Physical Model Synthesis and Performance Mappings of Bowl Resonators

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Abstract

The rich partial textures and beating of the traditional tibetan bowl have tantilized listeners for centuries. In this paper we propose a real-time physical model of a singing bowl meant for use in performance. In order to be able to use it in a performance context, we control it using a rubboard musical controller. We feel that the mapping between the two instruments is uniquely natural and complementary.

1 Introduction

In this paper we propose a physical model of a tibetan bowl, which works in real-time. This model is meant to be used in live interactive performances driven by musical instrument controllers. There are two main bowl playing techniques, striking and stick ringing, each of which has a distinctive sonic quality but both of which are encompassed in a single physical model.

We felt important to preserve the original intuitive gestural motion to excite the bowl physical model. As an example of an appropriate mapping we have chosen an instrument based on the washboard, which by nature provides the player with both striking and circular movement.

2 Tibetan singing bowls

Figure 1 shows a tibetan bowl.

Figure 1: A tibetan bowl.

Oral tradition dates the singing bowl back to 560-180 B.C. in Tibet. These bowls have been found in temples, monasteries, and meditation halls throughout the world. Singing bowls are said to be made out of five to seven metals such as gold, silver, mercury, copper, iron, metal and tin, each representing a celestial body. Each of these metals are said to produce an individual sound, including partials, and together these sounds produce the exceptional singing sound of the bowl. Each bowl is hand hammered round to produce beautiful harmonic tones and vibrations. Today they are used in music, relaxation, meditation, and healing.

3 Acoustics of singing bowls

The sound of a tibetan bowl has two main characteristics: long sustained partials and a strong characteristic beating. The pitch of a bowl depends on thickness, size, and weight. While the pitch is fixed, the tone and volume can be controlled by mainly three factors: the force of the blow, the hardness of the striking object and the point of percussion.

The strong perceived beating is due to the slightly asimmetry in the shape of the bowl, which makes waves propagating in both sides of the bowl arrive slightly delayed to the ears of the listeners. Figure 3 shows the analysis, synthesis and control steps followed in order to implement the physical model of the tibetan bowl. All these steps are described in the following sections.

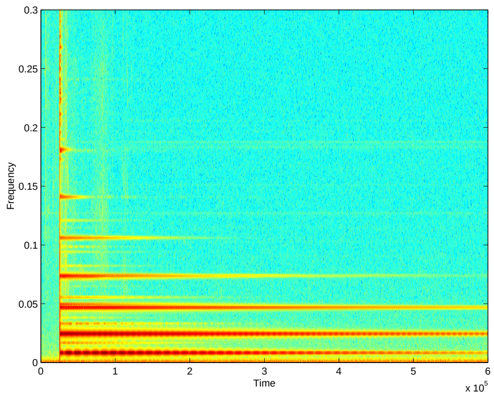

Figure 2: *Spectrum of the tibetan bowl used during the recordings. X-axis: time in samples, y-axis: normalised frequency (1 corresponds to Nyquist)*

Frequency (Hz)	Amplitude (normalized to 0 dB)	Bandwidth (dB)
186	0	0.0038
551	-18.20	0.0065
1007	-15.582	0.0026
1627	-16.34	0.0315
2337	-12.963	0.0723

Table 1: *Frequency, amplitude and bandwidth for the main resonances of the tibetan bowl.*

4 Analysis of a tibetan bowl

Figure 2 shows the spectrum of the tibetan bowl used during the recordings. The dimensions of the bowl are 21 cm in diameter and 6 cm in height.

The bowl was struck with a wooden mallet and allowed to resonate. Notice how the main resonances of the bowl are well defined and show a long decay time.

We first analysed the spectrum of the recorded bowl in order to obtain the frequency, amplitude and bandwidth of its main partials.

The analysis was performed using resonance models (8). The results are shown in table 1. In order to obtain the attack portion of the sound, we inverse filtered the detected modes. In order to model the effect of tapping the bowl the spectral characteristics of the residual were used.

5 Modeling singing bowls

Considering the strong inharmonicity present in the bowl, we decided to model each partial independently using a digital waveguide for each of them, as proposed by G. Essl and P. Cook (1).

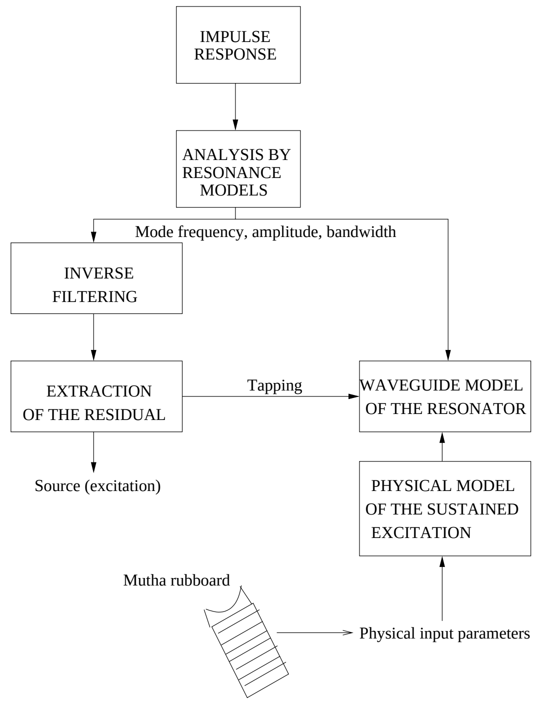

Figure 3: *Analysis, synthesis and control steps for the tibetan bowl model.*

This allows both a time and frequency domain control of the model. The time domain control is especially important while simulating the rubbing between the mallet and the bowl.

To reproduce beatings, each partial is modeled using a couple of digital waveguides simulating waves propagating in the two sides of the bowl.

Due to the asimmetry of the bowl, the two delay lines have a length difference of about three samples.

The waveguides are excited either by a sustained frictional mechanism similar to the one of a string excited by a bow (see, for example, (6)), or by a striking mechanism typical of the excitation in percussion instruments. In order to model the sustained excitation of the mallet, we develop the contact of the mallet with the bowl using a friction curve coupled with the resonator.

The shape of the curve is controlled by the velocity of the mallet, the force of the mallet and the position of the excitation.

The physics based model of the tibetan bowl is developed as an extension to Pure Data (5) called bowl∼.

The model is driven by the following parameters: size of the bowl which determines the fundamental frequency and the partials of the bowl, the force of the excitation, the velocity of the scrubbing mechanism (in the case in which the bowl is excited rubbing it in a circular motion around its lip) and an inharmonicity factor which determines the material of the bowl.

6 Application example

In order to use the bowl physical model in a real-time performance context we drove the parameters using the Mutha Rubboard. The Mutha Rubboard is a musical controller based on the rubboard, washboard, or frottoir metaphor.

It uses capacitive and piezo sensor technology to output MIDI and raw audio data.

This controller reads the key placement in two parallel planes by use of radio capacitive sensing circuitry.

The percussive output normally associated with the rubboard is captured through piezo contact sensors mounted directly on the keys. Additionally, mode functionality is controlled by discrete switching on the keys.

This new intrument is meant to be easily played by both experienced players and those new to the rubboard. It lends itself to an expressive freedom by placing the control surface on the chest and allowing the hands to move uninhibited about it or by playing it in the usual way seizing the gestural nature of the rubboard.

Figure 4 shows the way the Mutha rubboard is mapped in order to control the singing bowl.

The lengthwise position and the perpendicular position of the left channel are mapped to force and velocity of the excitation.

As with a real bowl, we can obtain an impulsive excitation by striking the board, calculating the position and the force of the excitation, and letting it resonate. On the other hand, we can also obtain a sustained excitation by moving the exciter with an almost constant speed in the vertical and perpendicolar position to the board with a circular motion.

The rigth channel is used to change the size and the material properties of the bowl. Each time the player excites a bowl with his left hand, he puts his right hand on a particular position on the right channel to choose the different frequencies and the material properties of the bowl itself.

7 Conclusions

In this paper we proposed a physics based model of a tibetan singing bowl.

The model is controlled in real-time using a new controller called Mutha rubboard.

8 Acknowledgments

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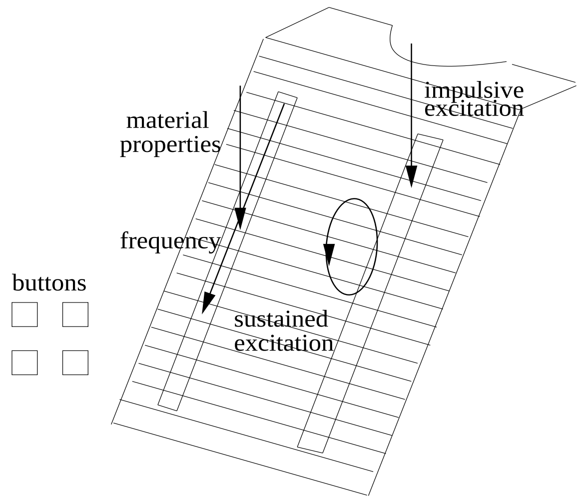

Figure 4: Mapping of the parameters from the bowl∼ model usingthe Mutha Rubb oard.

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