Modular tacTiles for Sonic Interactions with Smart Environments

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ABSTRACT

In this paper we present a prototype of a spatially resolved tactile surface that can serve as an ‘artificial skin’ to extend the perceptual capabilities of furniture or other artifacts in environments such as the floor or wall. The surface material is based on paper and flexible circuit board material, so that tacTiles – elements of this type – can be applied to various contexts. As an interactive application, we present a real-time sonification of interaction patterns with the tacTile doormat, allowing for instance to perceive how someone leaves or enters a room, or how the body weight is distributed.

Author Keywords

tactile sensing, ambient intelligence, smart environments, multimodal interaction, sonification.

ACM Classification Keywords

H5.m. Information interfaces and presentation

INTRODUCTION

Smart environments are in need of perceptual inputs to sense the behavior of humans. Tactile sensing is a good complement to visual and auditory information and may be regarded as an artificial skin for intelligent artifacts. However, such sensors should be flexible, versatile, low-cost, spatially resolved, cover a large pressure range, and allow real-time readout. Different from existing approaches our implementation fulfills many of these properties to an acceptable degree, and we furthermore address here the particular benefits from using such sensor matrices for closed-loop auditory display systems, presenting auditory monitoring and the basis for movement-based sonic games.

PAPER-BASED TACTILES TECHNOLOGY

For the tacTiles system we use force sensitive resistors (FSRs) made out of paper. The technique was first presented by Koehly et al. [1] for use in low-cost music controllers [2]. Black art paper dyed with carbon particles conducts electricity and its resistance depends on the applied pressure. It is cheaply available and easy to process. It is used in a three layer sandwich: the force sensitive layer in the middle and two contact layers above and below. The resulting sensor can be of any shape and is very flexible while showing similar characteristics as commercial polymer FSRs. Since the paper itself is very cheap, a single paper sensor costs only a few cents. For our application, we align the sensors in a grid to obtain spatially resolved pressure readings.

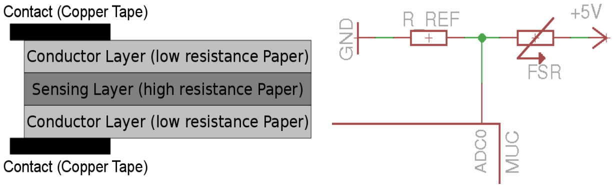

Figure 1: tacTile element principle and voltage divider

THE TACTILES PROTOTYPE

Our first and current prototypes have conductor layers made out of paper as well, with copper tape contacts and a transparent adhesive film protective cover. The sensor elements are read time-multiplexed with an AVR ATMega micro-controller and send to the host computer via USB serial emulation. Each sensor element is connected through a diode to the voltage divider to prevent crosstalk. As the diodes can not be integrated into the tile with this technique, they are placed on the micro-controller board, requiring ones separate wire per element. The building time for a single 8 x 8 sensors tile is approximately 6 hours.

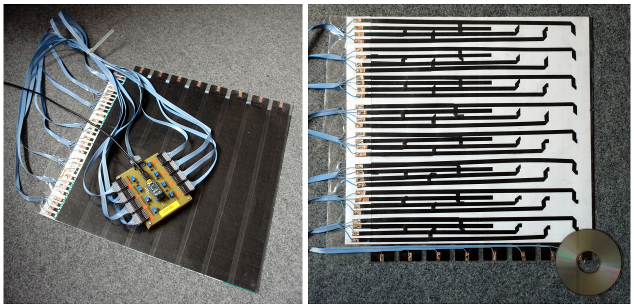

Figure 2: Photo of the tacTile 8 x 8 prototype, 42 x 42 cm²

SOFTWARE COMPONENTS

Our first prototypes were connected directly to the host computer, enabling a first visualization implemented in Processing[1] and sonification rendered with SuperCollider[2]. The next step was to connect the ATMega micro-controller

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[1] http://processing.org

[2] http://supercollider.sf.net

via SPI to an AVR32 micro-controller, which aggregates the connected tiles into an UVC USB Video interface, previously developed at CITEC [3]. Since any modern operating system provides drivers for this standard interface, it is easy to integrate our sensor grid into standard computer vision software such as the ICL[3]. Several tacTiles modules can communicate to a single AVR32 master over a SPI bus system, reducing cabling overhead and allowing for modular interconnection.

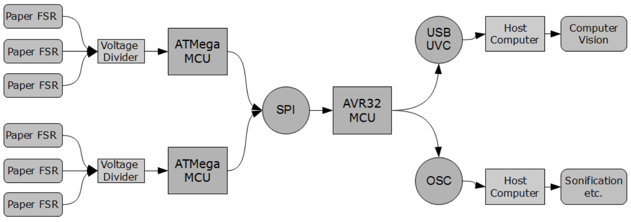

Figure 3: Illustration of the modular data processing architecture.

SONIFICATION OF TACTILES

Sonification, the non-verbal auditory representation of data, allows perceiving typically non-audible information by using sound that is systematically bound to the underlying data[4]. Sonification is a suitable communication channel in many situations, e.g. if the eyes are not available such as for visually impaired users or in dark environments or when the eyes are otherwise occupied such as in sports. Since sound is rapidly perceived and well suitable to direct the focus of attention, we consider it as the ideal feedback modality to support dynamic skills, e.g. to relearn balancing skills for specific patients.

There are many techniques how to sonify data, and a common approach is parameter-mapping sonification where data variables are mapped to sound parameters. We apply this idea here to present two types of sonifications: (a) a sonification for monitoring the dynamic interaction, allowing the listener to perceive how someone steps over tacTiles used as a doormat, (b) a sonification for perceiving the balance between two feet, to train certain weight shifting with the body, which is for instance relevant in Tai chi and other sports.

MONITORING SONIFICATIONS

This first sonification example demonstrates real-time generation of pressure profile-specific sound, mapping the pressure change to amplitude of 64 simultaneously playing sound streams. Each stream is located in the stereo image according to the x-coordinate and represented by a filtered noise whose center frequency rises with the y-coordinate. Thus, a step creates a time-variant spatially moving sound motif that allows to detect various features such as the direction, speed, weight, etc. Interaction examples can be found at [4].

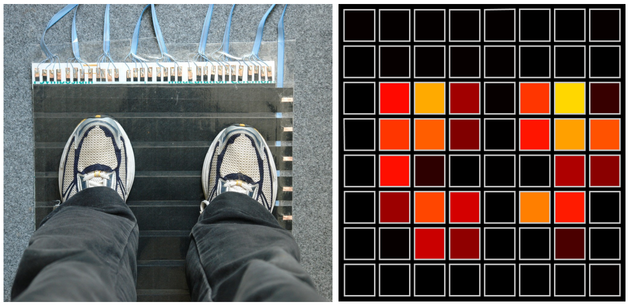

Figure 4: User stepping on tacTiles, heatmap visualization

BALANCING SONIFICATIONS

In this second sonification, we accumulate the sensor signals within the left and right half of the tacTile. The difference between these estimated weights represents the weight shift and is directly sonified by a simultaneous mapping to many acoustic variables: pitch, pulse rate, stereo panning and brilliance which cause a very salient change of sound with weight transfer. Interaction examples are also available at [4].

DISCUSSION AND CONCLUSION

With tacTiles, we show a new kind of modular low-cost flexible pressure sensitive surfaces designed for measurement of physical interaction. Compared to the initial tacTiles chair [5], resolution and versatility of the sensor matrix was greatly improved. The next step is to redesign the tacTiles to integrate the diodes and use thin PCBs as the contact layers, reducing building time to a minimum and improving durability, aiming towards tacTiles becoming a ubiquitous extension for smart environments.

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[3] `https://trac.cor-lab.uni-bielefeld.de/icl`

[4] `http://sonification.de/main-def.shtml`