SYNTHESIZING A JAVANESE GONG AGENG

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ABSTRACT

This paper considers the spectral properties of a Javanese Gong Ageng, the large gong used in gamelan music to mark the end of each gong cycle. The gong tone has about a dozen significant partials. The amplitude modulation of this gong is a characteristic part of its spectral evolution, and includes some synchronized frequency modulation when multiple components occur at nearly the same frequency. We have developed an additive synthesis Csound implementation for synthesizing the Gong Ageng. The model produces a tone that is very similar to the original.

1. INTRODUCTION

The Gong Ageng is the large bronze gong that marks the end of each gong cycle in Indonesian music. Gongs as large as 135 centimeters (54 inches) have been created in the past, but gongs larger than about 80 centimeters (32 inches) are rarely made now. The percent of copper mixed with other metals in the alloy varies, and iron is occasionally used if bronze isn't available. Indonesian gongs come in many sizes, but the Gong Ageng is the largest and deepest (see Figure 1). The instrument has a very deep, distinctly pitched rumble that sounds like thunder or the Ôrolling waves of the sea.' Slight differences in the opposite halves of a gong can create beating in the sound. People have poetic descriptive images for different speeds of beats, comparing slow beats with waves of water and faster beats with Bima's laughter. (Bima is one of the Pandava brothers from the *Mahabarata* epic.) The gong is considered one of the most important instruments in Javanese music. Even one missed gong tone can cause great confusion among members of the ensemble (Suryabrata 1987).

Figure 1.
Gong Ageng.

Previous work on modeling pitched percussion instruments has primarily focused on simulating Western and Chinese bells (Ma 1981, Rossing and Zhou 1989, Kuttner 1990, Rossing 1994, Zheng 1994, Horner, Ayers and Law 1997, Hibber 2003) and orchestral gongs originally from Turkey and China (Risset 1969, Chowning 1973, Harvey 1981). Our previous work explored the tones of the Woodstock gamelan, a tubulong instrument rather than a set of gongs (Horner and Ayers 1999). The Indonesian gongs are relatively unexplored by comparison, and the Gong Ageng has a lower and more focused pitch than its Chinese and Turkish counterparts.

Section 2 of this paper outlines the spectral properties of the Gong Ageng and Section 3 gives an additive synthesis model of the instrument, which is implemented in Csound (Vercoe 1992).

2. SPECTRAL PROPERTIES OF THE GONG AGENG

We analyzed a Gong Ageng that is part of Kyai Parijata, a Javanese gamelan from the 19th Century (Heins 1969) that is still used in weekly performances at the Nusantara Museum in Delft, the Netherlands. Geert Jan van Oldenborgh recorded 16-bit 44.1 kHz sample tones of the gamelan instruments (van Oldenborgh 2002). The fundamental frequency of the Gong Ageng is 44.5 Hertz.

We performed a phase vocoder spectral analysis on the Gong Ageng to estimate the amplitudes and frequencies of the partials. The phase vocoder uses a bank of bandpass filters centered on the harmonics of an Ôanalysis frequency' (Dolson 1986, Beauchamp 1993). Figure 2 shows a plot of frequency vs. time for the lower components. The dark flat lines indicate partials with significant strength. The partials at 44.5, 89, 133 and 260 Hz are at the first, second, third and sixth harmonics respectively. However, some of the partials are not at strict integer multiples of the fundamental. For example, because the inharmonic partial at 74 Hz falls between the first and second harmonics, the phase vocoder program does not have a separate bin for it, and puts it mostly into the bin of the second harmonic. Another inharmonic partial at 120 Hz falls mostly into the bin of the third harmonic. The five partials with the most significant amplitudes are the second, first, sixth, third and fifth, respectively. The fourth harmonic does not seem to be significant. Some of the partials are fairly close in frequency (e.g., components at 275 and 282 Hz). We decided to combine the harmonic and inharmonic partials that appear in the same harmonic bin into a single harmonic partial. The combined partials were originally close enough to beat together, and we have modeled the beating with amplitude and frequency modulation.

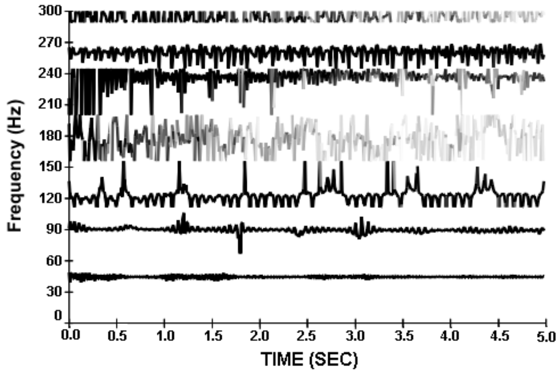

Figure 2. Frequency vs. Time Plot for the Lower Components of the Tone.

Figure 3 shows the amplitude envelopes of harmonics graphed by the phase vocoder. The first, second and sixth harmonics form the essence of the sound. The first two harmonics together form the Ôumble’ of the sound. The second partial is much louder overall than all the other partials and includes a deep modulation. As the second partial decays exponentially, the percent of modulation weakens considerably. The fundamental weakens much more slowly than the other harmonics, dominates the low points of the modulating second partial and increases in dominance as the other harmonics weaken in the decaying tone. The sixth harmonic produces the Ôing’ of the sound. The third harmonic adds a little bit more to the Ôing,’ while the other harmonics mostly contribute to the attack noise.

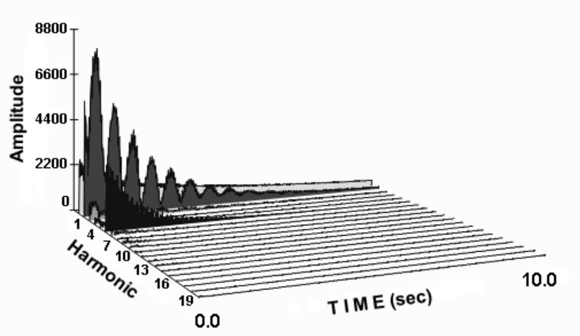

Figure 3. Amplitude Envelopes of the Harmonics.

The attack time is nearly instantaneous, as shown by the plot of the second harmonic in Figure 4. The original waveform reaches its peak within 0.015 seconds. The higher harmonics peak out equally quickly. The overall shape is an exponential decay with a deep 1.67 Hz amplitude modulation. The 15 Hz difference between the 74 Hz and 89 Hz partials superimposes a 15 Hz, shallower modulation over the slow, deep one. Figure 5 shows the amplitude envelope of the first harmonic, which has less modulation. The 1.67 Hz modulation is also apparent for the first few seconds, but is damped and quickly dies away. The difference between the 44.5 Hz and 74 Hz partials causes a shallower 29 Hz modulation. The third and sixth harmonics have similar double AM characteristics, with faster exponential decays. Figure 6 shows the amplitude envelope of the sixth harmonic, which is more representative of the higher harmonics, with only a single amplitude modulation at 15 Hz (representing the difference between the 260 and 275 Hz components).

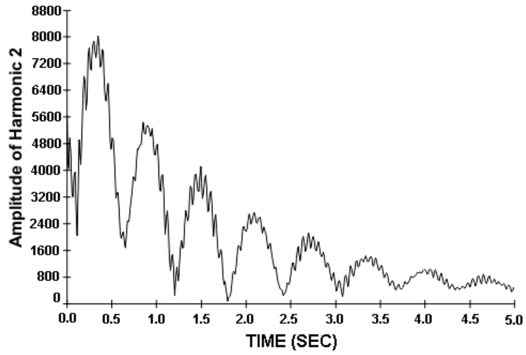

Figure 4. Amplitude envelope of the second harmonic over the first 5 seconds of the tone.

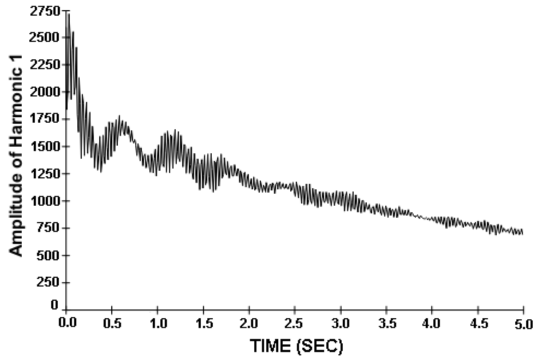

Figure 5. Amplitude envelope of the first harmonic.

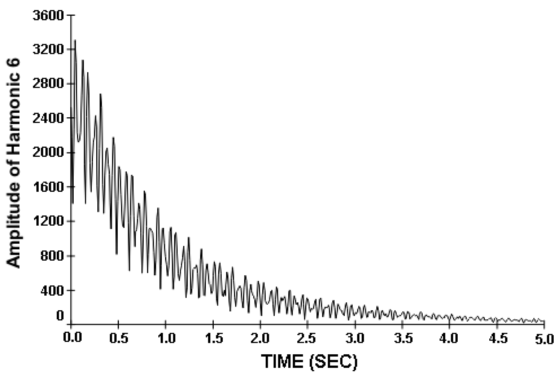

Figure 6. Amplitude envelope of the sixth harmonic.

Figure 7 shows the frequency envelope of the second harmonic. The frequency envelope contains both the 1.67 Hz and 15 Hz modulations that appear in the second harmonic amplitude envelope (Figure 5). The peaks of the frequency modulations correspond to the valleys of both amplitude modulations, repeating with a 180□phase difference. The other harmonics have similar synchronized amplitude and frequency modulations.

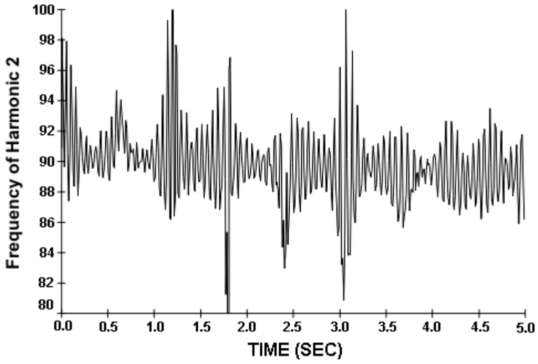

Figure 7. Frequency envelope of the second harmonic.

3. A SYNTHESIS MODEL FOR THE GONG AGENG

The synthesis model for the Gong Ageng reduces the parameter data from the analysis. Figure 8 shows the block diagram of the model, which uses additive synthesis of nine of the first 14 harmonics. We chose to exclude some harmonics in order to keep the model as simple and effective as possible without unduly sacrificing quality. For example, we omitted harmonics 4 and 8 because they consisted of incidental transient attack noise that was spread through all harmonics. Beyond harmonic 10, the clear ringing of harmonic 14 was the only significant component.

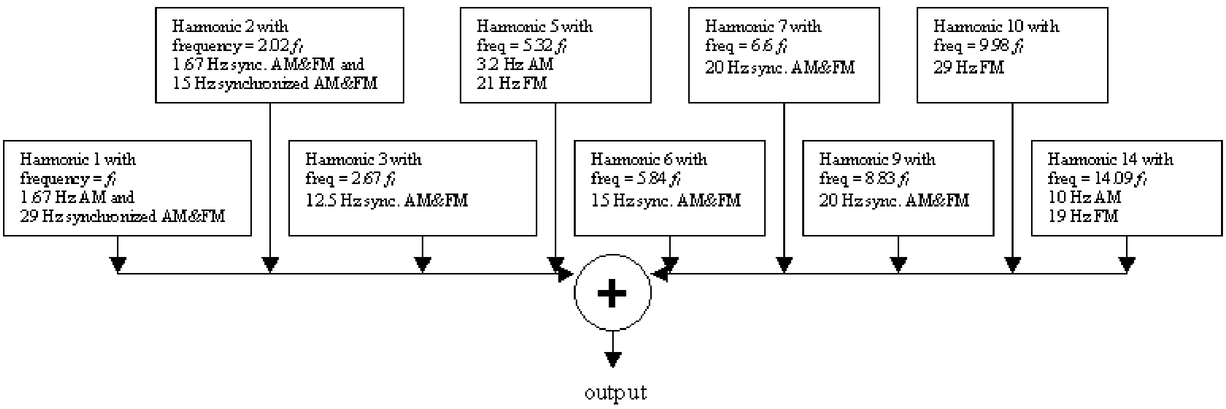

Figure 8. Block Diagram of the Model

Though many of the harmonics show double amplitude and frequency modulations, we omitted modulations, such as the slight frequency modulation at 1.67 Hz from the model of the first harmonic, that did not make a perceptual contribution. We also omitted the slow 1.1 Hz amplitude modulation from the third harmonic. To allow some spectral variation with each gong strike, each harmonic's amplitude is randomly scaled by ±15%. The harmonics with larger random amplitude scalars will have a slightly more pronounced effect on the resulting tone. Since each harmonic has its own amplitude envelope, this technique also changes the spectral evolution of the tone.

We used the models to construct a Csound instrument design. We used the breakpoint-picking idea described in Horner and Beauchamp (1996) to data-reduce the amplitude and frequency envelopes in the Csound implementation. To avoid selecting breakpoint values that would distort the envelopes, the program averaged the amplitudes of points with time values within ±20% of each breakpoint. The code includes a few extra lines at the end to simulate damping on early releases, with a 0.5 second release suitable for simulating hand-damping. Figure 9 shows the reconstructed Gong Ageng amplitude envelopes, which are very similar to the originals shown in Figure 3. The Csound orchestra and score are available at: www.cs.ust.hk/~layers/gong/index.html.

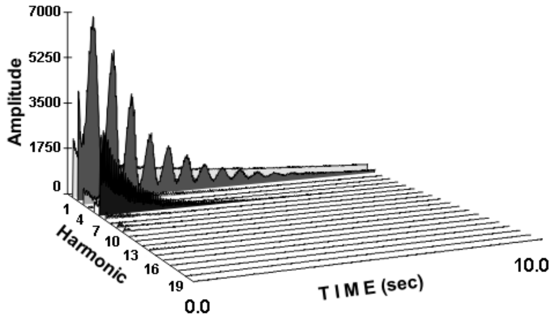

Figure 9. Reconstructed Gong Ageng amplitude envelopes.

We are also using this design for similar types of gongs, and with interesting effects such as pitch bend, which are not possible on the physical instrument.

4. CONCLUSION AND FUTURE WORK

The Gong Ageng has about a dozen prominent exponentially decaying partials, with some component frequency ratios that closely correspond to harmonics and others that are inharmonic. Many of the partials have a slow amplitude and frequency modulation of a few Hertz, and a faster modulation around 20 Hz resulting from multiple components falling into the same harmonic bin. With appropriate amplitude envelopes, we built a model for the Gong Ageng that can also produce tones within a range of about a perfect fifth above and below the original tone.

The model allows composers to synthesize the beautiful timbre of the Gong Ageng and use it to play other pitches without having a collection of gong instruments. Modifications include changing envelopes to manipulate the timbre and changing the frequency ratios to control the inharmonicity of the sound (for example, setting more inharmonic ratios for low tones and less inharmonic ratios for high tones). The model also lends itself to applications such as time stretching and timbral interpolation.

5. ACKNOWLEDGEMENTS

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