Virtual *New Musical Resources*

Henry Cowell's treatise on music theory and composition — *New Musical Resources,*[1] first published in 1930 — is a seminal work that affected later music in the 20th century and continues to affect the work of composers today.[2] Cowell's theories of meter and rhythms based upon relationships from the harmonic overtone series were prophetic for future generations of composers. Technology and mechanics were used by Cowell during his lifetime to demonstrate his musical theories based upon mathematical principles. Several composers and theorists have continued to use computers and technology to create musical tools based on Cowell's theories. This paper discusses the use of music technology as a tool to facilitate the understanding of Cowell's ideas. Specifically, I propose a computer-based system, using the musical software Pure Data, that aims to demonstrate theoretical principles from *New Musical Resources* with examples of music-based computer calculations and computer-generated visual and aural examples.

The bulk of *New Musical Resources* focuses on the discussion of rhythm. The basis of Cowell's theory of rhythm is rooted on mapping rhythms to the ratios of pitch occurring in the natural harmonic overtone series. Cowell's musical theories evolved from his studies at the University of California with Charles Seeger. Cowell was very influenced by Seeger's teachings. In Cowell's article, "Charles Seeger" from *American*

---

[1] Henry Cowell, *New Musical Resources*, with notes and an accompanying essay by David Nicholls. Great Britain: Cambridge University Press, 1996.

[2] Kyle Gann, "Subversive Prophet: Henry Cowell as Theorist and Critic." Excerpts from the article published in *The Whole World of Music: A Henry Cowell Symposium*, David Nicholls, editor (Great Britain: Harwood Academic Press, 1997); available from http://www.kylegann.com/Cowell.html; Internet; accessed June 15, 2008.

Composers on American Music he writes, "Charles Seeger is the greatest musical explorer in intellectual fields which America has produced, the greatest experimental musicologist."[3] He also states later in the article, "One could go on indefinitely and not exhaust the number of subjects in which he has been a pioneer."[4]

Seeger had pioneered a unique idea that polyrhythms and their rhythmic relationships could be likened to the pitch relations of polyphonic music, specifying distinct levels of "rhythmic dissonance" contained in the broader field of "rhythmic harmony."[5] Rhythm was only one aspect of Seeger's theories that also included a focus upon other non-pitch musical materials and how they can relate to pitch and harmony. Seeger formulated these musical theories into his pedagogy while teaching Cowell and Ruth Crawford and subsequently solidified them into his theoretical treatise, *Tradition and Experiment in (the New) Music*. Although he "finalized" the treatise with the help of Ruth Crawford in 1929,[6] it was only published posthumously as part of Seeger's *Studies in Musicology II: 1929-1979* in 1994.

Cowell systematized and furthered Seeger's ideas of "rhythmic harmony" in *New Musical Resources* by strictly mapping rhythms to ratios from the harmonic overtone series. Taylor Greer writes in his critical remarks for *Tradition and Experiment in (the New) Music* that Cowell's "correlation between pitch and non-pitch functions, of

---

[3] Henry Cowell, "Charles Seeger," in *American Composers on American Music*, ed. Henry Cowell, (New York: Frederick Ungar Publishing Co., 1962), 119.

[4] Ibid., 123.

[5] Charles Seeger, *Tradition and Experiment in (the New) Music* in *Studies in Musicology II: 1929-1979,* ed. Ann M. Pescatello, (Berkeley/ Los Angeles: University of California Press, 1994), 131.

[6] Ann M. Pescatello, "Introduction," In Seeger *Studies in Musicology II: 1929-1979.* ed. Ann M. Pescatello, (Berkeley/ Los Angeles: University of California Press, 1994), 8.

course, strongly resembles that of Seeger; Cowell, however, takes it to much greater extremes—as if he were writing a set of compositional variations on an acoustic theme."[7] Seeger's rhythmic approach is less systematic with a broader and more general outline of similar concepts.

Cowell's theoretical rhythms were fundamentally scaled or mapped onto the harmonic series that was already deemed "musical" by Western musicians due to the nature of its physical relationship to acoustics and resonance. Example 1 shows the harmonic series of a string based upon shortening its length by a half, third, fourth, fifth, and sixth. These harmonic overtones are integer multiples of the fundamental frequency. The first harmonic is the fundamental multiplied by two, the second harmonic is the fundamental multiplied by three, etc. Example 2 shows an expanded overtone series of the note A1 (55 Hz) notated on a grand staff. Musical scales that are constructed from whole number ratios such as the overtone series are considered to be in just intonation. The colored black notes are slightly out of tune compared to the equal-tempered tuning system and are signified as flat or sharp in the example by the plus and minus signs. Notice how each harmonic overtone's frequency is 55 Hz higher than the previous harmonic, but the intervals between subsequent harmonics become smaller due to the logarithmic nature of pitch.

In *New Musical Resources* Cowell describes how tones in the harmonic series have vibration speeds that are periodically related. Example 3 shows the first five harmonic partials and the relationships of their number of vibrations in a given space of

---

[7] Taylor Greer, "Critical Remarks," in Seeger *Studies in Musicology II: 1929-1979*, ed. Ann M. Pescatello (Berkeley/ Los Angeles: University of California Press, 1994), 37.

time. From this diagram we can see that in the time it takes the fundamental to vibrate at sixteen times in a second (or 16 Hz.), the second harmonic has accomplished two sets of sixteen vibrations for a total of thirty-two vibrations (32 Hz.). The third harmonic contains three sets of sixteen vibrations in the same space of time at 48Hz and with each subsequent overtone there are an additional group of 16 vibrations per second. Cowell writes in *New Musical Resources*, "The vibration lengths may thus be thought of as making a sort of pattern, in which the units start at the same instant, separate, and reassemble at a point a fixed distance away; and this they continue to do as long as the tones are sounded together. The reason why the simultaneous tones result in harmony instead of chaos of sounds is that at regular intervals the vibrations coincide; and in tones forming a musical interval, the smaller the number of units that must be passed over before that coincidence is re-established, the more consonant is the interval."[8]

If we apply the same concept of temporal relativity of pitches within the harmonic series to rhythm we can draw a close comparison between the two mediums. If we take the fundamental frequency and equate it with the whole note, which as Cowell states in *New Musical Resources* is "the accepted fundamental unit with which to measure musical time (or duration)"[9] we find that subdivisions of the whole note by integers greater than one (< 1) display a similar pattern. Example 4 shows these patterns polyrhythmically against one another in a similar fashion. The half notes are in a rhythm that is twice the speed of the fundamental (whole note) at a ratio of 2:1 are equated to the second harmonic. The triplet half notes are at a ratio of 3:1 and are correlated to the third

[8] Henry Cowell, *New Musical Resources*, with notes and an accompanying essay by David Nicholls, (Great Britain: Cambridge University Press, 1996), 47-48.

[9] Ibid., 49.

harmonic. This process continues and is shown in Example 4 up to the 12th harmonic where 12 notes sound in the space of one whole note.

Cowell's theories on rhythm were revolutionary in that they gave the harmonic series' pitch relationships known for ages a strange, new form of rhythmic life. Cowell discovered the close connection between pitch and rhythm in that they both share a physical relationship to time.

Cowell and Leon Theremin worked together in 1931 to invent a mechanical instrument, the Rhythmicon, which fundamentally exemplified Cowell's theories of rhythmic relativity to the harmonic overtone series and made the polyrhythmic overtone ratios easily performable through the use of a machine. The Rhythmicon's various rhythms could be turned on and off through the use of a mechanism similar to a piano keyboard, giving the instrument the ability to be used in performance. These features make the Rhythmicon one of the first interactive mechanical instruments.[10] Cowell wrote two pieces for the Rhythmicon; *Rhythmicana*, a concerto for Rhythmicon and orchestra; and *Music for Violin and Rhythmicon*;[11] demonstrating its compositional usefulness. In addition to its use in composition, the Rhythmicon was a useful tool for ear training and experimentation.

The influence of Cowell's *New Musical Resources* is further evident from the music theorists and composers who have embarked on creating new renditions of the Rhythmicon using computers and audio hardware. The highlights of these new

[10] Margaret Schedel, "Anticipating Interactivity: Henry Cowell and the Rhythmicon," *Organised sound: An International Journal of MusicTechnology* 7, no.3 (2002): 247-254.

[11]Alan Rich, *American Pioneers: Ives to Cage and Beyond*, (London: Phiadon Press, 2007), 128.

computer-based Rhythmicons include Nick Didkovsky's *The Online Rhythmicon* (using Java);[12] Leland Smith's computer realization of Cowell's *Rhythmicana*, along with the subsequent world premiere of the work;[13] and David Mooney's *Rhythmicon Sections*, a work for "virtual Rhythmicon" in twenty-four sections.[14] These computer-based Rhythmicon studies are a tremendous help in furthering the study of Cowell's theories.

However, there still does not exist a simple, freely available, computer-based system that focuses on all of the theories proposed by Cowell in *New Musical Resources*. I would like to propose such a system, where the various interactive computer programs could present each of the individual elements of the book's theories in an open-ended manner using mathematical algorithms. The individual programs could be combined by the user to create a "Rhythmicon-like" instrument if desired, but will also be able to function independently of the Rhythmicon paradigm for other compositional strategies and sound experiments. My approach is similar to the ideals that Cowell and Theremin sought after with the Rhythmicon in that it is fundamentally driven by how technology can be applied as a tool and function as an instrument to illuminate Cowell's musical theories.

The *Virtual New Musical Resources* computer program will include user-controllable tools that will be easy to comprehend, and their understanding can be augmented and easily followed by also studying *New Musical Resources*. The tools that I

---

[12] Nick Didkovsky, "The Online Rythmicon" commissioned by American Public Media; available from http://musicmavericks.publicradio.org/rhythmicon/; Internet; accessed June, 15, 2008.

[13] Leland Smith, "Henry Cowell's Rhythmicana," *Anuario Interamericano de Investigacion Musical,* 9, (1973): 134-147.

[14] David Mooney, "The Rhythmicon," available from http://www.city-net.com/~moko/rhome.html; Internet; accessed June 15, 2008.

have already developed include the heart of the program– the Overtone Ratio Calculator, along with the accompanying Rhythm Generator. Each of these tools is incorporated into the program to create a synthesis of the musical ideas from the book. The individual programs can be combined to discover new combinations of sound foreshadowed by Cowell's brilliant and visionary musical ideas.

The programs are developed using the free, open-source music programming environment, Pure Data, created by Miller Puckette. This allows anyone with a modern computer with Windows, Linux, or Apple operating system to run *Virtual New Musical Resources* and start experimenting with the programs. Pure Data programs are modular by nature and can easily be connected together by the user with virtual patch cords. This modular system lends itself well to the programs in *Virtual New Music Resources* as each program performs specific functions that can be flexibly interconnected. In addition, the modular approach allows the tools to be studied one at a time, while also encouraging the user to dream up his or her own combinations of the programs giving them the ability to be implemented into highly complex structures.

The Overtone Ratio Calculator program as shown in Example 5 is a simple program that calculates the frequency of the overtones by multiplying the fundamental frequency input from the user by specific harmonic ratios. In this example the harmonic ratios are integer multiples of the fundamental frequency. With this simple program the user simply controls the fundamental frequency and the computer quickly calculates all of the harmonic overtones of the fundamental. This particular computer algorithm is especially useful with regard to the theories from *New Musical Resources* in that it can be used recursively to not only calculate harmonic pitch relationships, but also tempo relationships in the design of the final Rhythmicon-like instrument. The frequency data simply is mapped onto the beats-per-minute control of the instrument. This is made possible by dividing 60 seconds or 1 minute by the given frequency to calculate the note's duration. For instance if we divide 60 (s)/ 60 (Hz) we get 1 second. This one-second duration is analogous to the beats per minute pattern of 60 bpm, or 1 beat per second. Therefore, beats per minute or tempo are mapped to frequency through the following formula: 60 (seconds)/ frequency (Hz) = rhythmic duration (seconds).

Using this Overtone Ratio Calculator as a controller we can start to build a Rhythmicon-like instrument, which maps both pitch and tempi to the harmonic series. For example, the next program, the Overtone Rhythmicon, as shown in Example 6, is an instrument that encompasses these ideas. This computer-based Rhythmicon model is similar to the Rhythmicon that Cowell and Theremin built, which featured piano keyboard-like control of polyrhythms and the ability to control fundamental frequency and fundamental tempo. Higher pitches play in faster rhythms and with each overtone an extra note is added. For instance, harmonic six gives a sextuplet rhythm against the fundamental's whole note. Overtone six's rhythm is a septuplet, and with each higher subsequent overtone, the subdivision increases by one. The user can also adjust the tempo (in beats per minute) of the fundamental rhythm. This Rhythmicon-like instrument, based on the ratios from the Overtone Ratio Calculator, is a useful tool for music theory, ear training, experimentation, and composition.

As mentioned earler, the algorithmic design of *Virtual New Musical Resources* is especially advantageous, because programs can be implemented recursively to complete similar or related tasks, can function modularly with one another, and are designed for maximum flexibility for use with the other programs. For example, what if the user decides that he or she wants to discover the corresponding relationships between pitch and rhythm based on a different scale than the one offered by the natural harmonic overtone series? By simply making modifications to the values for mathematical ratios of the the Overtone Ratio Calculator, I developed a separate pitch generator, which I simply call the Interval Ratio Calculator. The Interval Ratio Calculator is shown in Example 7. The program calculates all of the frequencies of a 12-note scale in just intonation based upon the supplied incoming fundamental frequency. This means that when a pitches' fundamental frequency is supplied, the Pitch Ratio Calculator outputs the frequency of all of the other eleven intervals of the 12-note just intonation scale based upon the value of the supplied fundamental.

Using the Interval Ratio Calculator program I developed a new and different Rhythmicon-like instrument, The Interval Rhythmicon, that demonstrates the relationships between the intervals of a 12-note just intonation scale and the polyrhythmic relationships formed from that same scale. The Interval Rhythmicon is shown in Example 8. The differences in the instrument's rhythms using Intervallic ratios in this model are much harder to aurally perceive than in the model based upon ratios of the harmonic overtone series. This is because they only approach the first overtone, or the interval of the octave, and consequently their rhythms span twelve rhythmic divisions between the fundamental (whole note) and its first overtone (half note).

These rhythms are impossible to notate using our traditional notation system. Cowell developed his own notations for these rhythms using differently shaped noteheads. Cowell's notations' rhythmic values are based on divisions of the whole note by odd values such as thirds, fifths, sevenths, ninths, elevenths, thirteenths, and fifteenths. These notes were called third-notes, fifth-notes, seventh-notes, etc. Cowell considered these notation innovations to be a natural musical development and employed them in his early piano composition, *Fabric,* which featured complex polyrhythmic strands demonstrating Cowell's notational innovations. Cowell states in *New Musical Resources* that, "until we develop further in rhythmic appreciation, only the simpler ratios of the scale will be used."[15] These subtle rhythmic variations are difficult to feel or hear, but we can begin to understand them by using programs for aural training of polyrhythms as exemplified by The Interval Rhythmicon.

I have several ideas for expansion of the *Virtual New Musical Resources* program: specifically, I would hope to see an extension of overtones to more than 11 harmonics or intervals. In addition, I have started to make significant process toward making a tone cluster generator based upon Cowell's theories from *New Musical Resources* on tone clusters and hope to present it as part of the software package soon. I would also like to see the project branch out into applicability with control specifications such as MIDI. Because of the broad nature of the project, I envision an expansion into an open development environment where other programmers could contribute to *Virtual New Musical Resources* to help make it a more complete culmination of Cowell's theories. The two fundamental qualities that should be imposed on these future programs are (1) the programs must present a system based upon theories from *New Musical Resources* and (2) these programs should also give appropriate aural or visual feedback when

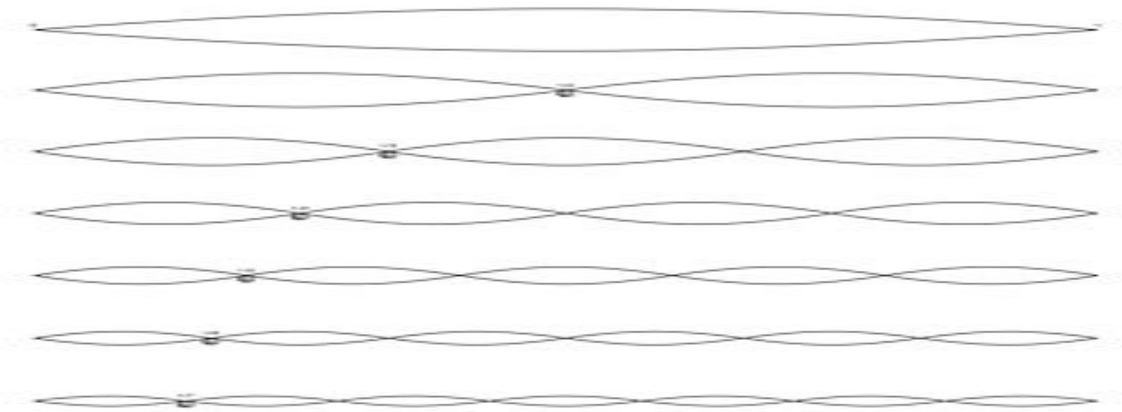
---

[15] Henry Cowell, *New Musical Resources*, with notes and an accompanying essay by David Nicholls, (Great Britain: Cambridge University Press, 1996), 101-102.

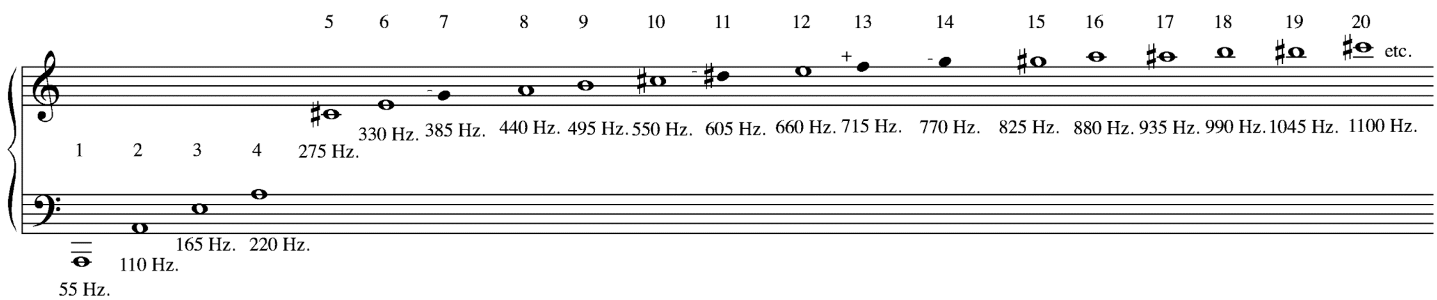
necessary.

In conclusion, Cowell's musical theories from New Musical Resources have been consistently incorporated into various technologies. This includes technology available during Cowell's lifetime as exemplified by Cowell and Theremin's Rhythmicon. Cowell's theories continue to be incorporated technologically and this is evident from the programs mentioned earlier by other composers and theorists and the programs that I have presented. Technology can be utilized to better understand the theories contained in *New Musical Resources*. I proposed that these theories be incorporated in a more flexible and open manner using my model, *Virtual New Musical Resources*, which gives musicians using the computer the ability to explore Cowell's theories. As the development of *Virtual New Musical Resources* proceeds it will become an even more useful tool for music theory, aural training, experimentation, and composition.

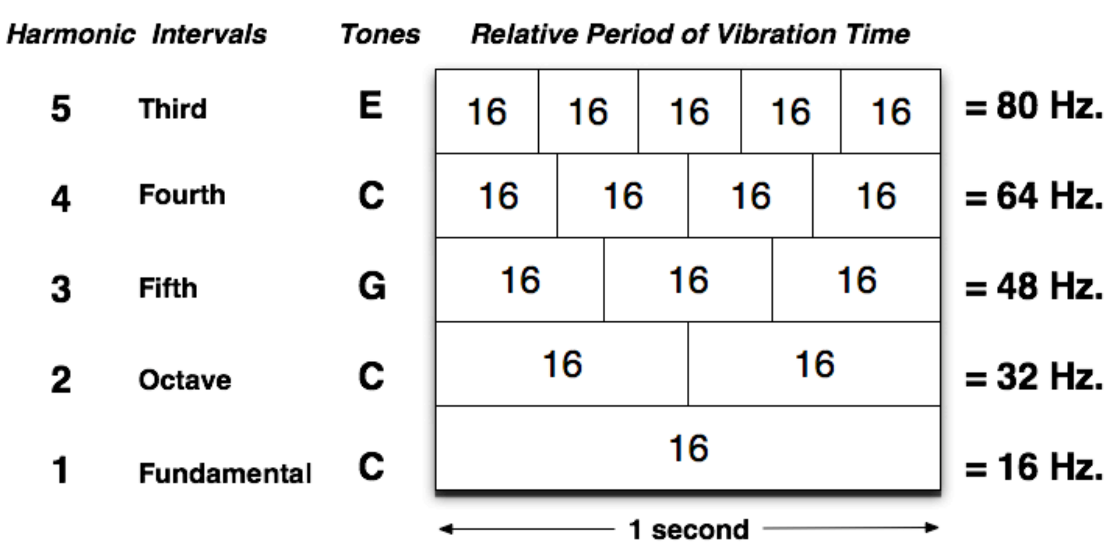
Example 1: Harmonic series of a vibrating string: fundamental and six harmonics



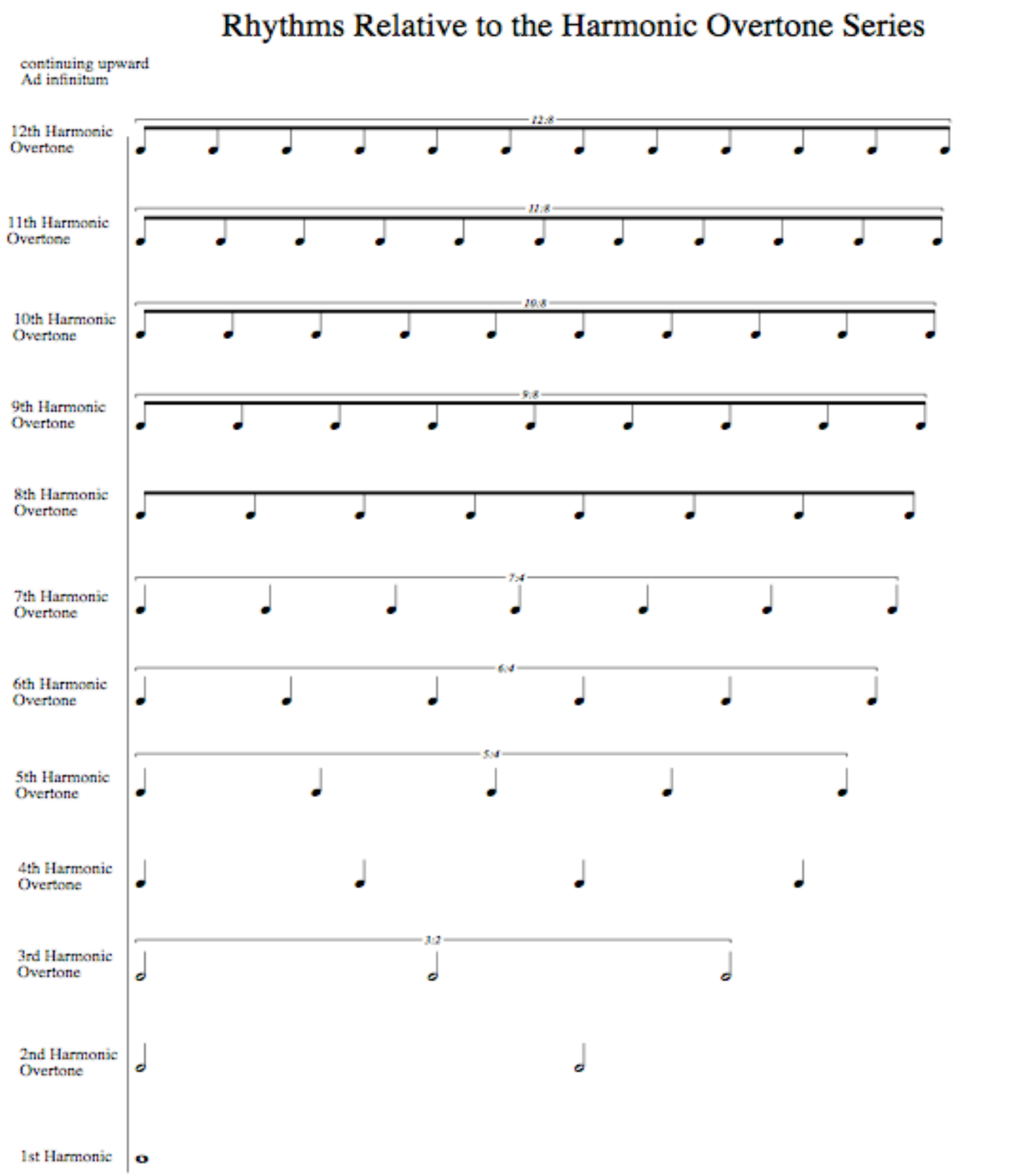
Example 2: Harmonic overtone series on grand staff based on A1 (55 Hz.)



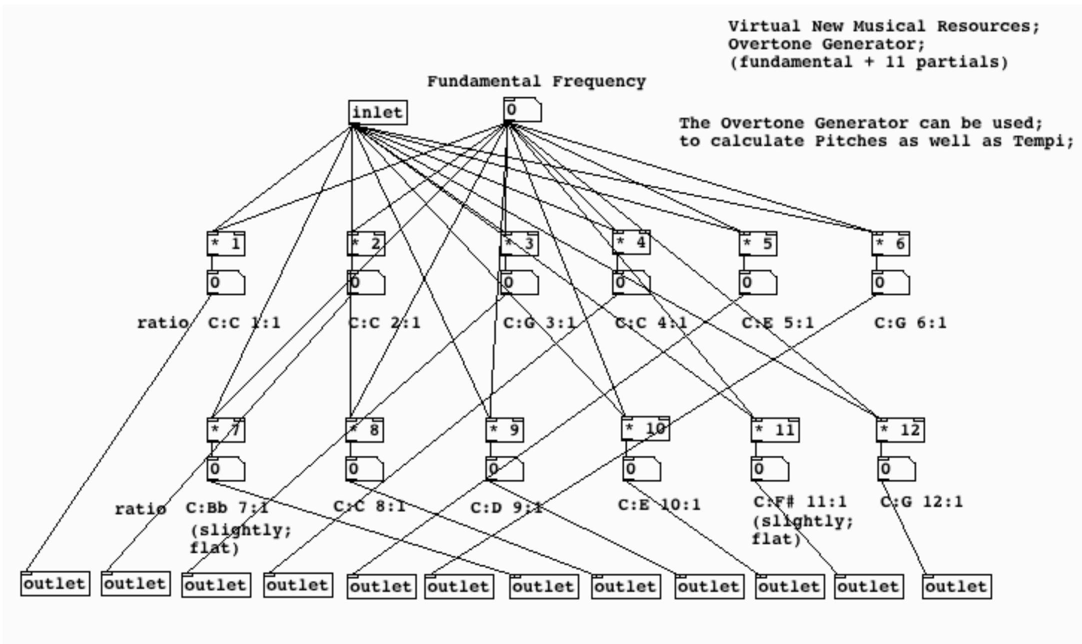
Example 3: Relationships between pitch and time



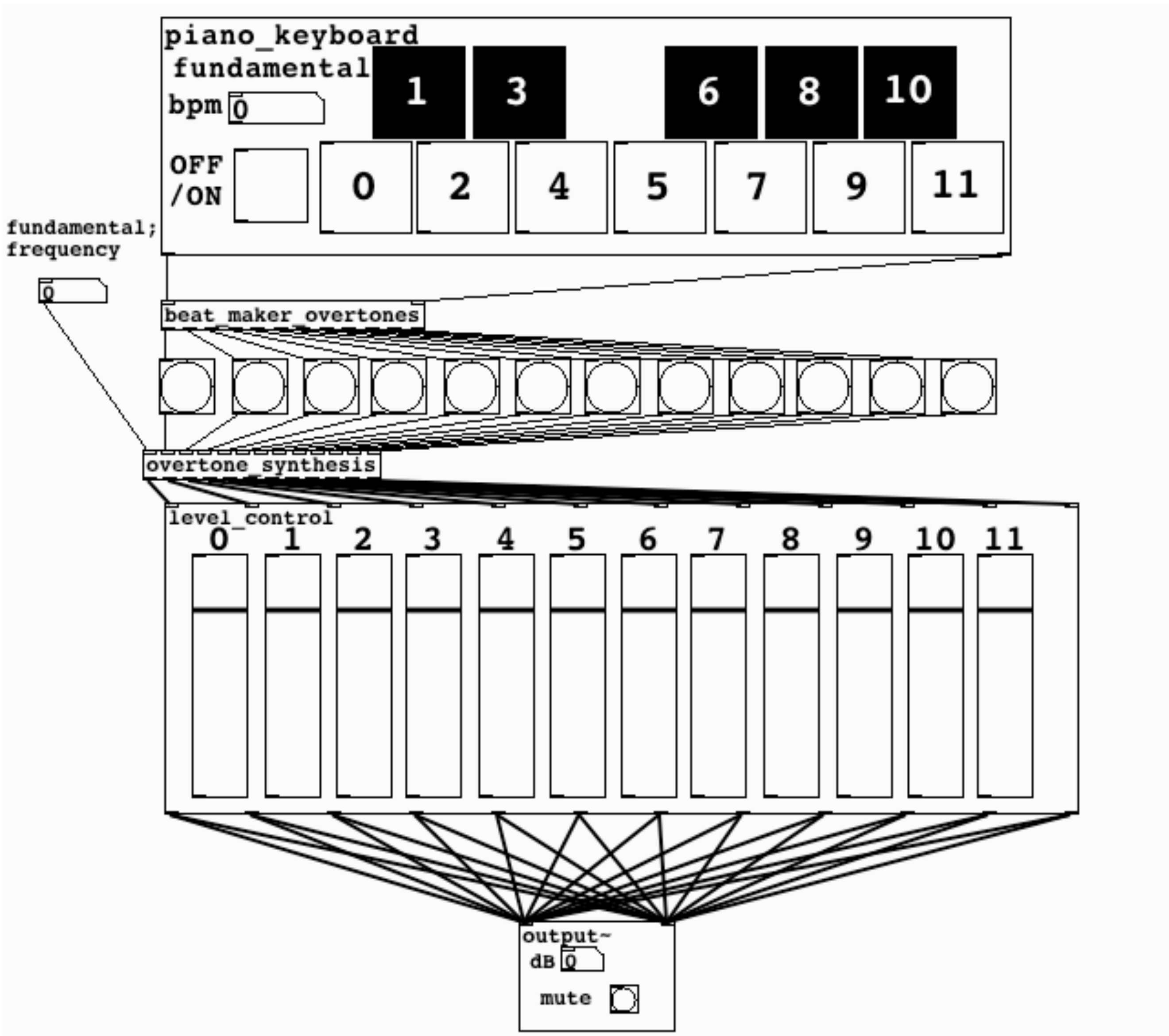
Example 4: Rhythmic / Pitch Relativity



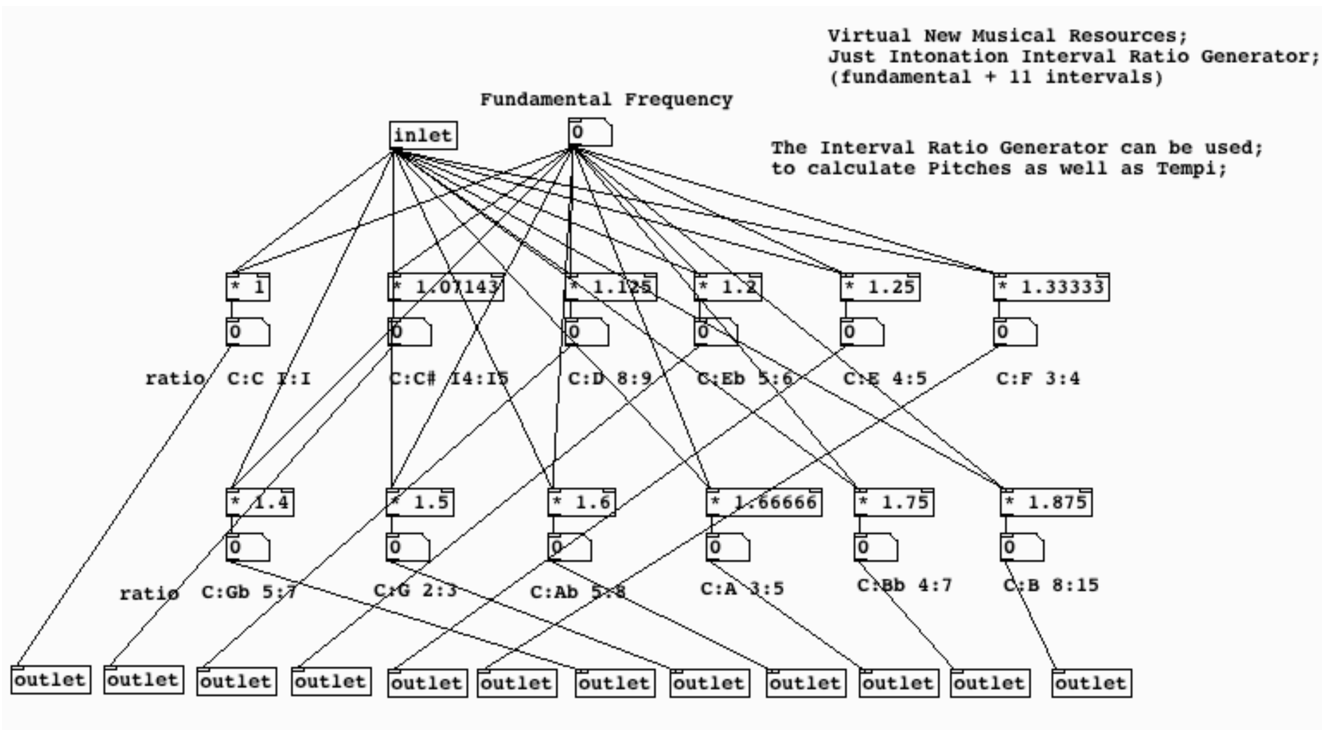
Example 5: Overtone Ratio Calculator



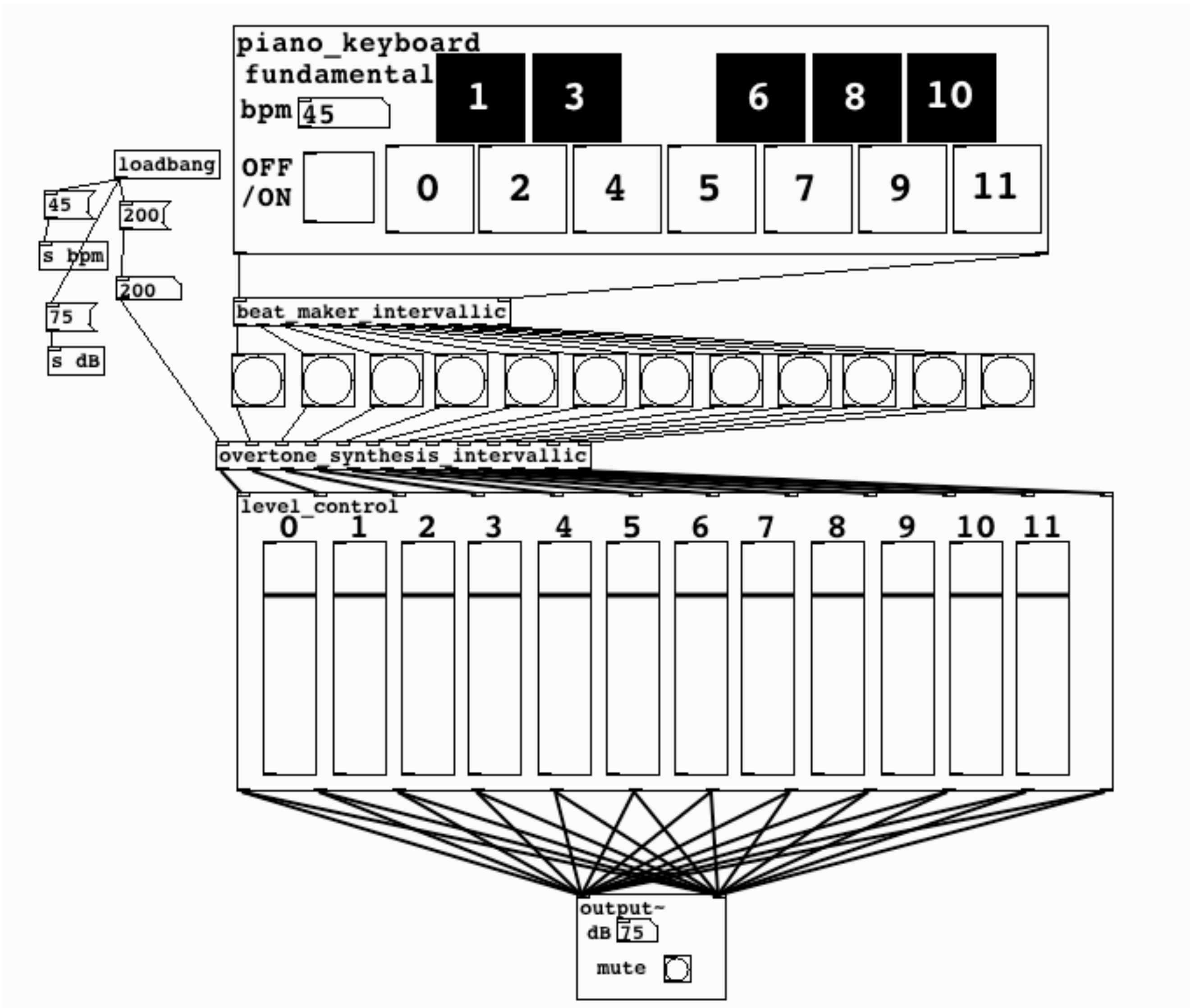
Example 6: The Overtone Rhythmicon



Example 7: Interval Ratio Calculator (Just Intonation)



Example 8: The Interval Rhythmicon



Selected Bibliography

Cowell, Henry. “Charles Seeger.” In *American Composers on American Music*, ed. Henry Cowell. New York: Frederick Ungar Publishing Co., 1962.

Cowell, Henry. *New Musical Resources*. With notes and an accompanying essay by David Nicholls. Great Britain: Cambridge University Press, 1996.

Didkovsky, Nick. “The Online Rythmicon” commissioned by American Public Media. Accessed June, 15, 2008. Available from http://musicmavericks.publicradio.org/rhythmicon/; Internet.

Gann, Kyle. “Subversive Prophet: Henry Cowell as Theorist and Critic.” Excerpts from the article published in *The Whole World of Music: A Henry Cowell Symposium*, David Nicholls, editor (Great Britain: Harwood Academic Press, 1997). Accessed June 15, 2008. Available from http://www.kylegann.com/Cowell.html; Internet.

Greer, Taylor A. “Critical Remarks.” In Seeger *Studies in Musicology II: 1929-1979.* ed. Ann M. Pescatello. Berkeley/ Los Angeles: University of California Press, 1994.

Hicks, Michael. “Cowell’s Clusters” *The Musical Quarterly* 77, No. 3 (Autumn, 1993): 428-458

Hitchcock, H. Wiley. “Henry Cowell’s *Ostinato Pianissimo*.” *The Musical Quarterly* 70, No. 1 (Winter, 1984): 23-44.

Mooney, David. “The Rhythmicon.” Accessed June 15, 2008. Available from http://www.city-net.com/~moko/rhome.html; Internet.

Pescatello, Ann M. “Introduction.” In Seeger *Studies in Musicology II: 1929-1979.* ed. Ann M. Pescatello. Berkeley/ Los Angeles: University of California Press, 1994.

Rich, Alan. *American Pioneers: Ives to Cage and Beyond*. London: Phiadon Press, 2007.

Schedel, Margaret. “Anticipating Interactivity: Henry Cowell and the Rhythmicon.” *Organised sound: An International Journal of MusicTechnology* 7, no.3 (2002): 247-254.

Seeger, Charles. "On Dissonant Counterpoint." *Modern Music*, 7 (June-July, 1930): 25-31.

Seeger, Charles. *Tradition and Experiment in (the New) Music*, in *Studies in Musicology II: 1929-1979.* ed. Ann M. Pescatello. Berkeley/ Los Angeles: University of California Press, 1994.

Smith, Leland. "Henry Cowell's *Rhythmicana*." *Anuario Interamericano de Investigacion Musical*, 9, (1973): 134-147.