The Future Role of Visual Feedback for Unobtrusive E-Textile Interfaces

Figure 1: We discuss how the promising research field of smart E-Textiles and emerging visual mobile displays can work together to achieve powerful and unobtrusive E-Textile controls.

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Abstract

Emerging mobile interfaces are characterized by an increasing need for socially acceptable interaction supporting unobtrusive input. Simultaneously, they require rich visual feedback for many dynamic and complex mobile tasks. With this paper, we want to identify and discuss design options and parameters for body-centric and personal mobile interaction techniques that aim to be well-suited for both: social acceptability and rich functionality. Wearable E-Textiles are a promising research field for unobtrusive mobile computing since they allow novel, subtle and personal input controls. Therefore, we investigate, how they can be combined with high-quality Augmented Reality (AR) glasses to seamlessly provide visually augmented controls. For this, we question the role of visual feedback for unobtrusive mobile interfaces by classifying and discussing task- and context-depending visual feedback along the dimensions of the feedback type, position, time and visibility. Based on the sweet spots that we identified in our design classification, we conclude with two augmented E-Textile prototypes for future discussions.

Author Keywords

mobile interaction; wearable; social acceptability; AR glasses; E-Textile; augmented controls; smart fabric

ACM Classification Keywords

H.5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles;

Introduction

The success of mobile computing interfaces depends decisively on the personal added value, user experience and social acceptability that future wearable system will provide. While the fast-paced technological progress and ongoing miniaturization of wearable devices develop rapidly, the need to rethink the social acceptability and the functional scope of such emerging wearable technologies is an increasingly important issue (cf. [7]). Even though promising approaches have been proposed, such as garment-integrated E-Textiles interfaces and high-quality AR glasses, the everyday usage and social compatibility, however, remain challenging. E-Textile controls often lack direct visual feedback and are thereby mostly used for simple control tasks in an eyes-free manner. While AR glasses provide promising visual capabilities, they are in many cases disturbing in social context. For instance, hand gestures floating in mid-air or voice input make it often physically demanding and weird-looking to select or adjust values in AR.

With this work, we want to discuss the future role of visual feedback for unobtrusive E-Textile interfaces by combining the promising subtle characteristics of body-worn E-Textiles input with rich visual enhancements to support more dynamic garment-integrated interfaces and thereby improve social acceptability. Therefore, we want to utilize the visual capabilities of emerging AR glasses, such as the Microsoft HoloLens[1], to seamlessly enhance interactive fabrics with task-specific visual overlays that allow to control widgets in a more socially acceptable, dynamic and personal way.

Related Work

There has been much progress in the cutting-edge research field of body-worn wearable technologies and emerging E-Textiles interfaces (see [9] for a critical review). In the following, we want to briefly summarize current research with special regard to the input and output capabilities of current E-Textile approaches.

E-Textile Sensors: Researchers investigate E-Textile sensors concerning their *degrees of freedom* (e.g., pressure, location, and direction), different *form factors & types* (e.g., zipper, interface-like widgets, cords or accessories)[2], technology *acceptance* [1] and *body locations* [11] aiming to provide unobtrusive and rich mobile controls. However, these input approaches are promising, most of them lack direct visual feedback and are thereby mostly used for basic mobile tasks with predefined interaction mappings or for fast micro-interactions in an eyes-free manner.

Direct Visual Feedback for E-Textiles: While there is an enormous amount of work regarding E-Textile sensors for novel wearable input, there has been only little research on how E-Textiles can be visually enhanced for direct interaction interfaces. Choi et el. [2] introduced highly flexible clothing-shaped wearable displays by using fabric-based organic light-emitting devices, while Hashimoto et al. [5] utilize diffusive optical fiber to directly display strip-type illumination on a fibre fabric. In addition, de Vos et al. use a dispenser printer [4] and screen-printing methods [3] to apply electroluminescent displays on textiles for smart fabric applications, such as a completely printed watch display.

Visual Feedback – Design Criteria

Since the aim of our work is to investigate visual feedback to improve E-Textile controls and its social acceptance, we question the role of visual feedback for unobtrusive interfaces and classify visual feedback along the dimensions of *type*, *position*, *time*, and *visibility* (see Figure 2, A-D).

[1] Microsoft HoloLens. See https://www.microsoft.com/hololens

[2] Example sensor designs can be found, for instance, at the Kobakant wearable technology documentation: http://www.kobakant.at/DIY/

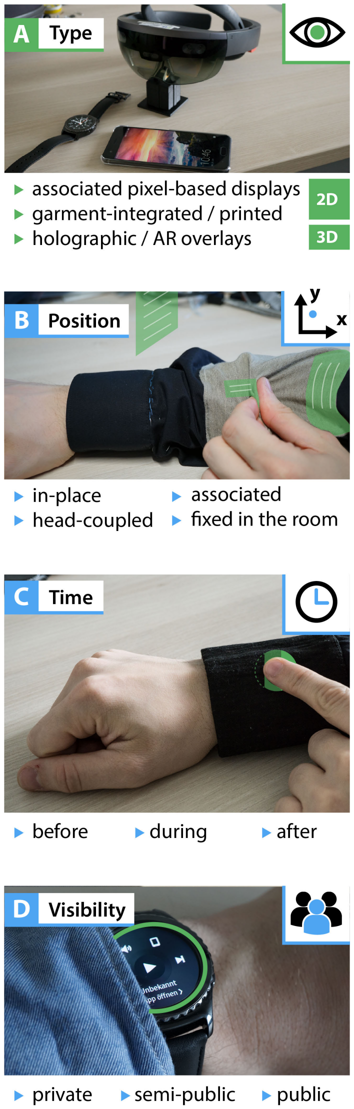

Figure 2: Possible visual feedback dimensions to enhance and design novel and rich E-Textile interfaces with regard to social acceptability.

◀ ***How can we provide visual feedback?*** *(A, Type)*
Associated pixel displays, such as smartwatches, can be used to visually support E-Textiles like smart sleeves. However, *garment-integrated* [2] or *printed displays* [4, 3] provide lower resolutions, they can enable dynamic visual feedback at same position of the E-Textile sensor. In addition, emerging AR glasses provide new opportunities to ubiquitously display AR overlays to visually enhance E-Textiles.

◀ ***Where can we place visual feedback?*** *(B, Position)*
In-place feedback combines the input and output modalities at same physical position enabling direct interaction. *Associated* visualizations are more loosely coupled and can be shown beside or above an E-Textile input or body part. *Head-coupled* feedback allows to view information fixed to the users perspective, while visualizations that are *fixed in the room* are suitable for interactions that will take a while.

◀ ***When can we provide visual feedback?*** *(C, Time)*
Depending on the current context or interaction tasks, the provision of visual feedback can be needed at different times. Feedback that is shown *before* an action is executed (cf. feedforward [10]), could be useful to communicate instructional or ambient notifications, while feedback that is provided *during* the interaction could help to visualize sensor states. Feedback that is provided *after* an interaction could help to show results, for instance of an mobile query.

◀ ***Who can see the visual feedback?*** *(D, Visibility)*
While it is obvious that a user should see the visual feedback, an interesting question with regard to social acceptability could be visibility of the output for others. Therefore, we distinguish *private* visual feedback that is only be visible for the user (e.g., by using personal AR glasses), *semi-public* feedback that can be potentially seen by others (e.g., smartwatches [8]) and *public* feedback that shows the hole visualization for everyone (e.g., LEDs in clothes).

First Example Designs & Initial Prototypes

In the following, we will choose promising design options out of our classification to investigate new approaches for unobtrusive E-Textile interfaces aiming to allow rich direct interaction with a decreased level of social obtrusion. We first focus on the following design parameters:

For our prototypes, we will use the Microsoft HoloLens as a state-of-the-art representative of emerging AR glasses. However, the current form factor and weight impact on acceptability issues, we assume that future generations of AR glasses look like normal glasses and are thereby more acceptable and unobtrusive.

Smart Cuff. We started to investigate our envisioned visually augmented E-Textile approach by first building a smart cuff E-Textile prototype that provides five pressure-sensitive interaction zones and can be combined with visually AR overlays to enhance the functional scope (e.g., dynamic controls and menus). To realize the prototype, we use piezoresistive Velostat (Figure 3, A), conductive fabrics (B) and threads (C) to integrate the sensor in the shirt cuff. With this sensor combination, we aim to start the discussion of the future role of visual feedback for unobtrusive E-Textile controls. Therefore, we decided to use *AR overlays* that are directly placed at the E-Textiles sensor supporting the interaction (D) *during* the adjustment of mobile tasks.

Smart Cords. In addition, we iteratively develop a series of *smart cords* (Figure 4, A-D) and introduce a wearable system in which a user can easily grab a garment-integrated cord, pull it away from the body and thereby open a cord-

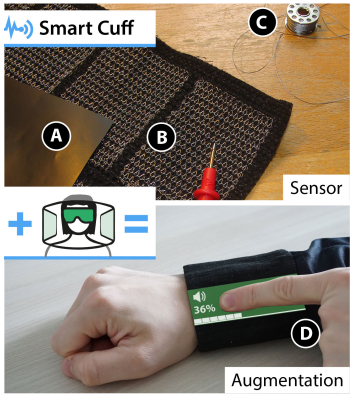

Figure 3: Our second **Smart Cuff** prototype is made of pressure-sensitive velostat **(A)** that is woven in a cuff with conductive fabric **(B)** and thread **(C)**. Our prototype **(D)** recognizes position & pressure input and provides visual feedback.

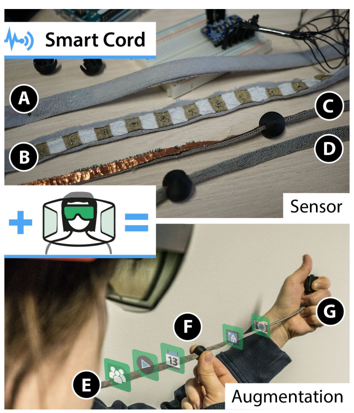

Figure 4: We iteratively develop a series of **Smart AR-Cords (A-D)** providing a cord-based visual interface **(E)** with a moveable slider ring **(F)** and an additional tactile confirmation button **(G)** [6].

attached visual interface for mobile services (E) [6]. The cord can be controlled by two modes of interaction. First, we aim to enhance body-worn coat cord with touch sensing capabilities to lay the basis for our visually augmented cord controls. As a second input modality, we also envision the use of a cord toggle acting as a moveable value slider (F). Further, we propose the use of an additional tactile button at the end of the cord (G) enabling explicit confirmations. With this combination, our visually augmented cord control can be used, for instance, to support precise single value and range selections for adjusting parameters, menu navigation for choosing options or switching states and selections of virtual or real objects in mixed-reality environments.

Discussion and Future Work

We investigate how the promising research fields of smart E-Textiles and high-quality Augmented Reality (AR) glasses can be combined to provide unobtrusive interactions and haptic and visual feedback for fundamental mobile control tasks. By classifying visual feedback for augmented E-Textile controls along the dimensions of feedback type, position, time, and visibility, we proposed a conceptual basis for designing unobtrusive E-Textile interfaces.

While we think that the success of rich and unobtrusive wearable controls is influenced by these design parameters, we started our exploration by choosing a set of promising options out of our classification and built two early prototypes that illustrate our principle ideas. Since we have to finish our implementation of AR overlays to evaluate our approach, we have no evidence for that our proposed techniques improve social acceptance at the current stage of our work. While we assume that our classification could be a valuable starting point for discussing important design criteria, however, additional studies are necessary to examine each design option and thereby gain a better understanding of possible social acceptability issues in relation to these dimensions. We are confident that our approach already now raise interesting issues that have to be discussed in the HCI community.

For future work, we plan to extend and refine our visually augmented E-Textile controls and conduct a user study comparing the usability and social acceptability. Therefore, we want to focus on the comparison between our novel approaches and current interactive solutions, such as mid-air gestures or E-Textile input without direct visual feedback.

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