SensorBox: Practical Audio Interface for Gestural Performance

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ABSTRACT
SensorBox is a low cost, low latency, high-resolution interface for obtaining gestural data from sensors for use in realtime with a computer-based interactive system. We discuss its implementation, benefits, current limitations, and compare it with several popular interfaces for gestural data acquisition.

Keywords
Sensors, gestural acquisition, audio interface, interactive music, SensorBox.

1. INTRODUCTION
Practitioners of interactive music frequently require sensing devices to obtain gestural control of various signal-processing parameters. While much attention is given to new and novel sensing devices, and to the interactive system itself, the interface that connects the two is often overlooked. This "middle man" which negotiates between the analog sensors and the digital computer is frequently a source of bottlenecks, latency variations, and system instability, not to mention considerable expense. These attributes combine to make such systems impractical for many artists [1].

SensorBox is an interface developed in an attempt to resolve these difficulties. Our initial experiences with the SensorBox have shown it to perform admirably when compared to most commercially available systems.

2. DEVELOPMENT
The SensorBox is the third generation in a series of solutions utilizing standard audio hardware to digitize sensor data. The initial solution, the TeaBox (so named because it was housed in a tea box), converted continuous voltages from two sensors into square waves, using a 555 timer, and transmitted them to the computer over two audio lines [Figure 1]. The data was represented as the frequency of the square waves. The computer decoded the sensor information by counting the zero-crossings of each signal. This solution worked well, however it uses bandwidth very inefficiently, and could quickly fill all available audio inputs on a computer.

The TeaBox2 improved on this design by replacing the square wave oscillators with sine wave oscillators. Still built in a tea box housing, the TeaBox2 collects data from three sensor sources and mixes the sine wave signals they generate onto a single audio line to send to the computer. The computer then separates the signals using band-pass filters and analyzes each signal individually. The data here is represented by the amplitude envelope of the sine waves, which is converted into a control signal in the software.

Figure 1. The TeaBox sensor-audio interface.

3. CONSTRUCTION
3.1 Hardware
The SensorBox is a single rack-space unit that connects sensors to a computer through any available audio input(s) on a computer. The front panel hosts 2 XLR inputs and 8 Neutrik combo (XLR or 1/4" TRS) inputs, while on the rear, two audio outputs feed the computer.

The premise of the SensorBox is that frequencies above 18,000 Hz in the audio input will not be needed by the interactive system. The SensorBox filters the audio input through a low-pass filter with a cutoff frequency of about 17 KHz. Meanwhile, the connected sensors drive oscillators in the range between 18 and 20 KHz, which are mixed back into the audio signal that goes to the computer. Software on the computer removes these high frequencies from the input stream and performs a computationally inexpensive analysis to acquire the data from the signal.

3.2 Software
Due to the simple methodology used to transmit the data, a variety of software may be used to interpret the acquired sensor data. This includes MaxMSP [Figure 2], PD, Jmax, and SuperCollider. Additionally we have created a VST/MAS/RTAS plugin for the Mac which will automate other plugins with the sensor data in realtime [Figure 3].

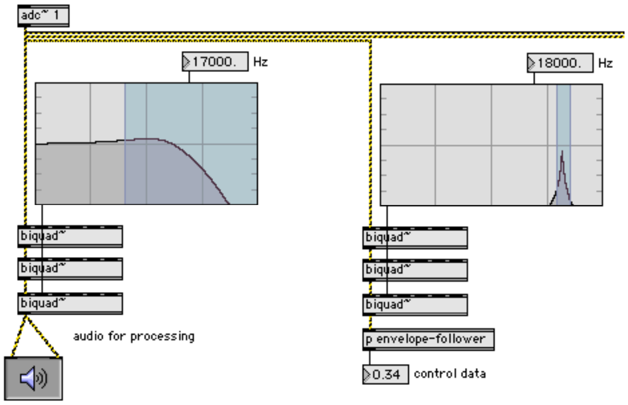

Figure 2. A portion of a MaxMSP patch for separating and analyzing the frequency regions.

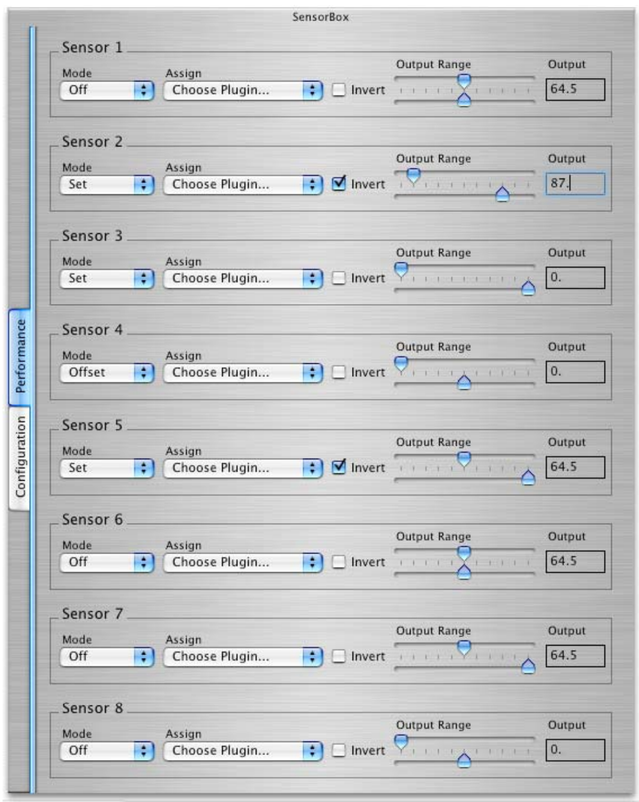

Figure 3. The SensorBox mapping plugin for VST/MAS/RTAS.

4. BENEFITS

4.1 Connectivity

One of the significant benefits of this approach is that it connects to the computer through the audio inputs. It is beneficial because most musicians already have an audio interface or audio input device of some sort, thereby eliminating platform dependencies and the need for custom drivers or extensions.

It also avoids the use of USB either directly or through a serial-to-USB converter. The authors have experienced reliability problems with USB, and we are happy to avoid it altogether by using these techniques. By using the audio stream we also avoid the use of MIDI.

4.2 Latency

One problem with realtime sensor acquisition systems is latency, and latency jitter, in the data from the sensor interface. By using the audio stream we are able to eliminate the jitter present in both MIDI-based systems [2] and some serial systems because the signals are digitized at audio sampling rates. This also reduces the latency vastly. Additionally, because all of the data is carried together on the same signal, and digitized by a common system, the gestural data is very tightly synchronized with the audio data entering the system, making overall system design a much less arduous task [3].

4.3 Resolution

While MIDI-based solutions typically have 7-bit (occasionally 14-bit) resolution, the SensorBox is able to leverage the dynamic range of the audio interface used on the computer (typically 16-24 bits). While we have not tested that the data the sensors produce can fully use this resolution, at least we can be assured that the interface is not a troublesome bottleneck for our data as is frequently the case with MIDI. Further empirical testing of this is currently in progress.

4.4 Cost

Most commercially available systems are expensive. The popular Icube system, for example, costs nearly $650 – not including the MIDI interface you need, nor any sensors [4]. The new Le Toaster for The Kitchen sells for $1200. Even do-it-yourself methods can be expensive, such as using the Basic Stamp. Systems like the Basic Stamp also require a significant amount of time and experience to get running smoothly. The Board of Education Kit for the Basic Stamp costs over $100, and doesn't include either the serial-to-USB adapter most Macintosh users would need, or a MIDI interface [5].

The SensorBox can be built for under $100 in parts, although factoring soldering time in will raise the price a bit. Variations, such as the TeaBox, can be built for as little as $5 or less.

5. FUTURE DIRECTIONS

As the SensorBox continues to develop, we are able to fine-tune its construction and improve its performance. Areas of particular interest are in making it a more easily scalable system, making the sensor acquisition wireless with the appropriate technology inside the box, and powering the box with phantom power from a microphone preamp or mixing board.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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