SimpleSkin: Towards Multipurpose Smart Garments

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Ubicomp/ISWC'15 Adjunct, September 7-11, 2015, Osaka, Japan.
ACM 978-1-4503-3575-1/15/09.
http://dx.doi.org/10.1145/2800835.2800935

Abstract
Smart textiles have been researched in the lab over the last 20 years. However, the gap between research and available mass-market products is huge. We identify challenges that are the core reasons for this gap. To tackle these challenges, we present our work towards a multipurpose smart textile with different sensing modalities. It separates the concern of developing textiles, electronics, infrastructure, and applications. Furthermore, it uses a similar application model as current smart-phones allowing developers to create applications for the smart textiles. We believe that this approach is capable of moving smart textiles from niche to mainstream.

Author Keywords
Smart Textiles; System Prototype.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

Introduction
Many different prototypes of smart textiles have been developed in research projects over the last 20 years. The prototypes demonstrate the feasibility of creating smart garments that act as sensors as well as actuators. Different smart textiles have been realized that can be

used for different applications, for example, monitoring vital signs [3], supporting user's while shopping [7], providing further information to tourists [8], or simply serve as an input device [4]. However, smart textiles are not yet widely available and very few smart garments are available in the consumer market. Looking at the examples created in the lab as well as at products available, we see the following reasons for the huge gap between research and mass market availability: (1) concepts and prototypes are monolithic constructions with a tight integration of textile, hardware, and sensing, (2) they are typically designed for one specific application and (3) when creating the prototypes little or no consideration has been given to how clothes are manufactured. To move smart garments from its niche to a mass market all these issues need to be tackled.

In our research we investigate how to separate textile sensing, acquisition hardware, processing, system software, and application software in a way that allows an effective division of labor between these different areas, as they require very different expertise [2]. In this paper we present a first prototype of a shirt that

- is created in a modular way, combining different sensing modalities and allowing for the use of different data acquisition technologies,
- separates clearly between the smart garment technology, the software for signal processing and data acquisition, the system software, and the application,
- and that supports through an API different applications on the same garment.

Design Considerations

For the system design, the modularity of the technical parts and a clear separation of concerns of the software parts are essential. With regard to the fabrication, the central consideration is that the sensing fabric can be mass produced with typical textile processes (e.g., weaving, knitting, etc.) and that smart garments can be tailored using a mix of smart fabrics and conventional fabrics through applying typical production methods (e.g., sewing, stitching, gluing). The resulting smart garments are designed to be usable (including wearability and washability) and sensing-ready. With sensing-ready we refer to the detachability of the active hardware for signal processing and communication in a simple to use way (e.g., a pouch).

The SimpleSkin Shirt

We propose integrating three different sensing modalities, namely capacitive sensing, resistive sensing, and bio-impedance sensing. We use each of the three sensing modalities on dedicated locations within the shirt. Since bio-impedance sensors detect vital parameters of the user (e.g., heart rate), we placed them on the chest area of the shirt. We use the capacitive sensor on the wrist and neck area of the shirt. With this placement, we are able to detect movement of the wrist and fingers as well as the head (cf., [1, 5]). Lastly, we use resistive sensor arrays (cf., [10]) at the user's joints and lower arm. The sensors at the joints are intended for detecting the angle of each joint and, thus, give insights about the current posture of the user. Since the lower arm is a part of the body in which explicit interaction is socially accepted [6], we selected this location for arbitrary touch input.

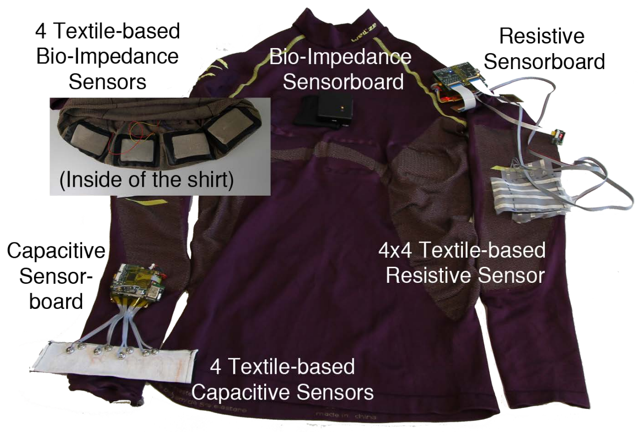

Figure 1: First prototype of the SimpleSkin Shirt. The sensors are put out of their pockets for visibility.

First Shirt Prototype
As a first step towards the proposed shirt, we developed a simplified prototype. We integrated all three sensing modalities but only one of each in an off-the-shelf long-sleeved shirt (cf., Figure 1). We placed the capacitive sensor at the left wrist with four textile-based capacitive sensors connected to a single control board. The sensor is fixed by sticking it into the sleeve of the shirt whereas the sensor board is using an enclosure attached at the forearm. For the resistive sensor array, we used a small patch of textile with a 4 by 4 pressure sensors similar to [10]. We placed it at the right elbow to explore the feasibility of posture detection with this sensing modality. Both fit into a pocket at the elbow. Additionally for bio-impedance sensing, we glued four fabric cushions inside the shirt. These cushions are connected to the sensor sitting on the outside of the shirt. All three control boards are connected via Bluetooth and continuously send their data.

Garment Operating System
Enabling developers to create applications for the SimpleSkin shirt requires a specific level of abstraction and infrastructure. The software separates clearly between an operating system level, that encapsulates and manages the system function and sensing primitives, and the application level. The application level software is independent of the specific garment and can be used independent of the actual realization of the smart garment. To ease the development up, we included the smart-phone of the user into the system. Hence, we developed an Android-based Garment Operating System consisting of a background service and a settings application.

Background Service
Each of the sensors provide the data to the smart-phone via Bluetooth. For each of the sensors, we developed a specific driver that communicates with the control board of the sensor and receives the data. The received data is then stored locally on the mobile phone and can be uploaded to one of three cloud services (i.e., Dropbox, Onedrive, or Google Drive).

We provide an Application Programmer Interface (API) for applications to access the sensor values. Using the API, developers either connect their applications to a number of events (e.g., *HEART_RATE_CHANGED*) or grant direct access to get the current values for each of the sensors. Since we strive to keep the system independent of the actual sensor, we developed interfaces for the most common sensors (e.g., HeartrateSensor). The driver of a sensor implements these interfaces (e.g., the driver of the bio-impedance sensor). The main advantage of this approach is that the sensors can be changed or updated without changing the applications.

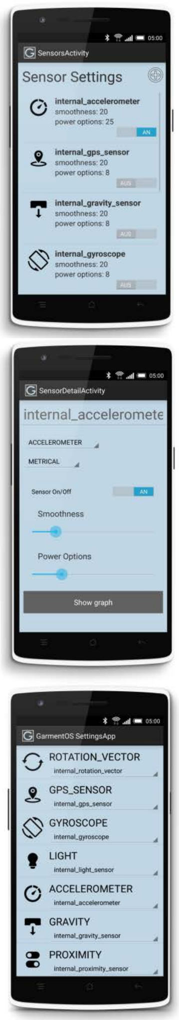

Figure 2: Sensor settings (top and middle) and privacy setting of the Garment Operating System (bottom).

Settings Application

The settings application (cf., Figure 2) is in charge of controlling the storage and privacy settings for the whole system. The user can enable and disable sensors (external wearable devices and internal smart-phone sensors) for specific applications so that the user always stays in control of his or her data.

Applications

We propose a number of sensors that can be used for applications. With these sensors, application developers can create their custom applications. To outline the possibilities, we highlight three application scenarios.

- **Long-term Heart-Rate Monitoring.** With the built-in bio-impedance sensor, the heart rate of the user can be extracted and stored. The cloud service can be used to upload the data once a week to reduce the storage needed on the mobile phone.
- **Input Device for Games.** The combination of the different resistive patches allow the reconstruction of the user‘s posture. Gaming applications can use this data as input in combination with hand gestures recognized with the capacitive wristbands.
- **Implicit Interaction.** The heart rate measured with the bio-impedance sensor can be used to infer to the stress-level of the user [9]. This information is valuable to adopt interfaces to the user‘s needs.

Acknowledgments

The research leading to these results has received funding from the European Union 7th. Framework Programme ([FP7/2007-2013]) under grant agreement no. 323849.

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