HyperPuja: A Tibetan Singing Bowl Controller

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ABSTRACT

HyperPuja is a novel controller that closely mimicks the behavior of a Tibetan Singing Bowl rubbed with a "puja" stick. Our design hides the electronics from the performer to maintain the original look and feel of the instrument and the performance. This is achieved by using wireless technology to keep the stick un-tethered as well as burying the electronics inside the the core of the stick. The measured parameters closely resemble the input parameters of a related physical synthesis model allowing for convenient mapping of sensor parameters to synthesis input. The new controller allows for flexible choice of sound synthesis while fully maintaining the characteristics of the physical interaction of the original instrument.

1. INTRODUCTION

In this paper we describe a new controller based on an instrument called the Tibetan singing bowl. These bowls have received increased attention in the Computer Music community in recent years [22, 15, 8, 23, 17, 3, 18, 19] for their intriguing sound and performance style.

Tibetan singing bowls are metallic or glass bowls in shapes varying from that of a spherical segment to an almost cylindrical shape. The bowls can be made to ring by striking. The sound of a bowl when struck is related to bell sounds [13]. The sound mainly depends on the shape, material and size of the bowl and the hardness of the striker.

However the more characteristic performance type is based on a rubbing interaction. The bowl is rubbed with a wooden stick called "puja", which may or may not be wrapped in a thin sheet of leather. The performer rubs with the stick around the outer rim of the bowl at various speeds and tangential forces that, if performed correctly, create a sustained ringing sound.

In recent years, research on Tibetan bowls has focused on two main aspects. One is the use of real and virtual bowls in performance through novel interfaces. Atau Tanaka [18] used an array of acoustic Tibetan bowls, which he played while controlling additional electronically created or modified sounds through electromyogram and position sensing technology developed by him and Benjamin Knapp [19]. The technology was used in two ways: The first was used to electronically augment the original sound through the control of the measured gestures. The second does not use original sound, but rather the gestures create independent sound articulations.

Carr Wilkerson and co-workers [22, 23, 17] used the Mutha Rubboard Controller to play physical models of the Tibetan singing bowl. The Mutha Rubboard Controller is a controller motivated by washboard playing as present in Zydeco music. A capacitive sensing technique was used to determine the position of the key. This was used as a contact free excitation mode for the virtual bowl. The performer would use circular up-down hand motions in front of his body to feed energy into the synthesis algorithm.

Research in controllers for musical expression has seen an increased development in theoretical foundations and guiding principles [2; 4; 5; 11; 21, for example]. The mapping problem, that is the relation of control-device output to synthesis algorithm input, has seen both theoretical and experimental advances [9; 10; 14, for example].

The type of friction behavior that is responsible for the oscillatory action of the rubbing stick on a Tibetan bowl is known as stick-slip friction [1], a mechanism also reponsible for the dynamic function of string instrument bows. Bowed string controllers are under ongoing development. One line of research augments the violin bow and maintains the original bow action [24, 20] whereas another line includes haptic feedback in the controller design [12].

In the remainder of the paper we describe the design of a new controller for Tibetan singing bowls by implementing an electronic sensor version of the "puja" stick that we call the "HyperPuja".

2. HARDWARE IMPLEMENTATION OF THE BOWL CONTROLLER

In designing the first prototype of the HyperPuja stick, there were several priorities established from the onset. Because the most immediate goal of this research is to allow the performance of the Tibetan bowl physical model using traditional playing technique, we wanted to maintain the ergonomics of the stick above all. Therefore, we wanted to make a system of sensors that was both as small and as light as possible. We also aimed to maintain the natural wireless feature of both the bowl and the stick, and so it was decided that the data transmission would be performed using an RF module.

In this work, we also sought to integrate as much of the electronics within the structure of the HyperPuja stick as possible, so that in all ways the stick would give the appearance and feel of that of its traditional counterpart. Therefore, a design was desired that allowed the various components of the electronics system to be placed almost entirely inside the stick itself.

Because we wanted to create an interface that could not only be used as a means of controlling a physical model, but could also offer the player the use of the acoustic sound of the bowl (so that, for instance, a player might be able to play a duet between real and virtual bowls), another priority of the interface design was that the bowl itself remain as untouched by technology as possible.

With the above priorities in mind, we sought to create a prototype of the HyperPuja interface that would be capable of measuring data relating to the velocity of the moving stick around the bowl, the pressure between the stick and the bowl, and the acceleration of the stick along its trajectory. The first two types of measurements are of obvious interest for this project, as they relate directly to parameters of the basic physical model of the Tibetan bowl. Though acceleration measurement is not crucial to the control of the model, we included it in our design specification for possible use in extended performance control.

The acceleration measurement was performed quite simply using a commercial 2-axis accelerometer.

In order to measure velocity, we began by placing magnets, which are the only visible components of the sensing system associated with the controller, on the inside of the singing bowl . These were temporarily affixed to the side of the bowl using a small amount of easily-removable putty. Two Hall effect sensors were then employed to detect the presence of the magnetic field produced by the magnets. The rate of the appearance of the peaks in the Hall sensor data is then taken to reflect the velocity of the stick in its trajectory around the bowl.

Building the pressure sensor for the HyperPuja was a challenge, as we wanted the model to be able to respond to continuous pressure changes between the stick and the bowl occurring at any contact point on the traditional playing area of a rubbing stick. This criteria concerning area, as well as the added constraints of working with a curved surface and our initial priorities demanding simplicity in hardware, made the common use of devices such as FSRs unfeasible here.

Through experimentation, a novel pressure sensor was designed. Conductive rubber, which responds to changes in pressure with a decrease in the resistance measured between the planar surfaces at the points directly above and below the point of contact, was ultimately used. The pressure sensor was comprised of three layers of material wrapped around the stick: a thin piece of copper foil carefully adhered directly to the stick, a sheet of conductive rubber (0.5mm think) placed around the first layer of copper, and a piece of finely woven copper fabric secured over the rubber. By this construction, the conductive rubber is held in place simply by the sleeve of copper fabric and a final piece of chamois placed over the entire assembly that closely resembles the leather found on many traditional rubbing sticks. The changes in resistance that occur as a result of pressure fluctuations are measured by making contacts to the two pieces of copper material.

We began the construction of the HyperPuja stick by first hollowing out the middle volume of a traditional rubbing stick. This process left a 0.9" diameter cavity in which to place our electronics. The electronics board that houses the accelerometer, Hall sensors, microcontroller, wireless transmitter, and the battery were all placed inside the barrel of the stick. The electronics board is powered by a 3V camera-style battery that has a lifetime of over 30 hours in this system. The microcontroller used for the HyperPuja is a PIC16LF877, which possesses an internal 10-bit A/D converter. The signals from the Hall sensors and the pressure sensor are sent to inputs here. The accelerometer (ADXL202) outputs two digital signals, which are routed to two other input pins of the PIC. The data stream for all of the sensors is transmitted with a wireless transmitter using a serial protocol that is received remotely. This data stream for all the sensors is then sent using the wireless transmitter with a serial protocol. This data is then collected by a receiver on a remote board that connects to the serial input of the Windows machine used for our experiments. The electronics inside the HyperPuja stick can be seen in Figure 1.

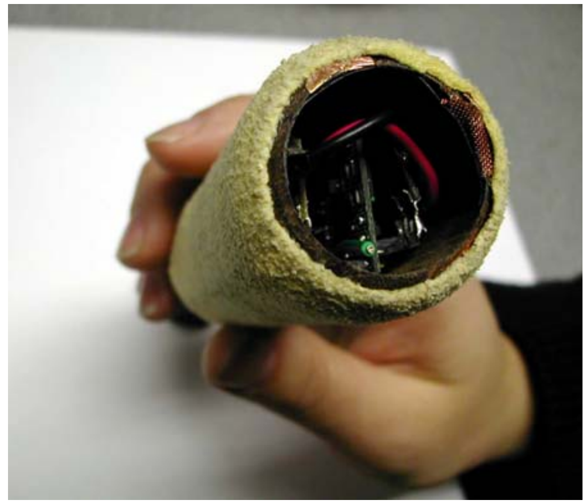

Figure 1: The electronics inside the HyperPuja stick.

The complete design can be seen in Figure 2. Here, the magnets used for the velocity measurement, the only apparent component of the sensing system, may be seen inside the bowl.

Figure 2: The HyperPuja stick with a Tibetan singing bowl. The magnet for the hall effect sensors can be seen inside the bowl.

2.1 Sensor Data and Synthesis Model Parameter Visualization

The HyperPuja data is displayed using a C++ stripchart application. For the first experiment using the HyperPuja to control the physical model of the Tibetan bowl, we established a C++ software link between this GUI and the tcl/tk GUI displaying the input parameters of the physical model. This method of interfacing between the controller and the