The Deckle Project : A Sketch of Three Sensors

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ABSTRACT

The Deckle Group[1] is an ensemble that designs, builds and performs on electroacoustic drawing boards. These drawing surfaces are augmented with Satellite CCRMA BeagleBoards and Arduinos[2].[1] Piezo microphones are used in conjunction with other sensors to produce sounds that are coupled tightly to mark-making gestures. Position tracking is achieved with infra-red object tracking, conductive fabric and a magnetometer.

Keywords

Deckle, BeagleBoard, Drawing, Sonification, Performance, Audiovisual, Gestural Interface

1. INTRODUCTION

Figure 1: Drawing boards proportional to their respective sensors.

A variety of musical practices have emerged from an impulse to draw sound. In the early twentieth century, composers like Arseny Avraamov and Rudolph Pfefiinger painted patterns on the optical tracks of film. This practice initiated an early form of sound synthesis through direct graphic manipulation of the medium, a process used to great effect by artists like Norman McLaren and Daphne Oram.[4] In these practices there is a delay between marking the material and the production of sound via the photosensitive element on the projector. Our drawing ensemble aims to close that gap between mark and sound by amplifying and processing drawings as they are made.

To do this, the first step was simply to draw on an amplified surface and attend to the sound of an otherwise visual process. Brought to the fore, this fricative of graphite on paper is no longer merely the muted outcome of a visual process; now gestures arise as much for their sound as the resulting image. The drawings that emerge reflect in their form these entangled modes of attention.

This platform for composing and performing with drawing gestures is in part inspired by a recent piece by Mark Applebaum, *Straitjacket* where amplified easels are used percussively in the fourth movement. We also look forward to the emerging work *Drawn Together* by The OpenEndedGroup[3] where computer animations and sound augment the real time sketch.

2. INSTRUMENT DESIGN

Three instruments emerge from these experiments. Their hardware design is determined in part by the affordances of each sensing technique. To explore these techniques we use BeagleBoards running PureData for sound synthesis and user interaction.

2.1 Tiny and Mighty: A New Form Factor

One of our objectives is to leverage the tools of computer synthesis without the usual dependence on a peripheral laptop. For this it was necessary to embed a powerful computer in the instrument itself. The Beagleboard, a micro-sized yet full-featured computer, was implemented in each drawing board to make them self contained with minimal cables.

The Beagleboard is still developing and we encountered a few constraints. For example, in the absence of a device driver for OpenGL implementation, we had to take the visualization/interaction module out of the box to run it on the laptop instead. Such experiments reveal present limitations of the Beagleboard, but also suggest possible directions for its ongoing development.

2.2 Using Magnetometer for 2D Sensing

To keep sound and gesture closely coupled, it was necessary not only to process resonance from the board, but also to track the position of the drawing utensil. To acquire this 2D position data, we used a magnetometer, a sensor that is conventionally used to detect the surrounding magnetic field resulting in a 3D vector oriented to the north pole.

[1] `https://ccrma.stanford.edu/groups/deckle/`
[2] `http://www.arduino.cc/en/Guide/ArduinoNano/`
[3] `http://openendedgroup.com/`

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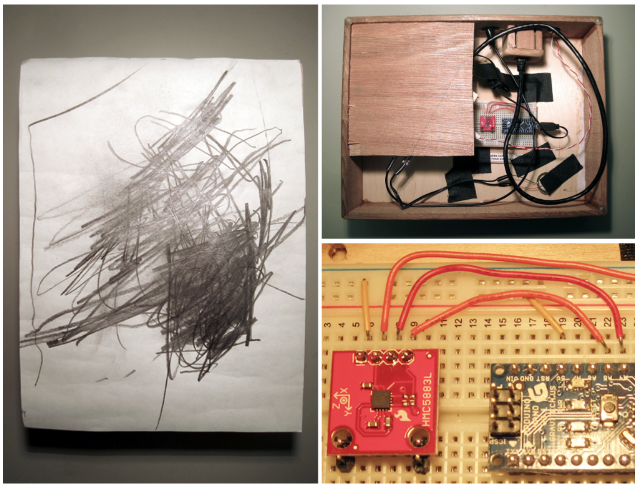

Figure 2: *Mag*: magnetometer drawing board

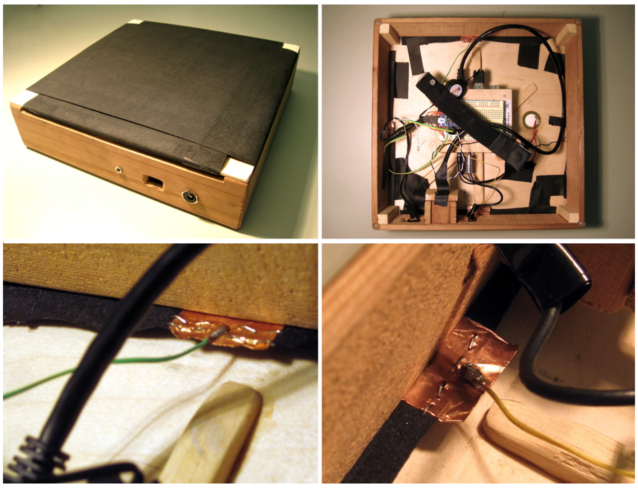

Figure 3: *Fab*: conductive fabric drawing board

We used a small magnet fixed to the drawing utensil to vary the orientation of the sensor inside the board and get meaningful data related to the drawing.

A magnetometer (Honeywell HMC-5883L)[4] is connected to an Arduino Nano board, and communicates with a BeagleBoard via the serial port. This setup requires specific circuitry and firmware. We programmed the firmware to get a 3D vector using a custom Arduino library for the HMC-5883L magnetometer [5]. With this 3D vector oriented to the north end of a magnet, we projected it into a 2D plane to get "magnitude", or distance between the sensor and the magnet, and the heading angle to the magnet. This implementation gives us 2D polar coordinates.

2.3 Pseudo-2D Sensing with Layered Conductive Fabrics

The fabric board is a also 2D position sensing system using a Eeontex conductive fabric (NW170PI-900)[5] with 900 Ohms per square inch resistance. The Eeontex fabric is a soft conductive textile that has a variable resistance depending on applied pressure. Two sheets of Eeontex fabric (10 by 10 inches) can be layered orthogonally on top of each other in order to create the equivalent of an one dimensional sliding potentiometer. One fabric has a voltage applied at opposite ends of the fabric (0V and +5V respectively), while the other fabric has an analog sensing line connected to the analog input pin of an Arduino Nano. When pressure is applied to a point on the surface, a variable resistance is produced depending on the position of touch. In order to achieve 2D position sensing, the two layers are alternated rapidly at 25-50ms, so that the horizontal and vertical position are alternatively polled at any point on the circuit. The Arduino Nano controls the switching parameters in its firmware. (See Figure 4.)

2.4 Infra-Red Optical Tracking with Wiimote

Using the Wiimote to track specific objects is now a widespread method [3]. We also implemented an optical tracking system with Wiimote, but took it one step further in terms of user interaction and musical application, discussed in the next section. In order to achieve a solid platform for infra-red tracking, we deployed an algorithm for 4-points homographic calibration based on Processing with `wrj4p5`[6] library, which provides reliable and stable platform for the performance. The 4-points calibration process compensates for distortions arising from the tilted viewing angle of the camera and ensures that tracking points are projected correctly in a virtual 2D plane. Using this procedure, we can map a tracking point to our musical system without adjusting physical setup of the infra-red camera, for example, its viewing angle and position. In addition to that, the `wrj4p5` library guarantees highly stable Bluetooth pairing between the Wiimote and a laptop, which can be otherwise unreliable.

Optical tracking in the above process depends both on a Bluetooth connection and an OpenGL visualization, both of which are not working properly on the current version of the BeagleBoard. Therefore, it is necessary in this case to run Processing on a laptop whose applets handle all the complex operations such as Wiimote paring, OpenGL visualization, matrix transformation, and collision detection in the Harmonic Table. The final parameters such as pitch, moving speed and angle are sent to a PureData patch running on the BeagleBoard via OpenSoundControl protocol.

[4] http://www.sparkfun.com/products/10530

[5] http://www.marktek-inc.com/eeontexconductextiles.htm

[6] http://sourceforge.jp/projects/wrj4p5/

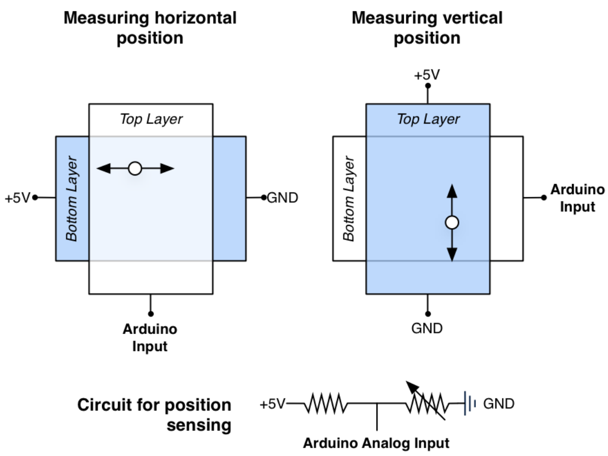

Figure 4: two conductive fabrics for pseudo-2D sensing

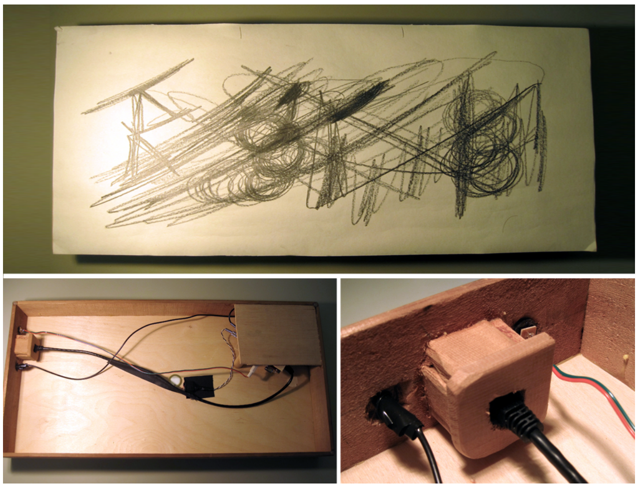

Figure 5: *Optik*: drawing board with infra-red optical tracking

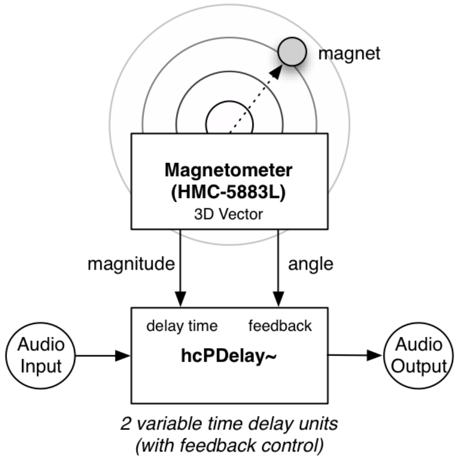

Figure 6: signal flow diagram of *Mag* drawing board

3. SOUND SYNTHESIS AND INTERACTION DESIGN

We implemented a package of encapsulated objects for Pure-Data. The package `hcPDX`[7] features many useful features such as onset detection, envelope following, and basic building blocks for sound synthesis. Creating `hcPDX` package was necessary in establishing sonic consistency between three drawing boards and facilitating rapid experiments and collaboration. We found the monitoring and mapping features in `hcPDX` were useful for analyzing the incoming data from various sensors including piezo microphones, helping us to accelerate a process of "error and trial" by plugging in parameters to synthesis engine with minimum effort. With this robust analyses of the available data, we could then map the boards to different types of synthesis, as well as incorporate the overall sound of the three boards playing together. The following sections describe the software design, which is mostly about interpreting user input and mapping data to sound synthesis.

3.1 "Mag": playing with feedback delays

Since the implementation of magnetometer required a custom firmware for Arduino, we deployed a `comport` object in PureData and devised a custom serial data stream parser. This board utilizes the audio signal from a piezo microphone attached underneath the surface as a source material, and its sound processing is mainly based on `hcPDelay~`. This object consists of two delay processors `vd~` with variable delay time and homographic interpolation which allows the performer to change the delay time without noticeable glitches. This use of delay units as playable musical parameters has been quite popular in electronic music. With extensive feedback, these delay units sound like a pitched string instrument.

The magnitude data transformed by `hcScale` is mapped to the feedback parameters for two delay units, and the heading angle is mapped to their delay time. Since the responsiveness of the magnetometer is fairly high, the association between the position of magnet and parameters of `hcPDelay~` enables a performer to transform the sound of strokes on the drawing board into dynamic and ever-changing electronic sound while maintaining its organic sound characteristics. We found this drawing board was the most successful of the three in terms of expressivity and robustness.

[7] https://ccrma.stanford.edu/groups/deckle/hcPDX

3.2 "Fab": cross-synthesis on strokes

Although pseudo-2D tracking was achieved on the fabric board, the noise floor in the data streams was considerably high and we had to apply cascaded low-pass filters with `hcSmooth`. This filtering introduced latency to the response time of the sensors. A 3Hz cutoff frequency was used to make this latency inaudible which also made the onset detection work properly. We used the`hcXDetect2~` object for onset detection and envelope following, allowing the performer to trigger sound and control the overall loudness contour. A pair of `hcScale` objects estimates horizontal and vertical pressure points on the board, and produces parameters (pitch, modulation index) for the sound synthesis module.

In this board, `hcFMOp2~` and `hcXSynth~` objects perform sound synthesis; `hcFMOp2~` object generates synthesized sound based on FM synthesis technique and `hcXSynth~` performs cross-synthesis, superimposing the input audio signal from the drawing board on the sound from the FM synthesizer. This synthesis scheme aligns with our goal of drawing sound as we can introduce a sense of pitch while maintaining the natural timbre of the sketch. At the end of the synthesis routine, `hcPDelay~` creates an echo-like reverberation helping the sound to be integrated into the overall timbre of the ensemble.

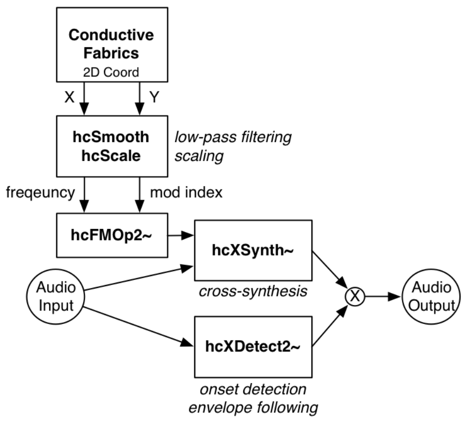

Figure 7: signal flow diagram of *Fab* drawing board

3.3 "Optik": drawing on Harmonic Table

With many more degrees of freedom, the infra red tracking system motivated us to design a more sophisticated system where a Harmonic Table was projected on the board. The performer could draw through this map of hexagonal regions, triggering discrete notes. Drawing geometric shapes on this board brings diverse musical results; linear marks result in melodic contours whereas a triangle on adjacent hexagons plays minor or major chord depending on the direction of the shape.[6] The sound synthesis engine is based on FM synthesis with phase modulation and onset detection. To feature this instrument as a pitched system, we did not include the sound from the microphone in the synthesis loop. The sound from the microphone is used solely for onset detection and envelope tracking, which is done by `hcXDetect2~`. Also the speed and heading angle of the drawing utensil are mapped to the timbral quality of the FM synthesizer and the cut off frequency of a resonant low-pass filter respectively. This combination results in a highly expressive and responsive musical instrument: tapping the board triggers an individual note and scratching the board with variable pressure creates a contour of notes with a dynamic change in timbre.

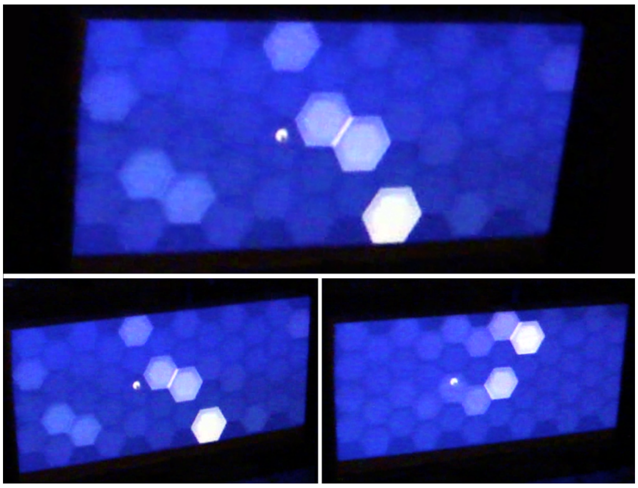

Figure 8: projected visualization of Harmonic Table on "Optik" drawing board

As shown in figure 8, we projected the visualization of Harmonic Table on the drawing board in order to provide a performer with visual feed back. Being able to draw certain geometrical shapes on a board brings diverse musical possibilities; a linear trajectory of drawing gesture results in playing a certain musical scale and drawing a triangle on adjacent hexagons plays minor or major chord tones according to the direction of the shape.

4. HAPTICS

The benefits of vibrotactile feedback in electronic instruments is well established. O'Modhrain and Chafe discuss the increased control on the theremin when an elastic band is secured between the hand and the instrument.[7] Danion et al. showed the same result with a virtual damped spring that improved motor control as well as facilitated learning of tasks.[2] We anticipate that similar results would arise if you compared control with drawings in the air with those on paper.

These instruments appropriate the very familiar tactile feedback of pencil and paper. The use of an already practiced series of gestures (drawing) with familiar sensory feedback makes the interface engaging and almost immediately accessible for exploration. The already known precision of shading and texture one can achieve with a pencil is here co-opted for sound.

Our objective was to keep the tactile feedback associated with drawing unchanged, while introducing engaging sonic outcomes beyond the simple amplification of the surface. The sensors are therefore tailored to these aims. For example, we use only two of the three axes provided by the magnetometer. The z-axis could sonify vertical gestures when the writing implement is lifted from the page. This however would dissociate sound from the mark and the engagement with material. It would become like the theremin. The piezo sensor under the board is used to trigger onset, and as such limits sound to the plane where the artist also feels the resistance associated with sketching. The sensor is constrained to correspond to a physical configuration, producing a kind of ventriloquy for the performer and listener, where the sound is perceived as emerging from the mark itself.

5. CONCLUSION

We have demonstrated 3 alternative instruments to sonify drawings using position and acoustic onset sensing. The influence of the sensors on the overall outcome is most apparent in the varying dimensions of the sound boards. Each sensor had a set of affordances that influenced our choices in design and code. We look forward to implementing other sensing technologies in the next set of instruments.

6. ACKNOWLEDGMENTS

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