Stage-Worthy Sensor Bows for Stringed Instruments

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ABSTRACT
The demonstration of a series of properly weighted and balanced Bluetooth sensor bows for violin, viola, cello and bass.

Keywords
Sensor bow, stringed instruments, bluetooth

1. INTRODUCTION
Reliable, practical stage-worthy sensor bows for the string family have not been available to experimenters, composers and performers. Now a complete series of bows for stringed instruments are presented. The bows provide hair tension, grip pressure, X-Y-Z acceleration, relative X-Y position wrt to the bridge and the tilt or twist of the violin bow. A Max based application using custom RFCOMM objects provides processed gesture outputs as well as a 2 axis trainable gesture extractor.

2. DESCRIPTION OF THE SENSOR BOW

2.1 Stick assembly
The Sensor Bow (named K-Bow) requires a specially designed and built Carbon Graphite stick, which has been made lighter than a normal stick giving a final weight and balance that is expected of a fine bow. Embedded within the stick are two full-length loop antennas that are placed at right angles to each other. These antennas are used to determine bridge – fingerboard placement and the twist of the bow wrt the instrument top. Cavities and connectors within the stick gather signals and convey them to the circuit board within the frog.

2.2 Grip Sensor
A cylindrical pressure sensor made of a 5 layer "sandwich" of conductive materials replaces the usual grip. Changes in resistance occur in relationship to the pressure and total surface area of the musician's grip. The sensor output is fed to a 12-bit ADC before it is transmitted to the host. Repeatability and return to zero are very reliable.

2.3 Bow Hair Tension
Many have tried to measure the pressure of the bow hair on the strings by measuring flexing [1] of the stick. While this provides a useable signal, it is inherently prone to damage from exposure to outside forces. In the K-bow a special angular measurement scheme is attached to the bow hair at the frog end. After bringing the bow up to tension, and upon power up, the sensor is auto calibrated. This provides a robust rapid signal with over a 40 dB dynamic range. Analog filtering was required to actually remove string audio acquired by this sensor.

2.4 Accelerometer
An integrated 3-axis accelerometer is located within the frog assembly. Sensitivity can be set from the host computer by the user. The signal is filtered (low passed) at 160Hz. Updated information can be retrieved down to 1.7 ms intervals.

2.5 Signals relative to the instrument
All the sensors mentioned prior, operate in free space with no sense of relative position to the instrument. While necessary and useful, knowing the bow's position relative to the string and bridge is essential for fully understanding the performer's gestures and intentions.

A small emitter PCB clips under the end of the fingerboard of any traditional instrument and most electric bowed instruments. The emitter creates an RF field and an IR (infrared) modulated wide field light cone.

The loop antennas within the stick are tuned to be resonant with the RF field. Further analog signal processing provides an accurate signal strength reading which is converted and used as a bow to bridge distance measurement.

The quadrature relationship between the two loop antennas provides a twist signal which is affected by the rotation of the bow stick relative to the emitter. This is timed and converted with a 1% accuracy per 180 degrees of rotation.

Directly beneath the bow hair sensor on the front of the frog is an IR photo detector. The detector receives a modulated signal from an array of LEDs that emerge from beneath the instruments fingerboard. Decoded signals from the IR detector represent the distance of the frog from the fingerboard. These are processed in the analog domain before being presented to the 12-bit ADC.

2.6 The board within the frog
Housing all of the circuitry in a frog not much larger than a traditional bass frog was challenging. The board, itself, forms the major structural element fastening the hair to the stick through a frog adaptor. The frog is fully adjustable providing the normal range of hair tension.

The circuitry includes 20 op-amps, two cpus (an ARM7 and a Silicon Laboratories F411), the Bluetooth transceiver, accelerometer and extensive power management systems.

A 6 gram lithium polymer battery provides a full days use. The battery is charged through a standard USB connector, which also provides for firmware updates.

Using different frog adaptors and hair mounting brackets alows the same circuitry and housing to be used for violin, viola, cello, and bass bows.

Monitoring the accelerometer's activity allows the CPU to determine bow activity and power down unused circuits to conserve power. A user settable "Off Interval" turns the entire bow off when this time is exceeded due to lack of bow motion. Toggling the power switch on the bow allows the bow to be automatically discovered and routed to its previous application address. These states are forwarded to the Emitter under the fingerboard so it can follow similar power management rules.

Connectivity is via Bluetooth 1.2 Class 2 devices. Normal line of site range is greater than 10 meters. Data rates can be updated as fast as 1.6 ms for a single bow. Up to seven bows can be supported by one host computer.

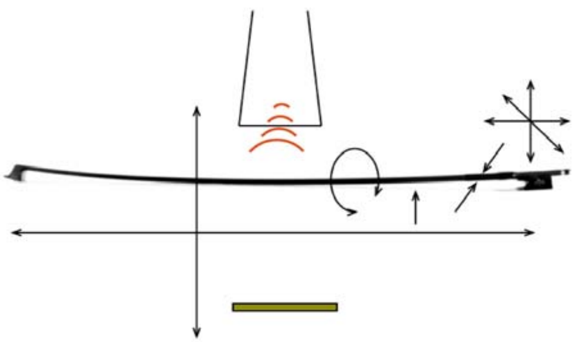

Figure 1 Degrees of Bow Sensor Data

3. Host Software

A host software program accompanies the bow. Written in Max/MSP, the Host application can be easily modified for extended functionality beyond that provided. This program provides user settable sensitivity options and a calibration routine. Triggers are extracted from inflection points in bow data. Data smoothing and sensor blending provides fluidly useful data for continuous control functions.

Programmable signal processing for violin audio provides a wide range of timbres for user selection. A four track "Looper" is integrated into the application with controls tightly coupled to the bow's capabilities.

Included in the application is a 2D OCR MXJ Object. This can be trained from any 2 outputs from the bow. One use is to map X and Y position into a trained object that recognize letters written in the air for control of recording functions or preset selection.

A custom Bluetooth object for the bow interfaces the RFCOMM layer directly to Max/MSP. Bows can be named for easy recognition when presented device lists by the Host OS.

4. ACKNOWLEDGMENTS

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5. REFERENCES

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