Colocated Surface Sound Interaction

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Abstract
We present three related schemes for colocating sensing and sound actuation on flat surfaces One uses conductive paper to create a musical instrument, another uses magnets mounted in gloves and printed conductors to form planar loudspeaker arrays. Finally we show how conductive and resistive fabrics can be integrated with loudspeaker drivers.

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Introduction
In this interactivity demonstration we bring together three different material embodiments of the idea of colocating sound and surface interaction with: paper, fabric and printed conductors on plastic. This represents an opportunity for designers and researchers to directly experience the potential of these new technologies. All three were developed and described by the authors in publications in 2012. The paper fingerphone won best poster award at NIME [1]. The fabric sensing loudspeaker was presented at AES [3] and the printed loudspeaker arrays were presented at ITS [2]. These designs contribute new material explorations for surface interaction and serve as platforms for experiments in multimodal and haptic

interaction design where sound is an important sense modality.

Printed Loudspeakers

Our system of flexible audio driver arrays is based on conductive materials that flex on flat surfaces, such as conductive inks and thin foils. Surface substrates consist of flexible magnetic strips, paper, foams, plastics such as clear acetate, and other lightweight flat surfaces which allow small rare earth magnets of 1 mm depth, or magnetic particles, to be attached or embedded in the material. Our 2-D voice coils are made from machine-cut copper sheets (.001” thick), or by inkjet printing and electroless copper plating onto flat surfaces. Figure 1 shows a typical array system using copper foil adhered to paper.

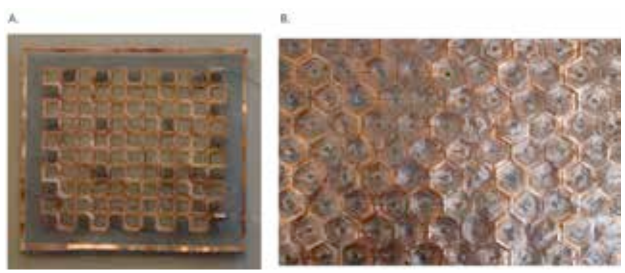

Figure 1. Two flat speakers designs using maximal tiling A. Square speaker. B. Hexagram speaker

The effectiveness of these surface speaker designs depends on maximizing the potential magnetic field and magnetic flux at the level of the surface itself. For maximum efficiency on the surface, the interaction of the electromagnetic field and the permanent magnetic field is strongest at the boundary of the magnet and drops off rapidly beyond. Therefore, maximizing this boundary across the sheet or surface is optimal for the strongest audio response. We used regular tilings, such as these ones using squares, or hexagons, to create a dense sheet of copper foil arrays on a clear acetate backing (Figure 1).

Interactivity

In addition to performing the function of a diffuse and distributed audio loudspeaker system, these arrays allow for interactivity through the use of magnetic gloves, and provide for multiple configurations of multichannel input and output.

Figure 2. A Sound Glove with Magnet Attached

By mounting the magnets in gloves worn by the listener, an active experience is created in which gestures control sounds from the speaker array. These “sound gloves” consist of every-day gloves with a permanent neodymium rare-earth magnet attached (Figure 2). Since there is no wiring or electrical system involved in the gloves themselves, users have the full use of movement freedom to explore the arrays. Sound levels from the surface are a function of the proximity of the user’s hand to the array. Since there is no computation, data measurement, or information control involved in this process, the glove provides a natural and unmediated alternative to the same functionality available in wireless proximity sensors generating audio feedback.

Arrays can also guide users to interaction points where the electromagnetic field is maximized, opening up possibilities for haptic, tactile, and audio feedback from the glove.

Fingerphone: a paper musical instrument

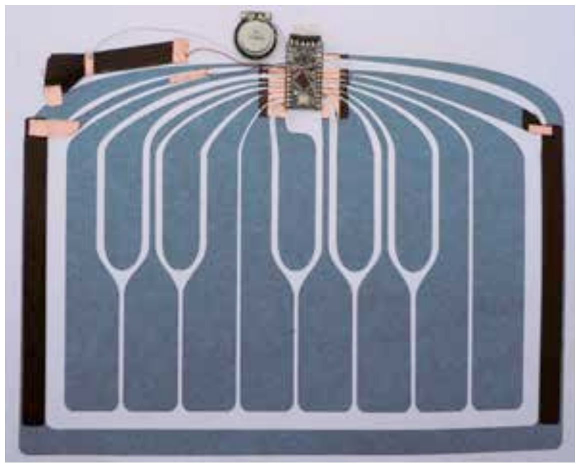

Figure 3: Fingerphone

The Fingerphone's (Figure 3) playing surface, vibrato and volume control functions are achieved using conductive paper. A single Atmel 8-bit micro-controller, is used to sense e-field touch and pressure on paper transducers, synthesize several digital oscillators and drive the sound transducer using an integrated pulse width modulation controller (PWM) as an energy-efficient, inductor-less class D amplifier.

The Fingerphone components are installed on a light, stiff substrate to provide a resonating surface for the bending mode sound transducer. This is a good opportunity to explore material reuse so prototype Fingerphones have been built on the lid of a pizza box, a cigar box, and a sonic greeting card from Hallmark - all of which would normally be discarded after their first use.

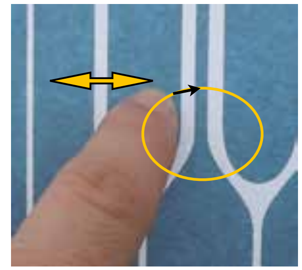

Figure 4:Trills

Surface interaction interfaces provide fundamentally different affordances to those of sprung or weighted action keyboards. In particular it is slower and harder to control release gestures on surfaces because they don't provide the stored energy of a key to accelerate and preload the release gesture. This factor and the ease of experimentation with paper suggest a fruitful design space to explore: new surface layout designs. The layout illustrated in Figure 4 resulted from experiments with elliptical surface sliding gestures that were inspired by the way Dobro and lapstyle guitar players perform vibrato and trills. Various diatonic and chromatic ascending, descending and cyclical runs and trills can be performed by orienting, positioning and scaling these elliptical and back and forth sliding gestures on the surface.

Colocating Fabric Sensing and Loudspeakers

Sound radiation components of most musical instruments fall within a few inches of the vibrating components and player interactions. Notable exceptions

include the organ, the electric guitar and many electrophones. Two practical challenges with electrophone design have frustrated the colocation of loudspeaker and performer interaction: uncontrolled feedback, and large, awkward driver geometries. The first problem is largely solved now that many of the key mathematical and engineering solutions for stable, active feedback are now available—from the scale of musical instruments [1] to the scale of rooms—as illustrated by the Meyer Sound Constellation system. We demonstrate introductory forays into the second problem: the colocation of touch sensors with new flat diaphragms. Two drivers from HiWave were chosen for preliminary explorations: a 3 inch, HIBM85C20-4 driver is used for palm interaction and the unusually long, narrow, HIBM130H10-6 drivers are used for finger interactions. Both these transducer models have the advantage over conventional cone drivers of having a flat and robust driver surface made of cardboard. They are installed in a wooden cigar box that is large enough to support experiments with various porting strategies to boost low frequency efficiency.

To judge the impact of the input transducer on sound quality one of the three finger drivers is installed without a touch sensor. One of the others hosts a commercial piezoresistive FSR strip from Interlink. The remaining finger driver and palm driver host custom made e-textile resistive sensors. A thin, conductive carbon-based paint is applied to the driver surface to establish the resistive track of a potentiometer. The "wiper" is a silver-plated spandex fabric that floats over the resistive track until pressed down at a contact region. By exchanging the usual roles of the nodes of this 3-node circuit and exploiting the piezoresistivity of the spandex it is possible to measure both pressure[4].

Conclusion

We demonstrate three different approaches to colocating surface interaction and sound. Unlike conventional acoustic musical instruments, the material substrates for these designs allow for rapid prototyping using accessible 2d printing and cutting technologies and the flexibility of digital computation for agile development of interactive systems.

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