Analysis and Synthesis of Real-World Objects

Alex Fink
Arizona State University
699 South Mill Avenue Room 395
Tempe AZ 85281
+1 480-965-9438
alex.fink@asu.edu

Harvey Thornburg
Arizona State University
699 South Mill Avenue Room 395
Tempe AZ 85281
+1 480-965-9438
harvey.thornburg@asu.edu

Andreas Spanias
Arizona State University
699 South Mill Avenue Room 395
Tempe AZ 85281
+1 480-965-9438
spanias@asu.edu

1. INTRODUCTION

As the performance of digital technology grows, so too may the complexity of methods by which we synthesize sounds for music and simulations. Conventional methods of sound creation, such as additive, subtractive, and FM synthesis, when used to simulate real-world objects only retain the characteristics of instruments and materials when stimulated in a particular manner. The inherent expressiveness of acoustic sound sources is lost in these types of synthesis; plucking a guitar string at the 12th fret, for example, produces a far different tone the plucking near the bridge. Various forms of physical modeling, such as banded waveguides, allow for a preservation of many of the characteristics that separate acoustic objects from their electronic simulations. With a physical model, we may also vary the method by which objects are excited, including bowing, striking, plucking, or even purely synthetic stimuli. This type of sound generation is desirable, as the sound made by an object conveys information about the physical properties of an object, as well as how it is being stimulated. Synthesis through such a method allows for more realistic virtual interactions as in [1], and analysis allows better examination of activity from sound recordings. We aim to explore how to best preserve this expressiveness of real-world instruments and objects.

2. BACKGROUND

One of the simplest and earliest physical modeling methods is modal synthesis. Simply put, modal synthesis consists of a bank of resonators excited by a driving force. The bank of resonators models the instrument or sounding object itself. The frequencies of resonance, their relative amplitudes, and rates of decay are determined by the size, shape, and composition of the sounding object. This typically involves finding solutions of the wave equation for a given object. Analysis of recorded sounds is also used to determine the various spectral characteristics of instruments and objects to be simulated. The driving force is the excitation that causes the sounding object to resonate. To provide for speedy synthesis, the varying modal properties are calculated for different locations of excitation on the sounding object [1].

Improving upon the idea of modal synthesis, banded waveguides provide an efficient method of physical modeling, easily allowing for spatial sampling [Essl, Cook]. With a banded waveguide system, the exciting input is bandpass filtered about each of the modes, run through a cascade of delays and attenuating gains within that mode, and then fed back. The feeding back of each of the modes may be carried out by another set of waveguides after first accounting for any reflective properties. The delay lines account for the differing speeds of propagation for each of the modes, and they allow for the simulated sounding object to be excited at different positions. The analysis portion of banded waveguide systems to determine the frequencies of each mode and other parameters is carried out in essentially the same manner as that of modal synthesis [2].

Yet other methods of modeling sounding objects exist. The waveguide structure may be altered, replacing delays with all-pass filters [2]. Of more interest, a hybrid state-space sinusoidal model may be used to model quasi-harmonic sounds. This method separates the signal into subbands, centered about the principal harmonics. The frequencies and corresponding rates of decay of the modes within each subband are then estimated. From instantaneous phase estimates of the modes, average instantaneous frequency estimates may be found and used to determine the movement of the subband's center frequency. This last property is important for the inherent inharmonicity found in real world objects. To aid in reconstruction, input and output residuals are found [3].

3. PROPOSAL

We wish to develop a method of analyzing and synthesizing the sounds created by real-world objects, not just musical instruments. Physical properties of resonant objects, such as size, stiffness, roughness, are expressed in the sounds produced by these objects. Understanding how these properties are audibly manifested allows us to receive information about the physicality of a space and how people interact with it from sound recordings. For example, size and stiffness have a large effect on the distribution of the spectral mode frequencies; the damping properties of the object's material will determine the decay rates of the various modes. Using banded waveguide technology, we intend to explore the audible effect of warping the physical characteristics of resonant objects and vice versa. Consider the bar of a vibraphone; lower pitched notes are produced by larger bars. By lowering the pitch frequencies of a bar model, the sound produced will be perceived as originating from a larger bar than originally modeled. Changing the decay rates of the modes can effect the perception of the type of material resonating. The effects of different excitations are also of interest; striking may be replaced by rubbing or bowing, for instance. Unrealistic or impractical excitations may also be applied, such as several extremely fast strikes. A better understanding of how these physical properties and excitations manifest themselves will allow for more expressive digital instrumentation, in addition to improved activity analysis of audio recordings.

4. REFERENCES

[1] van den Doel, K., Pai, D., “The Sound of Physical Shapes,” Tech. Report 96-03, Dept. of Computer Science, University of British Columbia, Canada, 1996.

[2] Essl, G., Cook, P., “Banded Waveguides: Towards Physical Modeling of Bowed Bar Percussion Instruments,” Proc. of the ICMC, p. 321—321, 1999.

[3] Thornburg, H., Leistikow, R., “Analysis and Resynthesis of Quasi-Harmonic Sounds: An Iterative Filterbank Approach,” Proc. DAFX, London, UK, 2005.