Lydia Ayers

Andrew Horner

The Hong Kong University of Science & Technology
Department of Computer Science
Clear Water Bay, Kowloon
Hong Kong
layers@cs.ust.hk, horner@cs.ust.hk

Synthesising Music in Csound with a Javanese Gong Ageng

Abstract

This paper describes synthesising music in Csound using an additive synthesis model of a Javanese Gong Ageng, the large gong used in gamelan music to mark the end of each gong cycle. The model produces a tone that is very similar to the original, with about a dozen significant partials and amplitude modulation as a characteristic part of its spectral evolution. This design also works for similar types of gongs, and allows for innovative effects such as pitch bend, time stretching, interpolation of hybrid timbres and experimental tunings, which are not possible on the physical instrument. Finally, we describe considerations, such as Indonesian notation and rhythmic structure, Csound pitch input and tuning methods, for using the synthesised Gong Ageng in a musical example.

Introduction

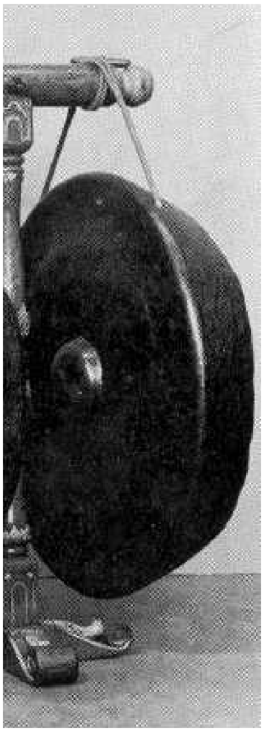

Figure 2. Gong Ageng

The Gong Ageng is the large bronze gong that marks the end of each gong cycle in Indonesian music. 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 "rolling 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, as well as "a floor to put the feet on" in Javanese dance. Even one missed gong tone can cause great confusion among the performers (Suryabrata 1987).

Previous work on modeling pitched percussion instruments has focused on simulating Western and Chinese bells (Ma 1981; Rossing and Zhou 1989; Kuttner 1990; Rossing 1994; Zheng 1994; Horner, Ayers and Law 1997; Hibbert 2003), and orchestral gongs originally from Turkey and China (Risset 1969; Chowning 1973; Harvey 1981). Our previous work also explored the tones of the Woodstock gamelan, a tubulong instrument (Horner and Ayers 1998). Indonesian gongs are relatively unexplored by comparison, and no one has analyzed a Gong Ageng.

The synthesised design also works for similar types of gongs, and allows for innovative effects such as pitch bend, time stretching, interpolation of hybrid timbres and experimental tunings, which are not possible on the physical instrument.

Synthesising the Gong Ageng

Spectral Properties

We performed a phase vocoder analysis (Dolson 1986, Beauchamp 1993) on the Gong Ageng from Kyai Parijata, a Javanese gamelan from the 19th Century (Heins 1969) 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). Figure 2 shows a plot of frequency vs. time for the lower components. The dark lines indicate partials with significant strength. The five most significant partials are

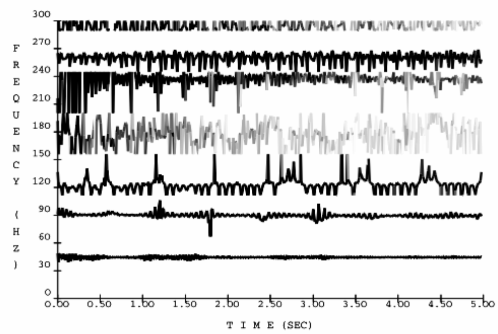

Figure 1. Frequency vs. Time Plot for the Lower Components of the Tone

significant partials are the second, first, sixth, third and fifth, respectively. The fourth partial seems to be insignificant. The fundamental frequency is 44.5 Hertz, with the second, third and sixth partials at 89, 133 and 260 Hertz, respectively. Some of the partials are not at strict integer multiples of the fundamental, and some are fairly close together in frequency (e.g., components at 275 and 282 Hertz). We combined the partials that were originally close enough together to beat, and modeled the beating with amplitude and frequency modulation. The modulation may represent the swinging motion of the gong.

Figure 3 shows the amplitude envelopes of harmonics graphed by the phase vocoder. The fundamental weakens much more slowly than the other harmonics. As the second partial decays, its deep modulation weakens. The first two harmonics together form the "rumble" of the sound. The sixth harmonic produces the "ring" of the sound. The third harmonic increases the "ring," while the other harmonics mostly contribute to the attack noise.

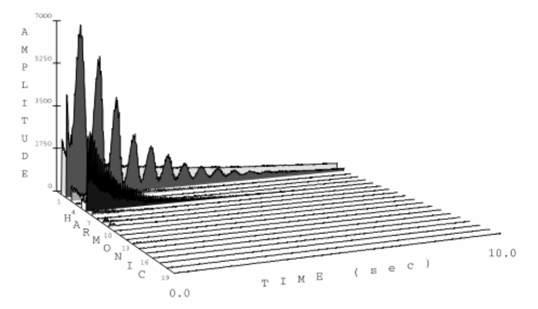

Figure 3. Amplitude Envelopes of the Harmonics

The Csound Synthesis Model

We constructed a Csound (Vercoe 1992) instrument design to model the Gong Ageng. The model uses additive synthesis of nine of the first 14 harmonics. Figure 4 shows the reconstructed Gong Ageng amplitude envelopes which are very similar to the originals shown in Figure 3. 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. To allow some spectral variation with each gong strike, each harmonic's amplitude is randomly scaled by ±15%. Since each harmonic has its own amplitude envelope, this technique changes the time-varying spectral evolution of the tone. The code includes an optional .06-second release that simulates hand damping. The Csound orchestra and score are available at: www.cs.ust.hk/~layers/gong/index.html.

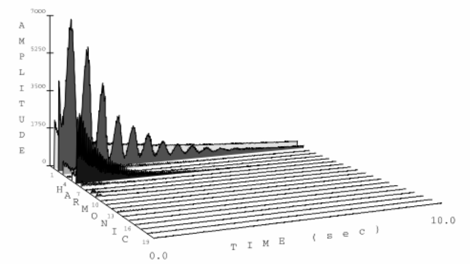

Figure 4. Reconstructed Gong Ageng Amplitude Envelopes

An Indonesian Musical Example

This section describes Indonesian music notation and the Csound pitch input and tuning methods. Although the single gong does not have the pitch range to play a full Javanese gamelan piece, it produces realistic-sounding tones within about a perfect fifth above the original tone because it has very few significant harmonics compared with many other low tones. Tones up to a major third lower than the original tone sound a little muffled, but are usable. This range sufficiently simulates the structural instruments used in an 8-beat gong cycle, where "G" represents the Gong Ageng, "N" represents the *kenong* gong and "P" represents the *kempul* gong (Becker 1984):

- N P N P N P N
G

Global Frequency Switch

Setting a global tuning frequency makes it easy to tune to the frequency of the original gong or retune the whole example in relation to a different gong frequency. In the Csound orchestra, instrument 1 sets the global tuning frequency for each example.

```
;----------------------------------
---
instr 1    ; set global frequency
gifreq     = p4   ; original: 44.5 Hz
endin
;----------------------------------
---
```

The Csound score provides the global tuning frequency for instrument 1.

```
;----------------------------------
---
; p1       p2     p3          p4
; inst     start  duration    gifreq
i1         0      1           44.5
;----------------------------------
---
```

Pitch Notation

Indonesian gamelan notation normally uses numbers from 1 to 7. This system represents Indonesian music more effectively than the fixed pitch system of western notation because the actual tuning of the pitches in Indonesian scales varies significantly (see tuning section below). Pitch 1 is the first note of the scale. Figure 6 shows a pentatonic scale in Indonesian notation. Pitch 4 is often considered an "enemy tone" that is used infrequently and usually replaces pitch 3. If pitch 7 is used, pitch 6 is usually omitted. A dot above or below a number means that the pitch is in a higher or lower octave, respectively.

1 2 3 5 6 $\dot{1}$

Figure 5. Pentatonic Scale in Indonesian Notation

Colotomic Structure, Rhythm Notation

Indonesian music typically uses a group of gongs to support the other instruments, which play the melody. The supporting gongs play in a metric structure that leads to the strongest beat, played by the largest gong. Units of 4 beats (called *gatra*), which are the opposite of 4/4 measures because the strongest beat is last, form the colotomic structure.

The modeled range of the Gong Ageng is sufficient to simulate the structural gong instruments used in a two-*gatra*, 8-beat gong cycle. In the following example, we set pitch 1 at the original frequency for the Gong Ageng, pitch 3 for the kenong gong and pitch 5 for the kempul gong. A number by itself usually represents one quarter-note beat. A 0 on all or part of a beat means a rest.

```
| (- N P N | P N P G) |
|  0 3 5 3 | 5 3 5 1  |
```

Pitch Input Method

It is easy to input pitches using the pitch notation system described in the previous section. We set up the Csound score with two pitch parameter fields: one handles the pitches, and the other controls the octaves. The following is a Csound score example using the Gong Ageng model at several pitch levels to create the 8-beat gong cycle described in the previous section.

```
;-------------------------------------
; p1   p2  p3   p4     p5   p6
;inst  st  dur  amp    pch  oct   gong
i2     1   10   7500   3    1     ; N
i2     2   10   4000   5    1     ; P
i2     3   10   9000   3    1     ; N
i2     4   10   4000   5    1     ; P
i2     5   10   7500   3    1     ; N
i2     6   10   4000   5    1     ; P
i2     7   10   6000   3    1     ; N
i2     7   20   12000  1    1     ; G
;-------------------------------------
```

Tuning

The tuning of the Gong Ageng varies from village to village in Indonesia. Each gamelan is tuned according to the taste of the owner or gamelan group (and the tuner). Instruments are usually tuned by ear to sound well as a set. We used pitch 1 for the Gong Ageng in our example because we liked it, but the Gong Ageng is usually tuned to pitch 2, 3, 5 or 6, according to the availability of particular instruments. The same Gong Ageng may be used in *slendro* and *pelog* if it is tuned to the *timbuk* (the pitch that is the same in both tuning systems). A particularly fine large Gong Ageng may be loaned to another group for a special performance, as the precise frequencies of the very low tones are less easy to hear.

Two function tables control the tuning of the pitches. The example shows function tables for just intonation frequency ratios for a slendro tuning described by Lou Harrison (1971), though Indonesian tuning is not usually in just intonation. Function table 9 finds the index for function table 10, which contains the pairs of numbers in the just frequency ratios. The ratio 10/7 is a placeholder for the infrequently used pitch 4, and, if needed, a higher pitch 7 could be added in a similar manner at the end of both tables.

```
;-----------------------------------
---
; function tables
; pitch to choose ratios
f9 0 16384 -17 0 0 105 1 205 2 305 3
405 4 505 5 605 6

; Lou Harrison's Slendro tuning ra-
tios
; pitch    1    2    3   4    5   6
f10 0 64 -2 1 1  8 7  4 3 10 7 3 2
12 7
;-----------------------------------
---
```

The next example shows the same scale using rational numbers in the function table. Rational numbers could more accurately represent the tunings of the Indonesian gamelan groups shown in McPhee (1966).

```
;-----------------------------------
---
; Lou Harrison's Slendro tuning ra-
tios
f10 0 64 -2 1.0   1.1429 1.3333 1.4286
          1.5    1.7143
;-----------------------------------
---
```

Alternatively, the function table could contain the frequencies, a system that works well enough for fixed tunings, such as a composition for a particular gamelan. An advantage of storing the tuning data in the function table, rather than in the instrument design, is that it provides flexibility in retuning to suit different gamelan groups.

Pitch Bend

One beautiful computer effect is bending the pitch up or down. Although few physical gongs can bend the pitch (and those that can are more likely Chinese than Indonesian), this effect works very well with the synthesised design. The same synthesised gong can bend to a variety of pitches within a reasonable range, unlike the Chinese pitch-bend gongs, each of which bends to a set pitch.

Finishing Touches

We wrote a short utility program which writes the tempo statement with subtle beat scaling to give the beat a more human feeling and added reverb for a large occupied hall, which works well for this instrument.

```
;-------------------------------------
; tempo statement
t0 59.5  1 61.0  2 59.6  3 60.0  4 61.0
5 60.4   6 61.2  7 59.6
;-------------------------------------
```

Conclusion and Future Work

The Gong Ageng has about a dozen prominent exponentially decaying partials. 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 synthesise the beautiful timbre of the Gong Ageng and use it to play other pitches without having a collection of gong instruments. The synthesised design also works for similar types of gongs, and allows for innovative effects such as pitch bend, time stretching, interpolation of hybrid timbres and experimental tunings, which are not possible on the physical instrument. Modifications including 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).

Acknowledgements

This work was supported in part by the Hong Kong Research Grant Council's Projects HKUST6167/03E and HKUST6020/02H. We would like to express our appreciation to Geert Jan van Oldenborgh for recording and making the excellent Delft gamelan tones available, and to James Beauchamp for the excellent spectral analysis and display package *Sndan* that we used for the spectral plots in this paper.

References

Beauchamp, J. 1993. "Unix Workstation Software for Analysis, Graphics, Modification, and Synthesis of Musical Sounds," *Audio Engineering Society Preprint*, No. 3479.

Becker, Judith, ed. 1984. *Karawitan: source readings in Javanese gamelan and vocal music*. Center for South and Southeast Asian Studies, University of Michigan, Ann Arbor, Mich.

Chowning, J. 1973. "The Synthesis of Complex Audio Spectra by Means of Frequency Modulation," *Journal of the Audio Engineering Society*, 21(7): 526-34.

Dolson, M. 1986. "The Phase Vocoder: A Tutorial," *Computer Music Journal*, 10(4):14-27.

Harrison, Lou. 1971. *Lou Harrison's Music Primer*. Edition Peters, New York.

Harvey, J. 1981. "Mortuos Plango, Vivos Voco: A Realization at IRCAM, " *Computer Music Journal*, 5(4): 22-24.

Heins, E. 1969. "Tempo (Irama) in de M.-Javaanse gamelanmusiek: ter introductie van Kjai Paridjata," *Kultuurpatronen* (patterns of culture); dl. 10-11, pp 30-57 (with English summary). Delft Ethnographic Museum.

Hibbert, B. 2003. *Simulation of Bell Sounds*. www.hibberts.co.uk.

Horner, A., Ayers, L. and Law, D. 1997. "Modeling Small Chinese and Tibetan Bells," *Journal of the Audio Engineering Society*, 45(3): 148-59.

Kuttner, F. 1990. *The Archaeology of Music in Ancient China*. Paragon House, New York.

Ma, C-Y. 1981. "Ancient Chinese Two-Pitch Bronze Bells," *Chinese Music*, 3(4): 81-86.

McPhee, C. 1966. *Music in Bali: a study in form and instrumental organization in Balinese orchestral music*. Yale University Press, New Haven, CT

van Oldenborgh, G. 2002. Museum Nusantara, Delft, the Netherlands, website: 222.xs4all.n./~gjvao/gamelan/delft/.

Risset, J-C. 1969. *Introductory Catalogue of Computer-Synthesized Sounds*. Bell Telephone Laboratories, Murray Hill, N.J.

Rossing, T. and Zhou, H-F. 1989. "Sound Spectra of Ancient Chinese Bells in the Shanghai Museum," (Paper M7) 117th Meeting of the Acoustical Society of America, abstract in *Journal of the Acoustical Society of America*, 85, S33.

Suryabrata, B. 1987. *The Island of Music: an essay in social musicology*. Balai Pustaka, Jakarta.

Vercoe, B. 1992. *Csound: A Manual for the Audio Processing System and Supporting Programs with Tutorials*. MIT Media Lab, Cambridge, MA

Zheng, R-D. 1994. "A Preliminary Investigation on the Designs and Characteristics of the Pre-Qin Two-Tone Set-Bells," *Two-Tone Set Bells of Marquis Yi*, ed. Chen Cheng Yih, World Scientific, Singapore, pp. 411-452.