# The Sound Flinger: A Haptic Spatializer

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## ABSTRACT
The Sound Flinger is an interactive sound spatialization instrument that allows users to touch and move sound. Users record audio loops from an mp3 player or other external source. By manipulating four motorized faders, users can control the locations of two virtual "sound objects" around a circle corresponding to the perimeter of a quadraphonic sound field. Physical models that simulate a spring-like interaction between each fader and the virtual sound objects generate haptic and aural feedback, allowing users to literally touch, wiggle, and fling sound around the room.

## Keywords
NIME, CCRMA, haptics, force feedback, sound spatialization, multi-channel audio, linux audio, jack, Arduino, BeagleBoard, Pure Data (Pd), Satellite CCRMA

## 1. MOTIVATION AND DESIGN
The Sound Flinger is an interactive sound spatialization instrument that allows users to touch, position, and throw sounds around a physical space. Our goal was to create a device that encourages playful experimentation and is approachable for uninitiated users while being complex enough to allow development of more advanced, if not virtuosic, techniques.

The instrument is situated in the center of a quadraphonic sound field. Users may grab and move up to four sliders that are positioned in a square configuration. If a user positions a slider at the current location of one of two virtual sound masses a force pulling the slider toward the mass will be felt. A pitch-based modulation of the sound associated with the mass occurs as the attraction between the slider and the mass increases, providing additional auditory feedback. Once a slider "latches" onto a sound mass users may wiggle the mass back and forth, or fling it toward another slider.

New sounds may be recorded into one or both virtual sound masses by connecting an external audio source and pressing one or both record buttons on the surface of the instrument.

## 2. HARDWARE
The heart of the Sound Flinger architecture is an embedded programming platform called Satellite CCRMA [8]. This platform consists of a Texas Instruments BeagleBoard [2] running a Linux distribution with Planet CCRMA audio packages [4] and other open source software. The integration of this platform allows the Sound Flinger to operate without being tethered to a laptop. The only external connections on the instrument are a 12V DC power supply, a 1/8" audio line in, and four 1/4" audio outputs to a mixer.

The primary hardware components include four motorized linear potentiometers (part no. ALPS RSA0N11M9A05) arranged along the edges of the instrument's square enclosure. Two momentary push buttons are placed at opposite corners. The sliders and buttons are embedded in a 9" × 9" sheet of Plexiglas on top of a wooden box containing an ATmega328-based Arduino Nano [1], an ARM-based BeagleBoard, a combination USB hub & Ethernet adapter (for remote programming), two AVR dual H-bridge motor controllers [5], a SIIG IC-710112-S1 USB Soundwave 7.1 Digital audio interface, and connective circuitry on a breadboard.

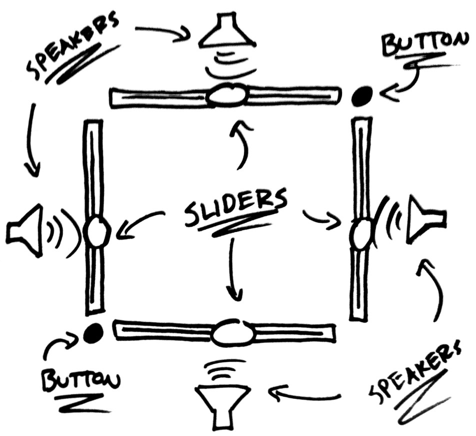


**Figure 1. Control Design Concept**

The instrument is positioned such that each attached speaker lines up with the center of a side, which corresponds to the center of a slider, as shown in Figure 1. All external connections are located on the bottom of the box to allow external wiring to be hidden. A 12V power supply is connected directly to the motor drivers and to two parallel power-regulator circuits that step down to 5V. One of the 5V sources supplies power to a USB hub, and the other powers the BeagleBoard.

## 3. SOUND DESIGN
The central software for the audio control and haptics is Pure Data [7]. There are two primary audio patches involved in the instrument. One patch manages audio sample recording and playback and the other handles spatialization.

The spatialization patch uses a vector base amplitude panning (VBAP) object, which is included in the standard Pd-extended distribution [6]. The `vbap` object interprets azimuth, elevation, and spread angle parameters to generate appropriate gain multipliers for the signals being sent to each speaker. Each virtual sound mass is associated with an individual spatialization object so sounds may be panned independently.

Two instances of the audio recording/playback patch manage the sound samples associated with each virtual mass. When a button is pressed its previously stored sample crossfades with live audio from the 1/8" input jack. The audio is buffered and loops when a user releases the record button. The pitch of a sample varies in proportion to the magnitude of the force exerted on its corresponding mass. This provides auditory feedback as a frequency wobble that indicates which of the two sound samples is being manipulated. This modulation can be "played" by gently wiggling a slider when a mass is attached.

# 4. HAPTIC MODELS

The haptic models for the Sound Flinger were developed in Pure Data (PD) and are based on Edgar Berdahl's haptic object library [3]. The `mass~` object is modified to modulo index the object's position to account for circular movement.

The slider handles are modeled with the `contact-detent~` object, which applies a force on the masses proportional to their distance from a handle. At a threshold distance this restoring force drops sharply to zero. The effect of this model feels as though a slider and mass are temporarily connected to a spring until the mass moves fast enough to break free.

It is possible to launch an attached mass by smoothly accelerating and then quickly stopping the slider. The mass will retain most of its momentum and break free of the detent region, continuing around the circle. It is possible to catch a mass by simply letting it pull a slider until its motion is sufficiently slowed by the sliders' friction.

# 5. RESULTS AND FUTURE WORK

We found the instrument to be very approachable, allowing novices with only a basic understanding of the device to experiment and immediately achieve interesting results. One common experience is gesture discovery, in which users develop repeatable sequences of interaction as they become more familiar with the instrument's behavior.

For example, if all sliders are held stationary while a mass is rotating around the sound field it will continue to circle indefinitely. Preventing the sliders from moving effectively eliminates all damping from the system. Another interesting gesture involves coaxing both masses onto a single slider, where the natural volatility of the mass-spring simulation causes the masses to oscillate in opposing directions. The modulation of the audio playback rates for each sound object gradually increases in magnitude as each mass gains momentum. Eventually a mass will break free and the system will return to a state of equilibrium.

In the future, we hope to extend this initial work and integrate feedback received from initial demonstrations. The most commonly requested feature is visual feedback to reveal the precise locations of the virtual masses, regardless of whether or not they are attached to a slider. This could be done with LEDs placed around the periphery that change color and/or brightness in relation to the positions of the virtual masses. A direct mapping from the gain multipliers generated by the spatialization patch to the brightness of the LEDs would provide appropriate visual feedback. Another potential improvement would be the addition of a separate headphone monitor connected directly to the instrument's audio input. This would allow users to more accurately cue sound samples from their input device of choice.

In addition to general design enhancements, we hope to observe people interacting and improvising with the instrument in a more public setting, such as a gallery or a concert. It would be useful to determine a timeline for gesture discovery based on trials with individuals of varying musical backgrounds. Furthermore, a systematic comparison between using the instrument with active versus inactive haptic feedback would provide insight into the significance of haptics for developing advanced performance techniques.

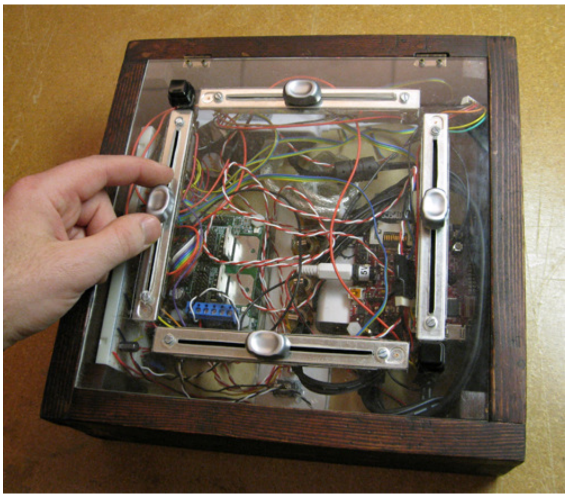

**Figure 2. The Sound Flinger**

# 6. ACKNOWLEDGMENTS

Special thanks to Ed Berdahl and Wendy Ju for their valuable guidance. Thank you to Bill Verplank, Max Mathews, Chris Chafe, Perry Cook, Matt Wright, and all of the additional people involved in developing the 250 course sequence that inspired this work.

**Figure 3. Playing the Sound Flinger**

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