E-textile Production of Wearable Ambient Notification Devices

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Abstract
Electronic textiles worn on the body provide interesting opportunities for ambient notification within assistive systems, as they can be seamlessly integrated into everyday clothing and accomodate for completely private modalities, such as thermohaptic feedback. In this paper, we present three different approaches to wearable ambient notification systems in textile for elderly users. We have constructed three interactive shawls, exploring how different outputs for ambient notification can be integrated into industrially knitted fabric. We describe the design process of the prototypes, present the challenges in constructing them and discuss their implications as ambient notification devices.

Author Keywords
Ambient notification; wearable; electronic textile; thermochromic; thermohaptic; knitting

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

Introduction
Pervasive computing systems are increasingly being implemented to monitor and support people in need of assistance. The notion of ambient notification within such a system is to present the user with context-

appropriate information without distracting them, reducing the overall information load. Ambient notification technologies are commonly embedded in the environment and made tangible, often with an emphasis on aesthetic qualities [1]. Due to their mobility and proximity to the body, wearables have an integral part of distributed intelligent systems, and ambient technology have been explored e.g. in the form of wristbands [2] and bags [3]. In this context, electronic textiles provide interesting new opportunities for ambient notification, since they can be seamlessly integrated into everyday clothing. They allow for experimenting with different output modalities such as haptic feedback.

In the project DAAN (Designing Assistive Ambient Notification) [4][5], we investigate the potential of wearable electronic textiles as ambient output devices within a pervasive assistive system for elderly users. The DAAN system learns the user's habits and selects the approriate notification channel depending on the situation. Since the type and degree of impairment differs for every user, the system is able to adapt to their individual needs, continually adjusting the level and intensity of the notification. We present the design of three different interactive shawls that each addresses a different feedback modality; visual, visual-haptic and haptic. In the following, we will report on the design of the shawls and discuss the implications of the models to provide notifications.

The wearable prototypes

Shawls are common and versatile accessories amongst elderly people, as we observed during a study at a daycare center prior to the design phase. They can be well appropriated by the wearer, they fit different body sizes and genders. As an accessory, shawls are often used over longer periods of time, and do not need to be frequently washed. This made them suitable for our project, in which we used a simple application scenario as a starting point for the design: The shawl reminds the user to wear it if the weather forecast is predicting cold weather for that day.

From a technical point of view, we were interested in embedding the active components as smoothly as possible with the fabric to achieve a high formal-aesthetic quality of the prototype, as well as integrating them efficiently in an industrial manufacturing process. From an interaction design point of view, we focused on outputs that were specifically suitable for electronic textiles. The three versions of the shawl represent two different approaches to visual output, i.e. a light-emitting display made from optical fibres and a non-emitting display with thermochromic color-changing prints. The thermohaptic output is an inherent part of the thermochromic display but can be used independently from it as a notification in its own right.

All the interactive shawls have the same basic technical setup, consisting of a microcontroller with an integrated WiFi module and a lithium polymer battery, sewn on a detachable patch. All prototypes work as standalone lightweight objects without further cable connections and a minimum of standard electronic components (Figure 1). The shawls were all knitted on industrial flatbed machines.

The optical fibres shawl

Light-emitting displays in textile provide for a reliable and easily adaptible output channel, however when integrated into clothes for the purpose of ambient

Figure 1: Interaction with the heat shawl over WiFi in a demo scenario

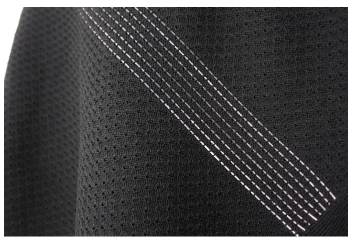

Figure 2: Optical fibers integrated into the knitted fabric

Figure 3: Thermochromic ink gradually returning to its original color blue after the printing process

notification they run the risk of attracting too much attention. Furthermore, Devendorf et al. found that light emitting garments tend to be associated with parties, children, and novelty, and are therefore not always suited for everyday clothing [6]. Optical fibers are a suitable way of distributing the light from a LED into the textile material and integrate the light sources more directly into the fabric itself. The optical fibres are flexible enough to preserve the overall softness of the wearables, however they are stiffer and more fragile than standard yarn and frequently break in an industrial knitting machine. We therefore chose a tuck-stitch pattern to keep the optical fibers in place on the surface without actually knitting it (Figure 2). The fibers were sanded prior to knitting to emit light evenly over their surface and connected to a custom-made sewable circuit board with a high-power LED. Since the light emission along the fibers is relatively dim, the surrounding fabric is black to provide maximum contrast. The optical fibers run from the back to the front of the shawl, to be visible from all sides.

The color-changing shawl

Non-emissive displays made from heating elements and thermochromics have lower resolution than standard displays and are less dynamic, with a gradual change over a few seconds. This makes them unobtrusive and inconspicuous interfaces, but also less suited for delivering messages in real time. Because they activate with heat, they can work as a visual and tactile output at the same time. When heated, the thermochromic pigments transition from color to transparent, or reverse, depending on the chosen activation temperature. An activation temperature of 38ºC proved most suitable for our purpose. A lower activation temperature (31ºC) gave fast results but also meant accidental activation from body heat, as well as causing damage to the pigment by the heating process. A higher activation temperature (43ºC) required too much power to activate the change.

We applied the thermochromic pigments to the knitted fabric through a discharge screen printing process. Discharge print is a chemical process that works with a reducing agent that takes out the existing dye of the fibers and replaces it with new pigment. This technique binds the pigments to the yarn rather than leaving it on the surface and also allowed us to print light colors on black yarn, providing for a maximum contrast in color change. By mixing thermochromic blue and non-reactive ink in red or yellow, we achieved a color change from blue to light red or yellow on a black substrate in just one print (Figure 3). We then added a transparent coating to protect the pigments from UV radiation. Four heat elements are integrated in the knitted fabric that are identical to those in the heat shawl (see next section).

The heat shawl

Thermohaptic stimulus is a less explored notification method in textiles, but it holds the potential of being completely private, as well as having affective connotations such as sympathy, love and friendship, but also danger [7]. A common way to construct heat elements in textiles is to use resistive heating of metal threads. Unlike peltier elements, they are soft and therefore can be worked on textile production machines. In our prototype we used a double-face knit with an inlay of steel yarn in between, to insulate it from the skin and to prevent shortcuts (Figure 4). The fact that the yarn is laid in but not knitted minimizes the length of the yarn needed and makes for a more


Figure 4: Inlay of steel yarn in double-face knit

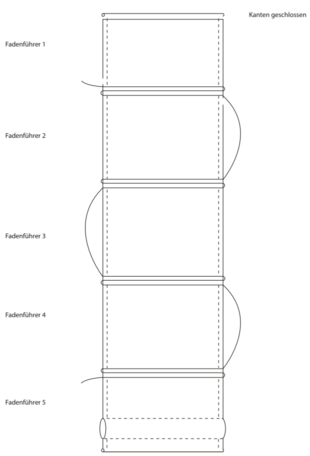

Figure 5: Placement of the steel yarn in the knitted fabric

efficient heat element. The surrounding fabric is knit from wool to maintain the heat. Each shawl has four individually programmable heating areas distributed over its length (Figure 5).

Discussion

In the following, we discuss some of the technical challenges in the production of the three prototypes and the implication of those difficulties with regard to their suitability as wearable e-textile devices.

The integration of optical fibers in a knitted fabric proved to be difficult because of their fragility. This limited the degree of automation of the production process – in the final version, the fibers had to be laid in by hand while the industrial machine was knitting. Although the fibers are soft, they are still stiffer than the surrounding material and thus affect the haptic quality of the prototype and limit the handling of it. So while the light-emitting display itself is usually a safe and reliable output, the difficulty lies in making it robust enough for everyday use.

In contrast to that, the thermochromic and thermohaptic output blend better with the surrounding fabric structure and can be integrated smoothly into the production process. The main challenge in building the heat elements is in dealing with the restrictions of a wearable device, especially to work with the limited power of a lightweight battery. The choice of components and yarn thus affects the amount of heat and the size of the area that can be heated.

At the same time we consider both the non-emissive thermochromic display as well as the thermohaptic feedback to be the more innovative output modes compared to light-emitting displays. The next step in our project will be to evaluate the three models with elderly users to learn more about the different qualities of the output modes in terms of ambient notification, such as disruption potential or privacy.

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