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

Konstantin Klamka¹, Raimund Dachselt¹,², Jürgen Steimle³

¹ Interactive Media Lab Dresden, Technische Universität Dresden, Germany
² Centre for Tactile Internet with Human-in-the-Loop (CeTI), Technische Universität Dresden, Germany
³ Human Computer Interaction Lab, Saarland University, Saarland Informatics Campus, Saarbrücken, Germany
Emerging E-Textiles

Recent advances are bringing a new generation of wearable user interfaces that are deeply integrated.
Maker & Innovators

- Great technical skills
- Capabilities to innovate and prototype
E-Textile Prototyping

- quite time-consuming
-cumbersome when done manually
Fashion Designer

- Require toolkits at early design stages
- Did not have access to textile expert machinery and knowledge
E-Textile Prototyping

- Automation requires expert machinery and knowledge
- Typically outside the realm of a prototyping space.
Smart Materials & Printed Electronics

- Conductive or (piezo-)resistive textiles & fabrics
- An emerging variety of (semi-)flexible printed electronics

But how can we develop a new fabrication toolkit for this class of emerging materials?
Tape Dispenser

- Sketching-like interaction
- Transfers a pre-manufactured film onto another surface
Rapid Iron-On User Interfaces

Our Main Contributions

- Novel Fabrication Technique combines design and fabrication into a single process
Rapid Iron-On User Interfaces

Our Main Contributions

- **Novel Fabrication Technique**
  combines design and fabrication into a single process

- **Handheld Ironing Tool**
  allows sketching and composing
Rapid Iron-On User Interfaces

Our Main Contributions

- **Novel Fabrication Technique** combines design and fabrication into a single process
- **Handheld Ironing Tool** allows sketching and composing
- **Library of Components** consisting of tapes and patches
Rapid Iron-On User Interfaces

Our Main Contributions

- **Novel Fabrication Technique**
  combines design and fabrication into a single process

- **Handheld Ironing Tool**
  allows sketching and composing

- **Library of Components**
  consisting of tapes and patches

- **Application Examples**
Rapid Iron-On User Interfaces

Our Main Contributions

- Novel Fabrication Technique combines design and fabrication into a single process
- Handheld Ironing Tool allows sketching and composing
- Library of Components consisting of tapes and patches
- Application Examples
- Technical Experiments & Expert Reviews
Related Work

1. **LilyPad Arduino**
   Buechley et al.,
   ACM CHI ’08

2. **Fabric PCBs**
   Buechley & Eisenberg,
   Personal and Ubiquitous Computing ’09

3. **Kit-of-no-parts**
   Perner-Wilson et al.,
   ACM TEI ’11

4. **Schnittmuster**
   Meissner et al.,
   ACM CHI ‘18
Related Work

1. **i*Catch**
   *Ngai et al.*
   *ACM CHI ’10*

2. **MakerWear**
   *Kazemitabaar et al.,
   *ACM CHI ’17*

3. **zPatch**
   *Strohmeier et al.,
   *ACM TEI ’18*

4. **BodyHub**
   *Peetz et al.*
   *ACM UIST EA ’19*

Modular Wearable Toolkits
Related Work

1. **Project Jacquard**  
Poupyrev et al., ACM CHI ’16

2. **SmartSleeve**  
Parzer et al., ACM UIST ’17

3. **RESi**  
Parzer et al., ACM UIST ’18

4. **Soft Inkjet Circuits**  
Khan et al., ACM UIST ’19

Advanced Fabrication & Sensing
Related Work

1. **ShapeTape**  
   Grossman et al.  
   ACM CHI ’03

2. **TouchTape**  
   Wimmer & Baudisch  
   ACM UIST ’11

3. **SensorTape**  
   Dementyev et al.,  
   ACM UIST ’15

4. **AMOHR Tapes**  
   Christoph Mohr  
   https://www.amohr.com

**Smart Tapes**
Related Work

1. Interactive Fabrication
   Willis et al., ACM TEI ’11

2. Interactive Construction
   Mueller et al. ACM UIST ’12

3. Sketch&Stitch
   Hamdan et al. ACM CHI ’18

Interactive Fabrication & Construction
How the material spools are constructed?
Iron-On Material Stack

1. Carrier Layer
2. Functional Layer
3. Adhesive Layer
Iron-On Material Stack

1. Carrier Layer
2. Functional Layer
3. Adhesive Layer
Iron-On Material Stack

1. Carrier Layer
2. Functional Layer
3. Adhesive Layer
Iron-On Material Stack

1. Carrier Layer
2. Functional Layer
3. Adhesive Layer
What can we do with the Rapid Iron-On Tool?
Traces & Circuits

Actions
- Create
- Connect
- Bridge
- Delete
- Sensor

Properties
- Highly-Conductive
- Arrangement
- Shielding
- Stretchability
- Multi-layer
Standard Traces in different sizes

Stretchable Traces in different sizes
Material: Shieldex, Zell - RS
Conductivity: 0.1Ω / 1cm
Thickness: 110μm
Pitch: 5.08mm
Trace Width: 1.50mm
- **Design**: horse-shoe pattern
- **Elasticity**: up to 40 %
- **Material:** sandwiched ultra-thin dialectic and conductive fabrics
- **Thickness:** 350μm
- **Usage:** CapSense, Antennae
- Single-Wire Traces ...

... can be easily connected by ironing on each other.
*Single-Wire Traces...*

... can be easily connected by *ironing on each other*. In addition, there is *no change in resistance*.
But how to realize angles and crossings for multi-wire traces?

- **Single-Wire Traces**
  ... can be easily connected by ironing on each other.
  In addition, there is no change in resistance.

- **Multi-Wire Traces**
  ... can be extended in the same direction if the user aligns the front axis to the existing one.
  ▶️ But how to realize angles and crossings for multi-wire traces?
Angles and Crossings for Multi-Wire Traces

1. Place
2. Iron-on
3. Peel-off
4. Insert trace spool
5. Sketch traces
6. Check Connectivity
Angles and Crossings for Multi-Wire Traces

1. Place
2. Iron-on
3. Peel-off
4. Insert trace spool
5. Sketch traces
6. Check Connectivity
Angles and Crossings for Multi-Wire Traces

1. Place
2. Iron-on
3. Peel-off
4. Insert trace spool
5. Sketch traces
6. Check Connectivity
Angles and Crossings for Multi-Wire Traces

1. Place
2. Iron-on
3. Peel-off
4. Insert trace spool
5. Sketch traces
6. Check Connectivity
Angles and Crossings for Multi-Wire Traces

1. Place
2. Iron-on
3. Peel-off
4. Insert trace spool
5. Sketch traces
6. Check Connectivity
Angles and Crossings for Multi-Wire Traces

1. Place
2. Iron-on
3. Peel-off
4. Insert trace spool
5. Sketch traces
6. Check Connectivity
But what about reversible connections?
Washability

Exchangeability
Spool Materials

- transfer
- isolation
- conductive
- piezoelectric
- resistive
- Custom Pressure-Touch Sensing Matrix

Sketch rows
Sketch piezoelectric
Sketch columns
Sensor result
Composition Techniques

Arranging

- Arrange different spools

Layering

- Multi-layer tapes
- Multi-layer circuits

Utilizing Textile Accessories

- Dual-used zipper
Library of Components

- Input
  - Pressure
  - Deformation
  - Identify

- Output
  - Light
  - Displays

- Actuation
- Solar Cells

- Computing
- Inductive Charging

- Wiring
  - Fabric Resistors
  - Breakouts
  - Semi-Flex MCUs
**Touch: Buttons & Sliders**

Example how to integrate capacitive user controls
Force: Pressure & Bend
Example how to integrate resistive sensors

Conductive

Piezoelectric

Conductive
Identify: NFC Tags

Example how to integrate existing printed electronics components
How to iron semi-flex SMD electronics?
Iron-on SMD-LED tape

U-shaped iron heats only edges
Heating Components

Resistive Heating Patch

Resistive Heating Tape
Printed Organic Solar Cells

Example how to integrate existing printed electronics components

- **Cuttable**: at any position
- **Thickness**: 150μm
- **Voltage**: 8-9V / m
- **Power**: 40-50mA / m
Example Applications

1. Smart Cuff
   - *slide joystick patch*
   - demonstrates how *existing garments* can be easily augmented using functional patches.
Example Applications

1. **Smart Cuff**
   - slide joystick patch
   - demonstrates how *existing garments* can be easily augmented using functional patches.

2. **Doctor’s White Coat**
   - NFC tag, e-ink display
   - demonstrates how *advanced electronics* can be easily integrated by ironing.
**Example Applications**

1. **Smart Cuff**
   - NFC tag, e-ink display
   - Demonstrates how *existing garments* can be easily augmented using functional patches.

2. **Doctor’s White Coat**
   - Bend Sensor
   - Demonstrates how *advanced electronics* can be easily integrated by ironing.

3. **Interactive Messenger Bag**
   - Bend sensor, capacitive controls, SMD-LEDs, zip-on electronics, solar tapes, moisture sensor
   - Demonstrates how *complex textile products* with non-planar surfaces can be enhanced with smart functions.
Expert Reviews

Textile Design Expert (P1)
Co-director of the textile & materials design department of an internationally recognized French design university.

Fashion Design Expert (P2)
Has expertise in practice-based and design-led research investigating tailoring.

Machinery & Fiber Expert (P3)
Research associate working at a large textile machinery research institute in Germany

Approx. 60 min. per session
Semi-structured interview
Hands-on sessions
Interviews & Hands-On Insights

Textile & Fashion Experts

» The iron-on roll & patch approach is in-between large-scale production and manual crafting – this makes absolutely sense «

» ... important to work from the beginning with final materials to consider the visual and sensory qualities in the whole design process. «

Machinery & Fiber Expert

... compared the rapid iron-on approach with other e-textile solutions like embroidery and knitting:

- Production time
- Required knowledge
+ Costs

- Comparable in the scope of functionality
- Durability
- Degree of integration
Conclusion
Rapid Iron-On User Interfaces

- Novel Fabrication Technique for E-Textiles
- Handheld Ironing Tool
- Library of Components
- Example Applications
- Technical Experiments & Expert Reviews
Rapid Iron-On User Interfaces: Hands-on Fabrication of Interactive Textile Prototypes

Konstantin Klamka, Raimund Dachselt, Jürgen Steimle

Questions?  
klamka@acm.org

Project Website  
imld.de/RIO
References (1/5)
(sorted in the order of appearance in the presentation)

Leah Buechley, Mike Eisenberg, Jaime Catchen, and Ali Crockett.
The LilyPad Arduino: Using Computational Textiles to Investigate Engagement, Aesthetics, and Diversity in Computer Science Education.
ACM, New York, NY, USA, 423–432. DOI: http://dx.doi.org/10.1145/1357054.1357123

Leah Buechley and Michael Eisenberg.
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

Hannah Perner-Wilson, Leah Buechley, and Mika Satomi.
Handcrafting Textile Interfaces from a Kit-of-no-parts.
In Proceedings of the Fifth International Conference on Tangible, Embedded, and Embodied Interaction (TEI ’11).
ACM, New York, NY, USA, 61–68. DOI: http://dx.doi.org/10.1145/1935701.1935715

Janis Lena Meissner, Angelika Strohmayer, Peter Wright, and Geraldine Fitzpatrick.
A Schnittmuster for Crafting Context-Sensitive Toolkits.
ACM, New York, NY, USA, Article 151, 151:1–151:13 pages. DOI: http://dx.doi.org/10.1145/3173574.3173725
Grace Ngai, Stephen C.F. Chan, Hong Va Leong, and Vincent T.Y. Ng.  
**Designing I*CATch: A Multipurpose, Education-friendly Construction Kit for Physical and Wearable Computing.**  

Majeed Kazemitabaar, Jason McPeak, Alexander Jiao, Liang He, Thomas Outing, and Jon E. Froehlich.  
**MakerWear: A Tangible Approach to Interactive Wearable Creation for Children.**  

Paul Strohmeier, Jarrod Knibbe, Sebastian Boring, and Kasper Hornbæk.  
**zPatch: Hybrid Resistive/Capacitive eTextile Input.**  

Andreas Peetz, Konstantin Klamka, and Raimund Dachselt.  
**BodyHub: A Reconfigurable Wearable System for Clothing.**  
In The Adjunct Publication of the 32Nd Annual ACM Symposium on User Interface Software and Technology (UIST ’19). ACM, New York, NY, USA, 39–41. DOI: http://dx.doi.org/10.1145/3332167.3357108
References (3/5)  
(sorted in the order of appearance in the presentation)

Project Jacquard: Interactive Digital Textiles at Scale.  
ACM, New York, NY, USA, 4216–4227. DOI: http://dx.doi.org/10.1145/2858036.2858176

SmartSleeve: Real-time Sensing of Surface and Deformation Gestures on Flexible, Interactive Textiles, Using a Hybrid Gesture Detection Pipeline.  
ACM, New York, NY, USA, 565–577. DOI: http://dx.doi.org/10.1145/3126594.3126652

RESi: A Highly Flexible, Pressure-Sensitive, Imperceptible Textile Interface Based on Resistive Yarns.  
ACM, New York, NY, USA, 745–756. DOI: http://dx.doi.org/10.1145/3242587.3242664

Arshad Khan, Joan Sol Roo, Tobias Kraus, and Jürgen Steimle.  
Soft Inkjet Circuits: Rapid Multi Material Fabrication of Soft Circuits Using a Commodity Inkjet Printer.  
In Proceedings of the 32th Annual ACM Symposium on User Interface Software and Technology (UIST ’19). DOI: http://dx.doi.org/10.1145/3332165.3347892
**An Interface for Creating and Manipulating Curves Using a High Degree-of-freedom Curve Input Device.**  

Raphael Wimmer and Patrick Baudisch.  
**Modular and Deformable Touch-sensitive Surfaces Based on Time Domain Reflectometry.**  

Artem Dementyev, Hsin-Liu (Cindy) Kao, and Joseph A. Paradiso.  
**SensorTape: Modular and Programmable 3D-Aware Dense Sensor Network on a Tape.**  

AMOHR Technische Textilien GmbH.  
**Conductive Tapes and Textile Sensors.**  
https://www.amohr.com
**Interactive Fabrication: New Interfaces for Digital Fabrication.**  

Stefanie Mueller, Pedro Lopes, and Patrick Baudisch.  
**Interactive Construction: Interactive Fabrication of Functional Mechanical Devices.**  

**Sketch&Stitch: Interactive Embroidery for E-textiles.**  
Image Sources

(sorted in the order of appearance in the presentation)

1. **Jacquard by Google - Levi’s® - Google ATAP**
   https://atap.google.com/jacquard/

2. **2019 WRAPUP: MAKEFASHION AT BEAKERHEAD SPECTACLE, PRESENTED BY CALGARY ARTS DEVELOPMENT**

3. **Kenya Engineer - Managing Fire Disasters**

4. **University of Borås - Smart textiles makes robots move**

5. **ANTELOPE Sportswear – Muscle Activating Smartsuit**
   https://www.antelope.de/
   Photo: https://thegadgetflow.com/portfolio/antelope-sportswear-muscle-activating-smartsuit/

6. **Lee Myung Su Design Lab - SEIL bag**

7. **Fab Lab Vestmannaeyjar Iceland**
   Photo: © by Frosti Gísason / Saethor Vido: http://designingreality.org/images/fablabs.jpg

8. **Lee Myung Su Design Lab - SEIL bag**