FlexTiles: A Flexible, Stretchable, Formable, Pressure-Sensitive, Tactile Input Sensor

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Abstract
In the FlexTiles demonstration, we present a flexible, stretchable, pressure-sensitive, tactile input sensor consisting of three layers of fabric. We demonstrate the implementation of FlexTiles for covering large areas, 3D objects, and deformable underlying shapes. In order to measure these large areas with high framerate, we demonstrate a simple measurement implementation. Finally, we outline the benefits of our system compared to other tactile sensing techniques.

Author Keywords
Sensor; Input; Pressure; Textile; Flexible; Stretchable.

ACM Classification Keywords
H.5. 2. [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles.

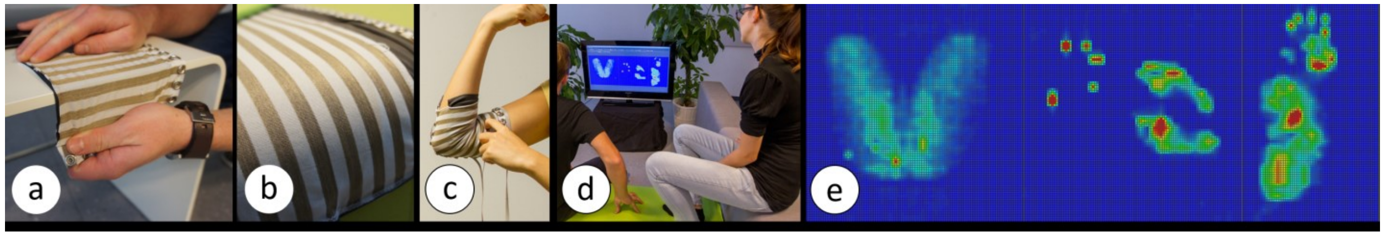

Figure 1: FlexTiles is a thin, flexible, stretchable and form-fitting pressure-sensitive tactile input sensor for sensing complex 3D shapes (a-c). It also enables the measurement of large areas like a couch in real-time (d-e).

Introduction

Tactile-sensing technology became popular over 30 years ago and it is still evolving [7]. Recent work [2,5,6,8] shows exciting new developments and application areas. However, most of those sensors have limited deformability, and may even break when stretched.

In this demonstration, we present *FlexTiles*, a flexible tactile sensor, which consists of three layers of stretchable fabric, which is not changing its sensing behavior while stretched (see Figure 1). Its ductility and form-fitting ability enables a wide range of novel use cases, such as input techniques on complex or deformable, underlying shapes.

Contribution

- Design and implementation of a highly stretchable, formable pressures sensitive tactile input sensor with real-time, interactive performance.
- Engineering of three sandwich layers, including measurement electronics and sensing hardware.
- Three prototype applications that demonstrate the versatility of this sensor for scalability, form-fitting, and integration with deformable objects.

Implementation

The sensing material consists of two layers of zebra fabric with one layer of EeonTex™ LG-SLPA in-between (as depicted in Figure 2).

Figure 2. FlexTiles consists of a sandwich design of two electrode layers and a force sensitive layer in between.

The two layers of fabric are oriented orthogonal to each other to form a matrix layout. The force sensitive material has to be placed at intersections of the electrodes. In [2], the force sensitive material was printed only in-between the intersection points. In this case the surface resistivity of the force sensitive layer was irrelevant, because there was no connection in-between two adjacent electrodes. In FlexTiles, however, we used one consistent sensing layer for the entire size of the sensor due to the reduced fabrication complexity.

For our purposes, the high surface resistivity compared to the volume resistivity makes it possible to have a consistent layer without taking electrical crosstalk between adjacent electrode layers into account.

Sensing Hardware

The measurement electronics consist of an off-the-shelf Arduino Due microcontroller (SAM3XUE), five multiplexers (74HC4051 8-channel analog multiplexer) and four shift registers (74HC595 8-bit). The shift registers apply 5V to one column while all others are connected to ground. Whenever the shift register is triggered, the high level moves to the next column. The multiplexers are connected to the row electrodes and either measure sensor resistance, or pull it to ground, while each sensor is individually measured. As the shift registers can change their states faster, the sensors are measured row-by-row. Via an additional multiplexer, various reference resistors can be set. This enables measurement of different force sensitive materials and changing the sensitivity level of the used material. We are using the embedded analog digital converter (ADC) of the microcontroller with a sampling rate of 500 kSPS. Our current version measures 1,024 sensors with an overall sample rate of 200 Hz.

Prototype Applications

To demonstrate the applicability and versatility of FlexTiles, we developed a set of prototypes based on three main categories: scalability, form-fitting, and flexible integration with deformable objects.

Scalability: Couch Cover

To demonstrate that our sensor can cover large surfaces, therefore we implemented a couch cover. The couch cover can detect a sitting person[3], hard and light touches, as well as, swiping gestures. The prototype demonstrates a non-intrusive way to cover a large object with tactile pressure sensors with less implementation effort and without losing the quality and softness of the couch. As possible usage examples we envision controlling home cinema, music playback, or video game applications. Beyond, detection of the position of a user could allow the home entertainment system to adjust the focal point to improve sound experience (cf. Figure 1d).

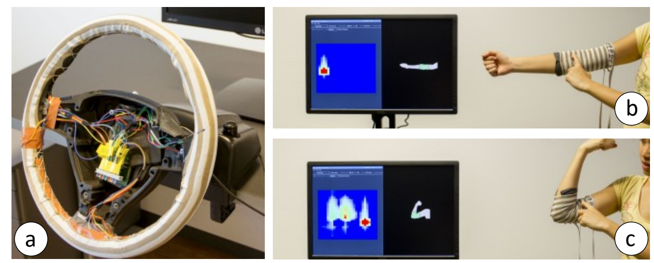

Figure 3: FlexTiles demonstrating its features in a steering wheel (a) as well as a deformable arm-cover (b-c).

Form-Fitting: Steering Wheel

To demonstrate the form-fitting ability, we covered a steering wheel (160 mm radius) with 15 mm of the outer ring with a tile design of 32 columns and 3 rows. We pulled it over the circular edge of the steering wheel and sewed it in the inner part. This non-intrusive fabrication allows tactile pressure sensing as well as swipe gestures without feeling a sensor mounted on the surface. The force distribution measurement could be used to detect fatigue of the driver[1], as well as, for interaction with the infotainment system, without taking the hands off the steering wheel (cf. Figure 3 a).

Integration with deformable objects: Arm Sleeve
The fabric can also be used for covering deformable underlying shapes (e.g., as an arm band), since applied stretch has negligible impact on the sensing behavior. This behavior enables the use of FlexTiles for wearables[4] or as artificial skin in robotics for collision detection (cf. Figure 3 b-c).

Conclusions & Future Work

In this paper, we presented a thin, flexible, stretchable and form-fitting cover, which can be used as a tactile input sensor. The whole sensor consists of three stacked layers of fabric. Our initial experiments show that FlexTiles are robust against high mechanical deformation. This non-intrusive way of measuring the distribution of force enables new design opportunities for human-computer interaction. The sensor can be stretched without breaking or losing its sensing behavior. While our fabric tactile sensor approach shows significant potential and leverages straightforward fabrication, there are still interesting areas to explore for future work such as seamless connections between textile sensors and electronic measurement hardware, patches with a higher sensor density, and stacking FlexTiles tiles on top of each other to get a greater and more accurate force distribution image, without losing information in-between the sensors.

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