The Airstick: A Free-Gesture Controller Using Infrared Sensing

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ABSTRACT
This paper describes the development of AirStick, an interface for musical expression. AirStick is played "in the air", in a Theremin style. It is composed of an array of infrared proximity sensors, which allow the mapping of the position of any interfering obstacle inside a bi-dimensional zone. This controller sends both x and y control data to various real-time synthesis algorithms.

Keywords
Music Controller, Infrared Sensing, Computer Music.

1. INTRODUCTION
The growing computation power allowed musicians to start considering instrumentation in live computer music. The typical computer interfaces proved to be poor for this new "instrumental" quality, resulting in the development of new physical interfaces. These interfaces tend to be fully customized and only limited by one's creativity. The technologies involved in the developing of such tools have become widespread and different instruments proliferate.

Some of these controllers are based on gesture mapping: music controllers that respond to body articulations performed "in the air", without any physical contact between a player and the instrument's body.

2. RELATED WORK
The first of these instruments was the Theremin. Over the years the Theremin maintained it's interest and many other musical interfaces were built with the same interaction principle. Among these are Tod Machover's Sensor Chair [1], the Soundbeam [2] or the recent Eyris [3]. Also Roland has commercially implemented the "D Beam" proximity sensor on some synthesizers [4]. The instrument here described is also closely related to Hasan's past work with the Termenova [7].

Multiple human tracking techniques have been implemented [5] using different non-contact sensor technologies like capacitive, optical or computer-vision sensing [6].

Some of them use infrared (IR) proximity sensors based on emitter/receivers that have, until now, used relative small ranges (around 80 cm).

3. INSTRUMENT DESIGN
3.1 System Description
The AirStick is based on the arrangement of six IR sensors, equally distributed along a vertical stand. It can detect the positioning of a hand inside this area, with continuous values along the x-axis and 11 discrete values along the y- axis.

Recently Sharp introduced the GP2Y0A02YK IR, equipped with special lenses and allowing larger ranges (150 cm). With a longer active field they can be used in the construction of a non-contact gestural instrument with a larger scale than most of the previous similar systems. This results on a better visual cue, where a more noticeable movement is translated into sound, which is important for the audience's understanding of a stage performance.

The IR's are 9.5 cm apart from each other, allowing an open hand to be detected by two consecutive sensors. This means that an intermediate y value can be inferred, ending up with 11 y-axis classes. Even with lower y-axis accuracy, by using time ramps, a pretty good estimation of a hand's position can be achieved

3.2 Hardware Implementation
The 10 bit ADC's of Netmedia's BasicX 24 microcontroller were used to digitize the sensors analog values, outputting different MIDI Control Change messages via serial port.

The GP2Y0A02YK IR needs the following linearization function:

$$f(v) = \frac{(0.082712905 + 9395.7652v)}{(1 - 3.3978697v + 17.339222v^2)}$$

The graphic in fig. 1 shows this relation between the analog voltage readings and their rather logarithmic behavior.

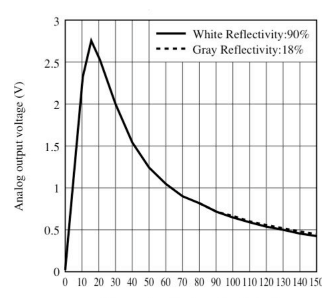

Fig.1 – Analog readings for the Sharp GP2Y0A02YK sensor

According to the graph the first 20 cm are not usable, so a low threshold was applied to ignore this lower interval.

On the lower end of the stand two connectors were installed: a 9V AC power supply and a typical MIDI output. On the top, a blue led flashes as a visual cue, whenever any object is within the active area.

4. MAPPING AND PLAYING

The Airstick communicates in real-time with the Max/MSP [8]. The MIDI messages derive on a 2D positioning array and a low pass/median filter smoothes any incoming noise from the sensors.

Many different musical interpretation programs can be assigned to the Airstick. However, due to the lesser resolution on the y-axis, it naturally evolved to a mapping where a note or a sound is triggered on y, whereas the finer x-axis controls different audio signal modulations.

Two different approaches were used for note/sound triggering:

- Sustained Events – where the pitch note or sound is triggered and sustained for modulation, until the hand/object is removed.
- Percussive Events – where each new triggered sound event decays, independently of any new events.

The events drive a real-time granular synthesizer with its respective ADSR envelope. The x position controls filters (comb, bandpass or lowpass) used for signal modulation. A sample-based synth allows the quick creation of a large spectrum of timbres.

The mappings were intentionally simple for the sake of coherence and clarity, using a "simple instrument" approach vs. the "one man band" idea, where generally mappings tend to be too complex, compromising the exploration of the instrument's subtlety.

5. INSTRUMENTAL QUALITIES

Typically our cognitive memory can easily induce an association between a new controller and a more traditional instrument paradigm. The Airstick can be found analogous to the digital harp or an "air percussion" instrument, depending on the choices of positioning, playing and synthesis algorithms.

Some types of mappings result almost intuitive and inspired on the nature of the instrument. For example, an audio modification like filtering is very suitable to be used with a property like proximity detection. The action of "closing in" on the object is related to the "closing" of filters, by lowering their control frequencies or bandwidths.

Fig.2 – The Airstick

Over many centuries traditional instruments produced sound by the physical contact manipulation of a resonant body. New instruments like the Airstick break this physicality barrier with no knobs, keys or resonant body. A plain gestural controller, played "in the air", tends to have this kind of "magical" quality, like the waving for a sonic spell.

Initially finding themselves on a new abstract timbral environment the players tend to rapidly develop some kind of sensibility with the playing. In this way this controller can be found to be "easy", falling more into the music toy type of instrument. However the author and other musicians have also found a continued interest and a possible virtuosity to it.

The nature of the Airstick also addresses a very common problem with new physical interfaces: force-feedback. On an acoustic instrument a force always results on a counter-force, helping the trained player to manipulate the instrument. Playing "in the air" obviously does not imply any counter-force so the player can initially find himself lost in the process of producing a very determined sound. Nevertheless this characteristic as revealed itself very challenging and fun to deal with, since most players rapidly tend to adapt their manipulation and explore different techniques.

6. CONCLUSIONS

The Airstick demonstrated some interesting sonic exploration and a good response for sensible playing, especially on the signal modulation controls.

It follows a design principle used for other similar instruments with the exception of its longer detection range, assuming a more theatrical performance and extending its stage potential.

7. ACKNOWLEDGMENTS

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