Knitted RESi: A Highly Flexible, Force-Sensitive Knitted Textile Based on Resistive Yarns

Andreas Pointner, Thomas Preindl, Sara Mlakar, Roland Aigner, Michael Haller
mi-lab@fh-hagenberg.at
Media Interaction Lab, University of Applied Sciences Upper Austria

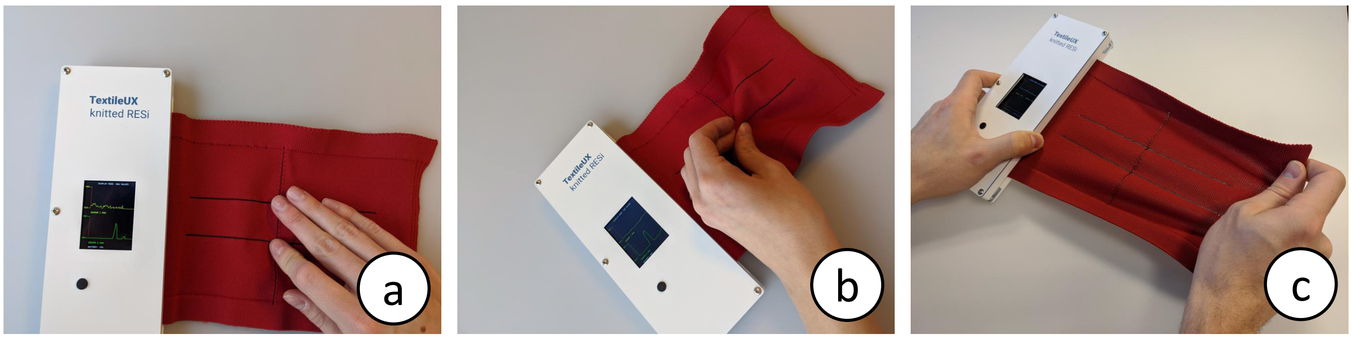

Figure 1: With Knitted RESi, we present a force-sensing flexible textile, based on piezo-resistive yarn. The textile enables to sense applied external stress, such as pressure (a), deformation, (b), and pull (c).

ABSTRACT

We demonstrate a force sensing knitted textile, based on a piezo-resistive yarn. The resulting elastic, stretchable, and robust textile exhibits sensors based on the widespread Force Sensitive Resistor (FSR) principle. As a proof-of-concept, we implemented a knit consisting of multiple piezo-resistive wales, each intersecting with a single vertical piezo-resistive insert, spawning discrete FSRs at the respective intersection points. While enabling monitoring of external stress, such as pressure, stretch, and deformation, the textile features inherent pleasant haptic qualities.

CCS CONCEPTS

• **Human-centered computing** → **Interaction devices**; **Haptic devices**.

KEYWORDS

Interactive Textiles, Textile Sensor, Wearables, Smart Textiles, Conductive Yarn, FSR

ACM Reference Format:
Andreas Pointner, Thomas Preindl, Sara Mlakar, Roland Aigner, Michael Haller. 2020. Knitted RESi: A Highly Flexible, Force-Sensitive Knitted Textile Based on Resistive Yarns. In *Proceedings of SIGGRAPH '20: Emerging Technologies (SIGGRAPH'20).* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/XXXXXXX.XXXXXXX

SIGGRAPH'20, July 19–23, 2020, Washington, D.C., USA

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00
https://doi.org/10.1145/XXXXXXX.XXXXXXX

1 INTRODUCTION

For millennia, textiles make up an essential and indispensable part of human's lives. Due to their favourable properties of being lightweight, highly flexible, and comfortable on skin, they are applied in a wide range of use cases. Nowadays, textiles can be augmented by electronic components, to gain additional capabilities for input and output, including sensing, actuation, lighting, etc.

We strongly believe that textiles can be used to fundamentally transform a range of everyday objects and provide new and exciting possibilities that are otherwise difficult or impossible to realize. Our primary goal is to create interactive textiles capable of sensing both pressure and deformation input in real-time. The technical foundation of our implementation is the usage of a conductive yarn with piezoresistive coating [4], we term RESi (RESistive textile Interfaces) yarn.

Our RESi yarn comprises a conductive metal core (copper-silver alloy with a diameter of 50 µm) with a coating (15 µm) by an organic polymer solution, containing conductive carbon-based particles. Whenever external stress is applied at intersecting yarns, the coating is compressed, consequently compacting conductive particles in the coating (cf. Figure 2), which corresponds to a change in electrical resistance.

2 RELATED WORK

Concepts for pressure sensing in the context of fabric have been explored and developed for a huge variety of applications. Tactile pressure sensing on fabric has been achieved through capacitive [3, 6], resistive [2, 5], and optical [8] methods. Resistance-based force sensors have been in use for over thirty years and can be easily implemented in textiles by stacking multiple layers. Rofouei et al. implemented a smart textile composed of an array of pressure

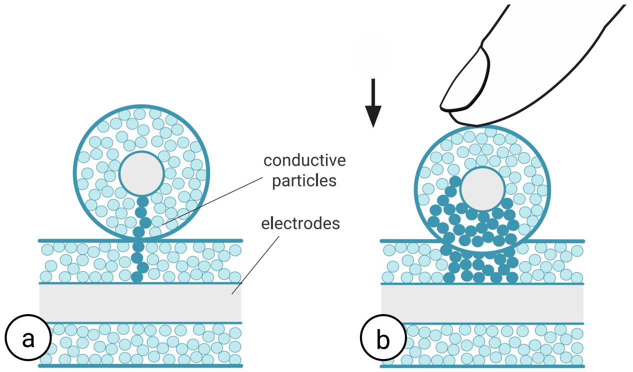

Figure 2: We use conductive yarn with piezo-resistive coating (a), which enables sensing of stress wherever traces of this yarn intersect (b).

sensors, by sandwiching a resistive textile in between of two conductive layers [7]. Numerous related projects employ this method, including SmartMat, eCushion, SimpleSkin, and FlexTiles [5].

3 KNITTED TEXTILE SENSORS

Stretchable woven textiles require elastic yarn (e.g. elastane core in combination with a twisted non-elastic fiber). In contrast, knits provide excellent elastic and tear-resistant behaviour, even though the yarn itself is typically non-elastic. Our proof-of-concept implementation, exhibits a fully knitted solution by intersecting two wales with a single vertical insert, cf. Figure 1. The textile itself was manufactured with an industrial 5 gauge flat-bed knitting machine (Shima Seiki SWG091N2 5G). As a yarn we used a 12×80 µm RESi yarn ply as presented in [4]. Figure 3 (a-b) shows the right and wrong sides of the implemented result. Note that our concept can be easily extended beyond two discrete pressure points.

Beyond the implementation we showed, our system is capable of operating an 8×8 sensor matrix. A shift register applies voltage to individual rows, while a multiplexer sequentially connects each column to an ADC via a voltage divider. We acquire and process the sensor data at 100 Hz using an ESP32 microcontroller, optionally forwarding the data wirelessly to a computing device at the edge for further processing, analysis, and utilization.

4 CONTRIBUTIONS AND LIMITATIONS

A valuable property of a knit is elasticity; consequently, beyond the implications on durability, stretching is a promising input modality we will further investigate. In our experiments, we found that stretch-based input is particularly easy to read, when compared to pressure, which depends on solid, uniform, and consistent support. In contrast to coating or polymerization [1], we can easily implement complex custom patterns at loop level and control the sensors' performance according to our requirements. Finally, the design and implementation of our knitted textile supports multiple input modalities, including continuous touch-input as well as deformation, such as stretch and wrinkle.

At SIGGRAPH 2020 Emerging Technologies exhibition we will demonstrate our Knitted RESi all-in-one prototype systems with

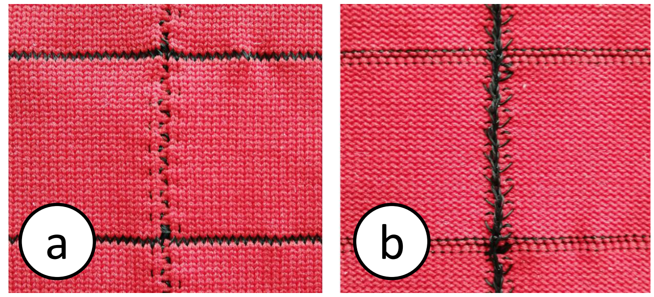

Figure 3: Right (a) and wrong side (c) of our knit textile sensor prototype. Two intersection points of RESi yarn (black) are created by two wales and one orthogonal insert, resulting in two distinct pressure sensors on the elastic fabric.

incorporated electronics for measurement and display via an embedded 2.2" TFT LCD display. Attendees will be encouraged to experience them first hand and get a sense of the notable haptic quality and durability of our knit sensor. Furthermore, example applications will be provided (both embedded and on a PC connected via Bluetooth), highlighting and demonstrating valuable sensor characteristics, such as low activation threshold and high dynamic range.

ACKNOWLEDGMENTS

This research is part of the COMET project TextileUX (No. 865791, which is funded within the framework of COMET - Competence Centers for Excellent Technologies by BMVIT, BMDW, and the State of Upper Austria. The COMET program is handled by the FFG.

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