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Hand Puppet as Means for eTextile Synthesis

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Abstract
To situate the skills of the textile designer within the HCI-process, we present a case of a hand puppet with a purpose-woven smart textile pattern. The qualities found in traditional textile design are tacitly synthesized into the eTextile-design process. We see this mentality as having a natural dialogue with HCI-practice. The hand puppet consists of two layers: an inner sensor glove, designed to detect the movements of the user's fingers, and a woven outer layer that has a touch sensitive user interface integrated into its woven structure. The two interfaces can be operated simultaneously by two separate users; an adult and a child. Our interest is to understand better how the traditional textile design variables can be utilized in the user interface and -experience design. We aim towards the synthesis of woven eTextile design, consisting of user interface design, pattern design, sensor structure design and textile layout design.

Author Keywords
eTextiles; weaving; smart textile design practice; hand-held; soft material.

CSS Concepts
• **Human-centered computing~Interface design prototyping** • *Hardware~Haptic devices*

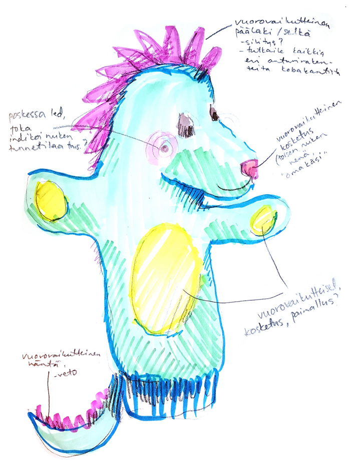

Figure 1: A sketch of the interactions of the hand puppet

Introduction

The textile design process and the role of textile designer have been evolving throughout recent years. Traditionally, the textile design process has been a lone journey with a focus on mastering a singular methodology, but recently that approach has been broadened by new technologies, sustainability agenda and participatory practices [16]. In the field of smart textiles, the recent advances have resulted in creating fabrics with computational, sensorial and actuating properties (for an overview see [2,14]). That positions the smart textile design practice in the intersection of multiple fields, such as textile design, material science interaction design and electrical engineering [15]. To situate the skills of the textile designer within the HCI-process, we present a case of a hand puppet with a purpose-woven eTextile pattern.

Firstly, we briefly touch how the textile designer's embodied knowledge is being utilized in an eTextile co-design process, and secondly, how weaving as a traditionally 2D-method supports designing eTextile layouts for an interactive 3D-object. Knowledge of textile materials, techniques and structures is essential for developing novel robust methods of integration of electronics into textiles. Lack of in-depth weaving expertise is frequently present in smart textile research related to weaving. This study examines this through weaving practice to make an original contribution, through the development of an in-between wearable [1]. The intent of this paper is to describe the work leading to the methodological analysis intended for the development of the role of an eTextile design practitioner. However, the analysis is beyond the scope of this paper.

Background

We see tacit knowledge [8] as the essence of the thinking distinct to a textile designer. Furthermore, we see the process of textile design as an inherently reflective practice [13]. Besides its tacit and reflective nature, the textile design knowing is often related to the understanding of different material-specific matters. For example, Fairburn et al. [4] write about the textile design specific knowledge: *"Textile designers tend to think in two- dimensions, and are largely concerned with surface, rhythm, scale, repeat, tactility, and with properties and functionality. The deep tacit nature of textiles together with their inherent tactile and sensorial qualities differentiates the textile designer's area of knowledge and contribution within innovative interdisciplinary practice."* (ibid.)

Similarly, Igoe [6] suggests that besides haptic, sensorial and tactile qualities, the design process is guided by emotive qualities, and those qualities are tacitly synthesized in the design process. We see this mentality as having a natural dialogue with HCI-practice. The "material turn" [11] that has taken place within the field of interaction design calls for embodied knowledge of materials and materiality, finding a sensible companion in tangible and embodied interaction [5]. More recently, this has evolved towards the materiality of interaction [18]: *"By explicitly focusing on craft, researchers are using a material lens to challenge assumptions about what constitutes design and who indeed performs this practice".*

We draw inspiration from three eTextile examples that utilise woven textiles, implying the possibilities of woven electronic structures. Both Project Jacquard [9] and Involving the Machines [19] focused on industrial-produced electronic functionality, and in general draw

Figure 2: Prototyping eTextiles. From the top down: a non-functional prototype of the hand puppet, a functional prototype of the outer layer, and a functional prototype of the inner glove.

parallels to focusing on the impact of fabric properties in woven eTextiles [10]. With these in mind, our eventual goal is the development of practical textile-HCI-design-methodology, to enable the skills of an eTextile design practitioner in the development of a woven textile as a true hybrid material.

Methods

The primary dataset for mapping the co-design process consists of field notes and a working diary of the process. In addition to this, additional pictures and video material were used to clarify project phases and specific details. These are collected to enable a later analysis of the development of a hand puppet from two perspectives. Firstly, the design process of an interactive hand puppet will be mapped against two design frameworks by Veja [17] and Sanders and Stappers [12]. Secondly, the prototypes of the hand puppet will be analysed by reflecting on the results of reflective weaving practice through technical structural analysis of the woven prototypes.

The interactive hand puppet

The interactive hand puppet is intended as a tool for interactive storytelling, to support child-adult-interaction with a thoroughly soft and textile-made object. The construction of the hand puppet consists of two layers: an inner sensor glove, designed to detect the movements of the user's fingers, and a woven outer layer that has a touch sensitive user interface integrated into its woven structure. The two interfaces can be operated simultaneously by two separate users; an adult and a child.

Design process

The first iterative design development cycle of the interactive hand puppet-project was carried out in spring 2018. In the early front end of the design process, the aim was to define the problem space and understand the users' needs within that space. The understanding was built through desk research, user interviews and user observations. The first initial design-hypothesis was established in quite an early phase, to start testing and collecting feedback. The concept description and the visualisation were created to make the concept idea communicable in the user interviews. The hand puppet was seen as a potential tool for parents to support kids in learning social and emotional skills, through focusing on child-adult-interaction.

The process evolved through brainstorming and concept creation towards concept definition that at the same time set the design objective for the eTextile design process. After defining the concept, the process proceeded into the design development phase. The central aspect to consider was that the user interface needs to cater to two users of different skill levels, and the inputs need to be measured from both inside and outside of the object. The design-hypothesis of the preferred interaction was embodied into two functional prototypes: one for recognizing the finger movements, and another for the touch sensitive user interface embedded into the outer layer, which also has the hand puppet character design. The hypothesis was validated with children, by testing a simulation of the user experience.

eTextile design process

A distinct eTextile design process took place parallel with the design development process. The first preliminary phases, the ideation, sketching and

Figure 3: A woven sensor textile

Figure 4: A colour and bind test

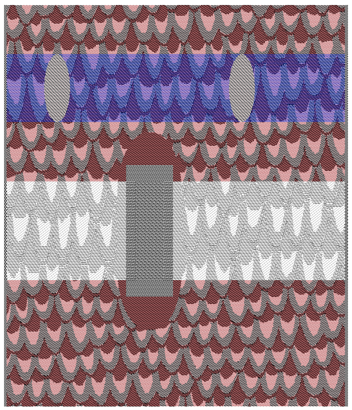

Figure 5: A pattern with UI

prototyping with eTextile materials, as well as the form-giving of the hand puppet, were carried out in cooperation with the multidisciplinary team. From the perspective of the eTextile design process, the key outcomes were the sensor validation, the final shape of the hand puppet and the placement of the sensors and wiring into the patterns of the object. Those were seen as prerequisites for the eTextile layout design, that also set the requirements for the chosen materials and the pattern design. Thus, the proposed user experience and interactions (shown in Table 1.) were a guideline for the eTextile design process, dominating the development of the technical solutions. That is also the point of departure of the woven construction development process, which aim was to integrate all of the outer layer sensors directly into the structure of the woven fabric and translate the desired user experience into jacquard weave patterns. Essential in this process was the reconstruction of the three-dimensional object into weaving files that consists the pattern of the object, and to understand the possibilities and limitations of the weaving technique.

eTextile development in practice

Weaving is a method of interlacing two separate set of yarns, warp and weft, to construct a fabric. The design process focuses on the development of a weave, which defines how the yarns are intersecting in the fabric. The skill of a textile designer thus is to determine a specific combination of yarns, yarn densities, binding points and dynamicity (i.e. how the yarns are allowed to move) to achieve a particular goal for the final textile.

First, the test samples of different kind of woven sensors were woven (see fig. 3) and tested to verify the suitable bindings and sensor structures of the user interface. Parallel with weaving the test sensors, a figurative jacquard pattern was designed and validated through woven samples of different bindings and colour scheme (see fig. 4). Next, the sensor structures and the jacquard pattern were synthesized into a complete eTextile layout design, and the pattern of the hand puppet served as a template, where those two merged (see fig. 5). The visual appearance of the hand puppet was designed to incorporate the user interface as an integrated part of the look and feel of the puppet (see fig. 6). The sensor structures and their placement became an apparent part of the design, and were either visually distinct from the pattern design, or blended into the design.

Location	Adult	Child
Outer Shell – Tummy	-	Tickling, hugging, pushing
Outer Shell – Hands	Clapping hands	Holding hand, ‘gimme-five’
Outer Shell – Cheeks	Putting hands on the cheeks	Stroking the cheek
Outer Shell – Back	-	Stroking the back
Inner Glove	Bending thumb / middle finger (waving, nodding)	-
Outer Shell + Inner Glove	Sobbing (bending middle finger, covering eyes with puppet’s hands)	-

Table 1: The interactions through the in-between eTextile hand puppet

Loom:
TC1 digital Jacquard loom

Warp:
Material: cotton
Density: 24 yarns / cm

Weft:
Material: linen, silver/polyamide

Density alters:
Pocket weave 84 yarns /cm
Capacitive and segmented slider sensors 63 yarns /cm
Jacquard design 42 yarns /cm

Weaves:
Pocket weave, 4/1 and 1/4 satin weave
Capacitive sensors and jacquard design, 7/1 and 1/7 satin weave

Table 2: The technical details of the woven prototypes

The user interface consists of four capacitive sensors (hands + cheeks), capacitive segmented slider sensor (back) and a piezoresistive pressure sensor (belly). The capacitive sensors and the segmented slider sensor are woven by using the *fil coupé*-technique, where the conductive yarn is interwoven into the jacquard pattern by using weft floats. The floating conductive weft forms the electrodes on the surface of the fabric, and the floats between the motifs are being cut after weaving. The pressure sensor applies a pocket weave structure (see fig. 7), where both layers contain an additional conductive weft system, and a piece of velostat is placed in between the layers before the pocket structure is completed during the weaving. For technical details of the materials and woven structures, see Table 2. The pocket weave structure of the pressure sensor functions well enough, even though the woven textile layers are able to move with respect to each other and the velostat decreases the friction even more. The velostat appears slightly resistant to movement, which mitigates the problematic movement. A structure with selected binding points connecting the layers together could provide a more durable outcome. While each of the textile elements used for the weaving of the overall structure itself are not novel, the combination is unique, especially so as an eTextile structure.

Our work also suggests ways to develop the textile structure towards more complex multilayer weaves, with respect to casing and pressure sensors. This direction is especially noteworthy, as it implies a controlled way to isolate or combine overlaid conductive layers concerning each other. One crucial element to consider when designing woven eTextile structures consisting of different materials and a varying number of layers is the density of the weft. The density varies depending on how many yarn systems are being applied throughout the design, including both electronic and non-electronic aspects. The first prototype, shown in Figure 6, contains woven sensor-areas; however, the signaling has been attached afterwards as a separate step.

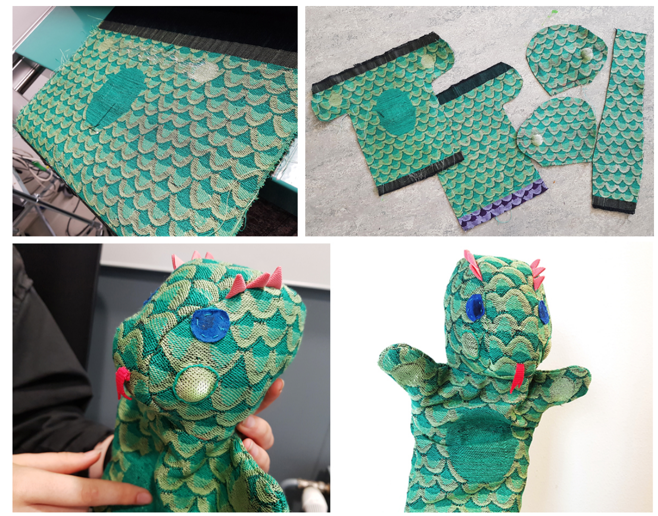

Figure 6: Constructing the prototype and the final prototype

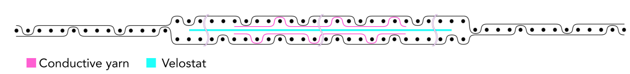

Figure 7: a cross-section of the pressure sensor structure

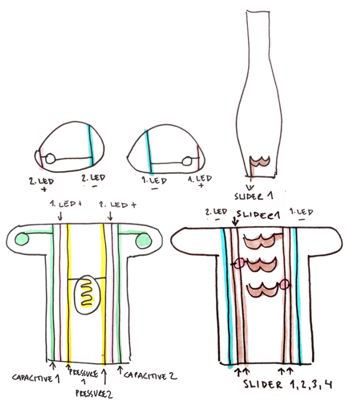

Figure 8: A sketch of the signal traces in textile patterns

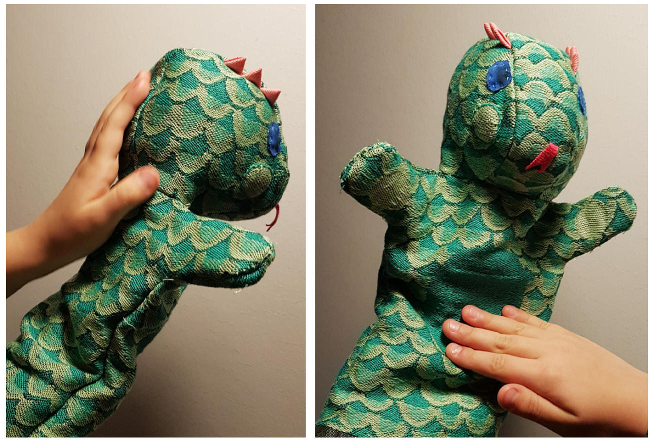

Figure 9: The Hand puppet as worn by an adult and interacted upon by a child

Final remarks

In this paper, a case of developing an interactive hand puppet was presented, and we have discussed an approach to woven eTextile layout design. The development and fabrication process of an eTextile layout design for the hand puppet was described, with an intent to further study the development of the role of an eTextile design practitioner. Next, the design process of an interactive hand puppet will be mapped against two design frameworks by Veja [14] and Sanders and Stappers [9], to understand better the role of the textile designer in a co-design process. This mapping aims at transdisciplinary method development. The next steps in the smart textile designer practice development will focus on a subsequent version of the woven hand puppet with the signalling built into the weave (see fig.8).

Furthermore, we aim to validate the woven prototypes and their user experience through user testing and technical structural analysis of the woven construction. What is in our interest is to better understand how the traditional textile design variables (e.g. look and feel) can be utilized in the user interface and -experience design. This future work will be conducted with a team of textile designer, an electrical engineer and an interaction designer. This work will push towards the inclusion of electrical components for textile design [3,7], and interfacing them within the textile design methodology drawn from this work.

We aim towards the synthesis of woven eTextile design, consisting of user interface design, pattern design, sensor structure design and textile layout design. How could a pattern be designed to be fully utilised in the user interface design? How the visual cues in the design or the different textures and material feels can support the use of the user interface? By tailoring hand puppet textiles to meet the user’s needs and desired user experience, the sphere of smart textile design practice will become more defined.

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References

[1] Paul Biedermann, Jekaterina Aleksejeva, Jussi Mikkonen, and Danielle Wilde. 2018. Sensepack: An In-between Wearable for Body-backpack Communication. *Proceedings of the 10th Nordic Conference on Human-Computer Interaction*, ACM, 922–927.

[2] Kunigunde Cherenack and Liesbeth van Pieterson. 2012. Smart textiles: Challenges and opportunities. *Journal of Applied Physics* 112, 9: 091301.

[3] Tilak Kithsiri Dias and Anura Rathnayake. 2017. Electronically Functional Yarns. Retrieved September 5, 2018 from https://worldwide.espacenet.com/publicationDetails/biblio?FT=D&date=20170928&DB=&locale=en_EP&CC=US&NR=2017275789A1&KC=A1&ND=4.

[4] Susan Marie Fairburn, Josie Steed, and Janet Coulter. 2016. Spheres of practices for the co-design of wearables. .

[5] Eva Hornecker. 2011. The Role of Physicality in Tangible and Embodied Interactions. *interactions* 18, 2: 19–23.

[6] Elaine Igoe. 2010. The tacit-turn: textile design in design research. *Duck Journal for Research in Textiles and Textile Design* 1: 1–11.

[7] Jussi Mikkonen and Emmi Pouta. 2016. Flexible Wire-Component for Weaving Electronic Textiles. *2016 IEEE 66th Electronic Components and Technology Conference (ECTC)*, 1656–1663.

[8] Michael Polanyi. 1966. *The Tacit Dimension*. Doubleday & Company, Inc., Garden City, New York.

[9] Ivan Poupyrev, Nan-Wei Gong, Shiho Fukuhara, Mustafa Emre Karagozler, Carsten Schwesig, and Karen E. Robinson. 2016. Project Jacquard: Interactive Digital Textiles at Scale. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, ACM, 4216–4227.

[10] M. M. Quirk, T. L. Martin, and M. T. Jones. 2009. Inclusion of Fabric Properties in the E-Textile Design Process. *2009 International Symposium on Wearable Computers*, 37–40.

[11] Erica Robles and Mikael Wiberg. 2010. Texturing the “Material Turn” in Interaction Design. *Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction*, ACM, 137–144.

[12] Elizabeth B.-N. Sanders and Pieter Jan Stappers. 2014. Probes, toolkits and prototypes: three approaches to making in codesigning. *CoDesign* 10, 1: 5–14.

[13] Donald A. Schön. 2017. *The Reflective Practitioner : How Professionals Think in Action*. Routledge.

[14] Matteo Stoppa and Alessandro Chiolerio. 2014. Wearable Electronics and Smart Textiles: A Critical Review. *Sensors* 14, 7: 11957–11992.

[15] Riikka Claire Townsend, Antti J. Karttunen, Maarit Karppinen, and Jussi Mikkonen. 2017. The Cross-section of a Multi-disciplinary Project in View of Smart Textile Design Practice. *Journal of Textile Design Research and Practice* 5, 2: 175–207.

[16] Louise Valentine, Jen Ballie, Joanna Bletcher, Sara Robertson, and Frances Stevenson. 2017. Design Thinking for Textiles: let’s make it meaningful. *The Design Journal* 20, sup1: S964–S976.

[17] Priti Veja. 2014. An investigation of integrated woven electronic textiles (e-textiles) via design led processes. Retrieved from http://bura.brunel.ac.uk/handle/2438/10528.

[18] Mikael Wiberg. 2016. Interaction, new materials & computing – Beyond the disappearing computer, towards material interactions. *Materials & Design* 90: 1200–1206.

[19] Smart Textiles Design Lab Blog » Archive » Involving the Machines. Retrieved November 14, 2018 from http://stdl.se/?p=2024.