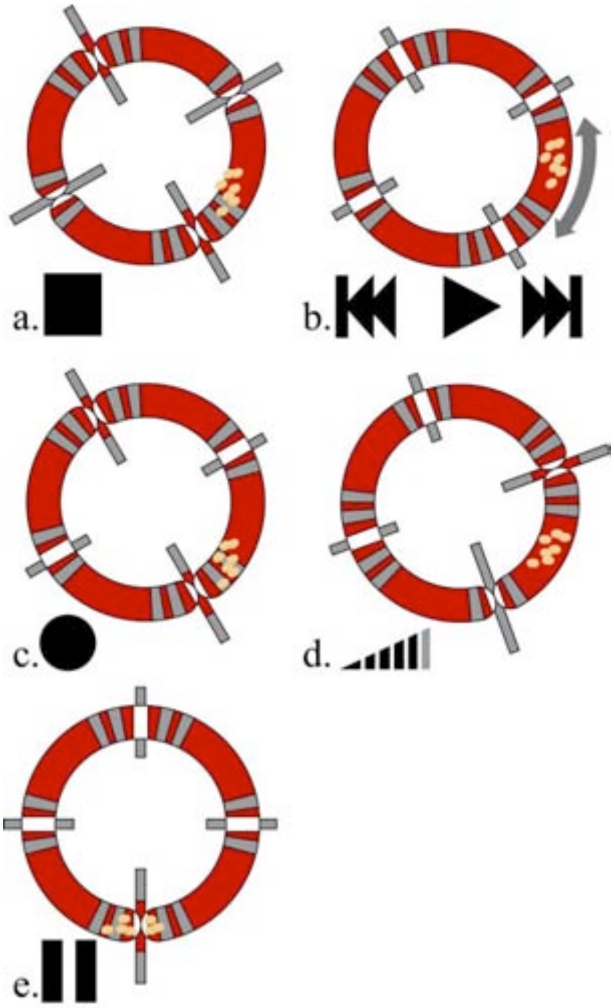


Figure 4. Position of coins and state of strings mapped to functions of the music player. In a., all strings are closed to stop the device; b. shows the coin movement to play and skip tracks; in c., opposite strings are tied for the shuffle mode; d. displays the volume mode with consecutive strings tied; e. to pause, tie the string with coins on both sides.

example of how the material quality of fabric can be central to the interaction. In other words, how can the fabric material be exploited as an interface medium for electronics.

## THE DESIGN PROCESS

At the beginning of the design process, we deliberately decided that the physical qualities of the fabric as the necessary and central aspect for creating new interactions, i.e**. to address fabric as a medium for the interface**. Our process thus involved the following steps:

1. Identifying the significant properties of fabric as an interface, e.g. the stretchiness of fabrics;
2. Collecting visual references on fabric interactions to appropriate them for electronics;
3. Sketch and prototype fabric interface elements (see Figure 5);
4. Assemble single interface elements into a more complex whole and map electronic functions with them.

After several iterations at step 1, we have come to an emergent insight between fabric and electronics: The opposing qualities between them hold the most potential for new modes of interaction and user experience. When one combines electronics with fabric, it is most interesting to use the opposing qualities. For example, the softness and versatility of the fabric open up new ways of interacting with electronics, which are normally stiff and hard. One can make a switch by tying two textile strings. One can make an electronic contact by folding. One can increase or decrease a resistance value by stretching. Tying, folding, stretching and many more interaction modes are afforded by the physical quality of fabric. We investigated many of those interaction modes through sketching and prototyping, although we did not employ all of them in the Music Sleeve.

As a result of step 2, we realized that any interaction with fabrics would of course happen within a context that included other conductive objects as well, like small change, bike frames, pots and pans etc. We then systematically searched for conductive objects that would interact with fabric, and fabric objects that would come in contact with conductive artefacts. We were especially looking for those combinations that pointed to interesting ways of using the fabric's softness: For example, the metallic frame of a bicycle also evoked riding the bike in a rainstorm, and the fight with skirts or raincoats to keep them from lifting up or blocking sight, and coins in a wallet reminded us of holes in trouser pockets, or the residues collected in the bottom corner of a backpack. Those scenarios and contexts were developed in step 3 and 4, and chosen based on the range of their interaction potential for conductive objects with fabric.

### DOUBLE MEANINGS: USING COINS AS SWITCHES

We chose to work with coins as conductor in the end for the Music Sleeve because we found their material properties as well as their aesthetics and meaning sufficiently rich and versatile: They produced a nice distinct sound and feel, were nice to handle and play with, and at the same time their stiffness and weight could be juxtaposed with light and soft fabrics to create an interesting contrast of materials and textures.

We first investigated different variations through sketching: adding pressure to the coins within a pocket or sling through knotting or sitting on them; using gravity to locate their position within a pocket, lump or spread the coins, or sort them by size. We tried multiple design options to increase the reliability (see figure 5) of the electronic connection between coins and fabric. Finally we decided to only detect the presence of coins rather than their amount, and thus to use them for digital switches. Closing a circuit by putting coins between its two open ends just needs a slight contact to work and avoids the high noise inherent in the bad connection of fabric and coins.

ADOPTING FABRIC SHAPES: STRANGE FORMS FOR FAMILIAR ACTIONS

As a result of our insight to contrast fabric and electronic properties, we wanted to define **unfamiliar independent fabric shapes that invited familiar actions** like folding or crumpling. Our aim was less to merely use familiar fabric shapes as interface metaphors. The interaction should be meaningful, but leave enough room for new interaction and experience.

After first having produced a broad range of object-fabric interaction scenarios in step 3, we refined them according to how well we could actually detect them electronically through the shape of the fabric alone – i.e. without additional electronic sensors. For example, the action of 'spreading' a piece of cloth on a table can be used to detect its shape, according to how the folds around the table fall (this will look different for a small, round table than for a big squared one). Unlike the tablecloth scenario, we could not come up with similar fabric-based solutions for some other situations (like the amount of wind that a piece of fabric is exposed to), because the electronic components required more stability and reliability than our prototypes could provide.

After having prototyped a large number of those interaction possibilities in fabric, we assembled the most reliable ones into a coherent interface. Usually, the electric contact between coins and fabric was too unreliable, despite our various attempts to improve it. This resulted in too much noise in the circuit that made it difficult to clearly read a range of concise values, indicating a distinct number of coins. For the final prototype, we combined the interactions of slinging a bag around the body, enclosing stuff by knotting it in, and moving things in a pocket by shifting them around inside. We developed the narrow shape of a hollow, closed sling as the final form for the interface. The hollow shape assured to keep the coins inside in a cluster that would act as one conductive body. The coins could move freely inside the sling, and the location of the coins could be detected as they triggered the respective switches on the inside. The strings on the outside would block the flow of coins when pulled, while working as fabric switches at the same time.

FUNCTION FOLLOWS FORM: MAPPING FUNCTIONALITY TO THE SLEEVE

We neither wanted to design an electronic fabric interface for a specific purpose, nor make the prototype's electronic function necessarily the most important one. While we were already detailing the form and interactions, we left the purpose of the sling undefined: The interface as such could have been mapped to control all sorts of electronic functions where a continuous directional movement was useful.

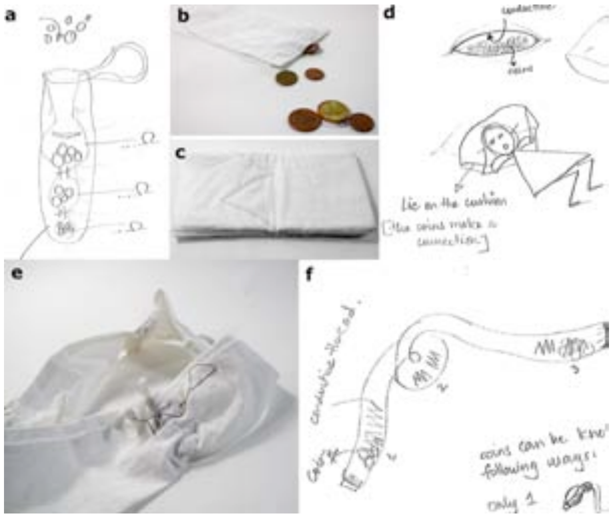


Figure 5. Examples of initial prototypes and sketches that use coins with fabric. a) Gravity coin sorting pouch – When coins are dropped in, they get sorted into the different compartments according to their size. b) A prototype for a coin sorter – Only small coins pass through the slit at the end of the bag. c) Prototype of a cushion concept that has triangular conductive areas and can be filled with coins. The connection is made when someone applies pressure by sitting or rolling it up. d) A concept sketch for interacting with a coin filled pillow. e) and f) Prototype and sketch for using the action of knotting coins within a sling form.

However, the sense of direction in the flow of coins within the sleeve and the ability to break and manipulate the movement of coins fitted well with the function of a music player, as the movement reminded us of scrolling through tracks. The coins in the sleeve thus took on the role of the 'play head' on a tape recorder. Similarly, the idea that the 'pause' function freezes the movement of the play head got translated into blocking the flow of coins in the sleeve.

Using fabric output as well as input would have been most consequential, but turned out to be too energy-consuming for our project. At the same time, stiff and heavy components in the fabric interface itself would have made it clumsy and obstructed the rotational movement. Thus, we externalized all necessary components by connecting the fabric sling to a mobile phone via blue tooth to keep the softness and flexibility of the fabric interface intact. The mobile phone thus takes the role of a multi-purpose minicomputer where electronic components are included and safely stored away.

## REFLECTIONS

The materials and production techniques provided the unavoidable material constraints to our design. We literally had to bend these techniques to our purpose, and explore their potential in a foreign medium. Figuring out the most intriguing use for a particular production technique was similar to identifying intrinsic material interfaces. Both processes were very tightly coupled. They went through the following stages:

1. exploring the opportunities and constraints of

Figure 6. Opened view of revered side of sleeve - Conductive yarn knitted in rows to form a location switch circuit.

Figure 7. Close ups of the rows stitched in the jersey to carry the data lines securely.

the production techniques,

2. combining them into single interface elements,
3. working out solutions to assemble a more complex prototype,
4. learn from 1-on-1-prototyping about the feasibility of the design.

1. We used **sewing and knitting** in the final prototype. The knitting machine allowed us **to knit our own custom fabric** with unique properties in terms of conductivity, stretchiness, pattern, colour and dimension. With the machine, we could produce closed hems, where the conductive yarn would be protected on the inside, and strings of different thicknesses with conductive yarn plated to the outside.

2. We **combined those techniques to create the string switches**. Similar to this, the location switches on the inside of the sleeve had to be parallel lines of conductive knitted fabric, following the direction of the machine (see figure 6).

The connection from the switches to the microcontroller had to run in vertical direction, while being just as stretchy as the knitted fabric. **We thus used jersey to carry the soft circuitry**, as its elasticity matched that of the wool.

3. To insulate the data lines in the sleeve properly, **we thus them into narrow cordings, coming from the switches**. These parallel tubes would contain the (un-stretchy) conductive thread, insulate it and at the same time create a nice ruffle-pattern, thus giving it a unique aesthetic quality (see figure 7).

4. The available production techniques thus had a big impact on how we planned the interaction in detail. **It was only in the concrete implementation that we could decide how the interface should finally work.** Our design process therefore was highly bound to the material and its physical limits.

## CONCLUSION

In this paper, we described a design research project on fabric interaction to find out some interface possibilities intrinsic of the material at hand. We developed the interface constrained mostly by the material properties. This constraint inspired us to determine alternative interface elements in the medium of fabric, with different aesthetics and interactions as a result.
We shared our experiences from developing the Music Sleeve and explained our design decisions based on the fabric properties. We now draw some hypotheses on the further development of fabric interaction, and the mutual impact between material constraints and aesthetic impressions that our fabric interface evokes.

### DEVELOPING FABRIC INTERACTIONS

The development of the fabric interaction elements was a highly iterative process between sketching and prototyping. It was common to have beautiful ideas on paper but fail in practice when prototyped.

However, the interaction elements literally had to be shaped as a parallel development between concept and material, sketching and prototyping. Details, like the thickness of the conductive thread, the length of a sewing stitch, or the distance between conductive stripes in a piece of knitted fabric was crucial to failure and success. This conversation with the material, in turn, inspired us to new interface elements. We realized that our experiences were very much in line with the pragmatist account of thinking, as expressed by John Dewey (Dewey, 2005, pp. 61-62) and addressed in Design Research on experiential knowledge.

### HOW FUNCTIONAL DECISIONS INFLUENCED THE AESTHETICS

By judging our production techniques mainly by their adaptability as electronic element, we treated their aesthetic expressions as secondary. However, we intentionally looked for translatable elements in fashion, which carries a lot of expressive meanings. Also, we were using familiar objects like coins in the interface that should also evoke diverse associations. While we did not develop our interface primarily by the aesthetics, we deliberately tried to avoid well-known 'electronic' interactions, like pressing buttons.

As a result, we suggest that our prototype displays ways to use fabric as an interaction element rather than a substrate for electronics. Accordingly, the sleeve is aesthetically quite different from standard electronics: it reminds us of shawls, leisure sweaters or elegant pullovers, it is feminine and delicate, collapses nicely when laid down on a table, it can be worn over the shoulder or around the neck, it stretches under the weight of the coins, which jingle with each movement.

By adopting the material and production means, we were adopting the interface aesthetics of fabrics at the same time. We therefore suggest that merging two different media – electronics and fabrics – on a functional level also leads to new aesthetics and functions for both domains. However, while a functionally designed form automatically has an expressive meaning, an expressively designed form does not automatically have a functional meaning as well. We suggest that our project can be understood as such an example of how to explore new aesthetics from a functional point of view.

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