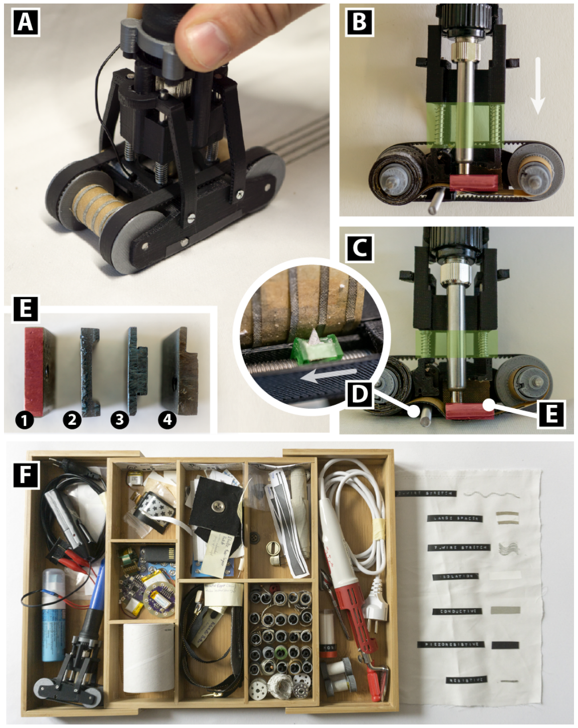

Figure 1: Rapid Iron-On User Interfaces constitute a new fabrication approach for textile prototypes. By using a handheld ironing tool for applying adhesive functional tapes and patches, the designer can create rich interactive functionality in a fast and intuitive sketching-like manner.

Demonstrating Rapid Iron-On User Interfaces: Hands-on Fabrication of Interactive Textile Prototypes

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Abstract
Rapid prototyping of interactive textiles is still challenging, since manual skills, several processing steps, and expert knowledge are involved. We demonstrate *Rapid Iron-On User Interfaces*, a novel fabrication approach for empowering designers and makers to enhance fabrics with interactive functionalities. It builds on heat-activated adhesive materials consisting of smart textiles and printed electronics, which can be flexibly ironed onto the fabric to create custom interface functionality. To support rapid fabrication in a sketching-like fashion, we developed a handheld dispenser tool for directly applying continuous functional tapes of desired length as well as discrete patches. We demonstrate versatile compositions techniques that allow to create complex circuits, utilize commodity textile accessories and sketch custom-shaped I/O modules. We further provide a comprehensive library of components for input, output, wiring and computing. Three example applications demonstrate the functionality, versatility and potential of this approach.

Author Keywords
Electronic Textile; Smart Fabric; Wearable User Interface; Rapid Prototyping; Fabrication; Iron-On; Tapes; Patches;

CCS Concepts
•**Human-centered computing** → *Interaction devices; Interaction techniques; User interface toolkits;*

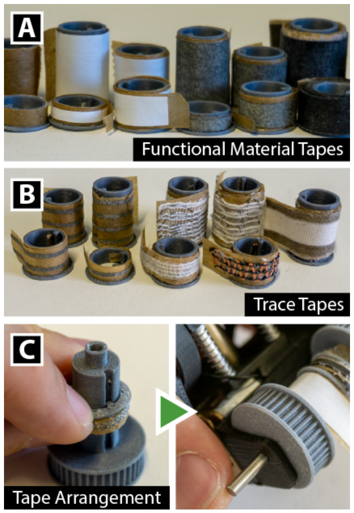

Figure 2: Customizable Tapes.

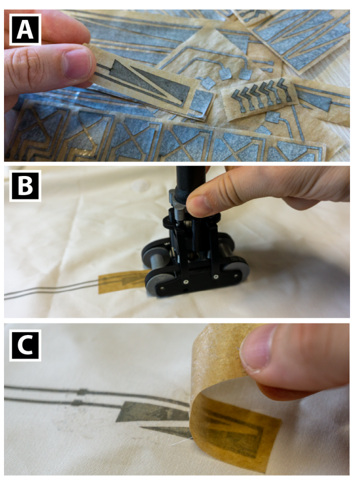

Figure 3: RIO Patches.

Introduction

Recent developments in e-textiles and miniaturized electronics are fueling a new generation of wearable user interfaces which are deeply weaved into garments and other fabrics. Their ergonomics, softness, direct reachability and close body contact, alongside other benefits, make them an outstanding platform for mobile computing and interaction. While these textile innovations are on the advance, it remains open how to support designers and makers with tools to create, iterate and evaluate functional prototypes at an early stage. Unfortunately, the fabrication of textile interfaces on the yarn-level is commonly time-consuming and cumbersome when done manually. Automatizing these processes would require machinery and knowledge typically outside the realm of a prototyping space.

Our goal is to accelerate rapid prototyping of smart textiles and to considerably simplify their design process, particularly in the early design stage. We present *Rapid Iron-On (RIO) User Interfaces*, a novel approach for rapid fabrication of custom interactive textile prototypes in a sketching-like fashion [3]. Inspired by the simplicity and versatility of package and sewing tapes as well as textile stickers and patches, our approach is based on functional textile adhesive tapes and patches that each implement a specific functionality. By introducing a handheld ironing tool that combines the dispensing and bonding of various functional materials into a single, rapid and consistent process, our approach introduces an additive fabrication concept to *physically sketch and compose* functional electrical circuits and versatile interface functionalities directly onto textiles.

Background and Related Work

Previous research on electronic textiles has investigated several functional fabrics to integrate electrical circuits and I/O modules including stretch, touch, and pressure input. Depending on the material and intended purpose, different *yarn-based* or *additive* manufacturing processes are required. While the results have a high degree of integration, machines used in textile industries are typically inaccessible for designers and maker and often incompatible with low volume prototyping. They also require specialized skills, knowledge and production time. In order to make textile prototyping accessible for a broader audience, a body of research has been conducted to either contribute *new fabrication techniques for e-textile prototyping*, like Sketch&Stitch [2], or provide plug-and-play *wearable construction toolkits*. For instance, the LilyPad allows to easily connect electronics components with conductive yarns. As an alternative to e-sewing, Buechley et al. [1] also introduced fabric PCBs consisting of laser-cut conductive fabric and iron-on adhesive to integrate traditional electronics and novel textile sensors. In addition, zPatch [4] uses laser-cut functional fabrics to provide hybrid resistive and capacitive e-textile input. We have taken inspiration from this early work (see [3] for a more detailed account) that laid the foundations for ironing conductive fabrics onto garments.

For our work, we wanted to build on iron-on approaches since they allow for ease of use, low costs and versatile opportunities while probably offering far more fabrication possibilities than those currently described in the literature.

The Rapid Iron-On Concept

With our novel Rapid Iron-On prototyping principle for e-textiles, we present a system that allows to physically "sketch" user interfaces in a hands-on manner directly onto textiles. Our approach builds on functional textiles, as continuous tapes (see Figure 2, A+B) or discrete patches (see Figure 3, A), which comprise heat-activated adhesive to be easily ironed onto a base textile. Those patches are made of smart fabrics and printed thin-film technologies, offering a rich variety of electronic functions while preserving

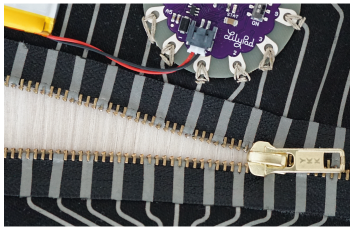

Figure 4: Reversible Zipper.

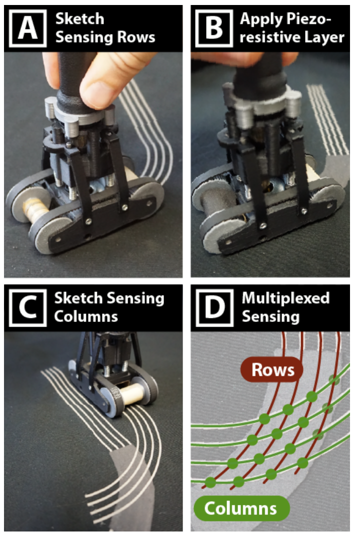

Figure 5: Pressure Touch Matrix.

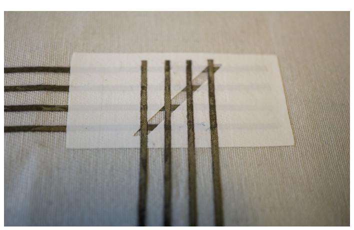

Figure 6: Connection Patch.

soft and flexible properties. A new handheld iron tool (see Figure 1, A) allows the designer to rapidly add functional patches on textiles, similarly to sketching with a pen. For instance, she can create conductive traces with desired properties by "drawing" lines, and can add functional patches for specific I/O functionality, circuit design, power supply, etc. By flexibly combining, layering and juxtaposing, she can create custom interfaces with rich digital functionalities.

RIO Tool: To allow designers to rapidly apply functional tapes (see Figure 2) and patches (see Figure 3), we develop a handheld device that is capable of directly dispensing and iron-bonding materials at the same time (see Figure 1, A-E). It allows to dispense continuous functional material rolled on spools directly onto the fabric (A) by pressing down (B+C) and moving the device, similar to the way one sketches with a pen. Spring-loaded exchangeable irons (E) transfers the heat-adhesive tape by pressing and moving the device to the fabric while a small blade (D) cuts the tape materials. The tool also supports an iron-only mode to quickly bond discrete patches (see Figure 3). Our technical realization builds on 3D-printed parts, a modified soldering iron, two timing belts, a blade and exchangeable spools[1].

Material Stack: RIO tapes and patches consist of three layers: An *adhesive layer* (1) using iron-on fusible web to bond it to the base textile, a *functional layer* (2) with a wide range of functional (e.g., laser-cut conductive or resistive fabric, electroluminescence (EL) or SMD electronics) and also non-functional (e.g., isolating) materials, and a *carrier Layer* (3) for holding the layout of functional material in position until it is actually transferred to the textile.

Composition Techniques

By using tapes and patches, the Rapid Iron-On (RIO) fabrication approach enables a variety of techniques:

[1] All technical details are available online: https://www.imld.de/rio/

Arranging: Functional tapes can be combined with patches that are placed at the required position, ironed-on and then electrically connected in one stroke (Figure 3). While tapes can be arranged side by side manually (Figure 2, C), there are cases where a certain arrangement is needed.

Layering: The RIO approach also supports versatile layering options to *create new functionalities* (e.g., shielded traces, multi-layer circuits or custom-shaped sensors by ironing multiple material layers on each other as shown in Figure 5) or *to combine existing functions* by ironing functional modules one above the other (e.g., combining visual output and touch tapes at the same position). Since our materials are ultra-thin and flexible, the capability of layering is one of the major advantages over existing approaches that use yarn or threads to isolate or extend conductors.

Utilizing Textile Accessories: Finally, the approach also enables the digital enhancement of existing textile accessories like zippers (see Figure 4) that serve as a physical connection or shirt buttons (Figure 7, C) that act as joystick by ironing a four-electrode capacitive patch underneath.

Traces

The flexibility to create conductive traces of custom length, direction and shape is a primary requirement. Moreover, traces are characterized by various additional properties for customization: level of *conductivity*, *number of parallel wires* (e.g., as required for bus systems), presence or absence of *electrical shielding*, *strechability*, and its *connector pitches*. We demonstrate how our iron-on device works in concert with iron-on trace spools to create basic conductive traces or traces with advanced multi-wire, elastic, and shielded properties. We further present methods to create, connect (see Figure 6) and delete complex trace designs and realize custom-shaped sensor matrices (see Figure 5).

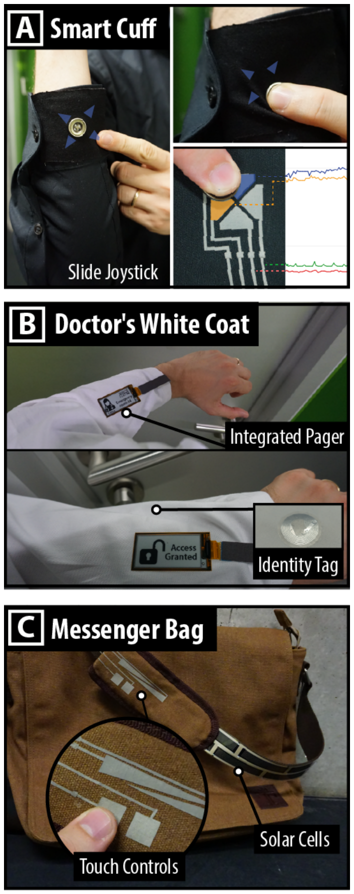

Figure 7: Example Applications: Elastic Smart Cuff button at the cuff (A), Doctor's White Coat with identification and e-ink patch (B) and a Messenger Bag (C) with solar cells, touch controls, interior lights as well as moisture sensors.

Library of Components

To demonstrate the feasibility of integrating various functional textile materials, printed electronics components and flexible PCBs inside iron-on tapes and patches, we present a repertoire of RIO components (see Figure 1, F) that allows us to leverage on a rich set of established principles for building functional iron-on modules. We contribute a comprehensive library of components, both in tape and patch form factors, that offer support for on-textile *input* (e.g., touch, pressure), *output* (e.g., EL, E-Ink), *wiring*, *energy supply* (solar cells) and *computing* (flex PCBs).

Example Applications

To demonstrate the versatility of the RIO fabrication approach, we realized three example applications (Figure 7):

Smart Cuff (A): We demonstrate how existing garments can be easily augmented using functional iron-on patches. Therefore, we iron-on a four-way button patch underneath a existing metal button. The result is an interactive slide joystick button that can be slightly displaced in all directions and snaps back elastically. The position sensing is realiuzed by measuring the capacitive change. The user can switch between slides by moving the button back and forth.

Doctor's White Coat (B): Demonstrates how advanced electronics can be integrated by ironing. The coat helps medical staff to quickly get access to secured areas by using a sleeve-integrated RFID patch for quick identification. Further, it contains an e-ink patch that show visual notifications.

Interactive Messenger Bag (C): Shows how complex textile products with non-planar surfaces can be enhanced. We integrated various smart functions including interior lights that illuminate when the bag is open, moisture sensors at the bag's bottom that notify when a bottle leaks, generic buttons and slider controls at the shoulder pad for controlling a music player, and solar cells for power harvesting.

Conclusion & Future Work

We presented *RIO User Interfaces* that allow to enhance fabrics with digital functionalities for textile prototypes. Therefore, we introduced iron-on tapes and patches, that are made of functional materials and thin-film printed electronics, and demonstrated how a handheld dispenser tool enables rapid fabrication in a sketching-like fashion. We further demonstrated the versatility of our toolkit by implementing applications for ubiquitous and wearable computing. For future work, we plan to run workshops in design schools.

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REFERENCES

[1] Leah Buechley and Michael Eisenberg. 2009. Fabric PCBs, Electronic Sequins, and Socket Buttons: Techniques for e-Textile Craft. *Personal Ubiquitous Comput.* 13, 2 (Feb. 2009), 133–150. DOI: http://dx.doi.org/10.1007/s00779-007-0181-0

[2] Nur Al-huda Hamdan, Simon Voelker, and Jan Borchers. 2018. Sketch&Stitch: Interactive Embroidery for E-textiles. In *Procs. of CHI'18*. 82:1–82:13. DOI: http://dx.doi.org/10.1145/3173574.3173656

[3] Konstantin Klamka, Raimund Dachselt, and Jürgen Steimle. 2020. Rapid Iron-On User Interfaces: Hands-on Fabrication of Interactive Textile Prototypes. In *Procs. of CHI '20*. DOI: http://dx.doi.org/10.1145/3313831.3376220

[4] Paul Strohmeier, Jarrod Knibbe, Sebastian Boring, and Kasper Hornbæk. 2018. zPatch: Hybrid Resistive/Capacitive eTextile Input. In *Procs. of TEI '18*. DOI: http://dx.doi.org/10.1145/3173225.3173242