ARTIST'S ARTICLE

Software as Sculpture: Creating Music from the Ground Up

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ABSTRACT

The author discusses two electronic music compositions that typify his approach to composing with small computer-music systems. The author's compositional technique is characterized by bottom-up software design and close attention to emerging details of the computer medium. These methods result in a sculptural process of composition that is unique in the field of computer music. Some of the details of this process are outlined and distinctive features of the music are discussed.

This article discusses two compositions that I composed by writing software for small computer-music systems. Both pieces are entirely electronic. All sounds are synthesized or triggered by the computer program, which is partially guided by a human performer. The process by which these pieces were constructed is characterized by bottom-up design and the empirical method. Starting from an initial idea or perception, I composed each piece by adding a feature at a time, making aesthetic choices by repeated close listening. As a result of this process, some features were refined, others were dropped. Finally, the identity of each piece emerged. Although this way of working within a medium is common in visual art, it is unusual within the field of computer programming. It is generally thought that programmers implement their ideas on the computer with as few unforeseen developments as possible, and that ideas flow in only one direction, from the operator to the machine. From the vantage point of an artist, though, it is just as easy to see the flow going in the opposite direction: the medium reveals itself as the artist proceeds, and such revelations shape the direction in which the artist continues. This interaction between artist and medium, and the intimacy it suggests, is no different for a computer artist.

In programming a computer to generate music, distinctive characteristics and limitations of the computer medium are inevitably revealed in the sonic behavior of the program. These characteristics might include timing complexities, effects created by sudden transitions in loudness or pitch, or unforeseen artifacts that are the result of the unique flow of the program. As these features arise and become part of the musical process, the composer/programmer is brought into contact with the fundamental nature of the computer as a musical instrument.

I began using computers to make electronic music in 1977. Prior to that time, I had composed electronic pieces using analog synthesizers, tape recorders and custom-built circuits designed for particular musical functions. Often the sonic character of a synthesizer patch or a custom circuit defined the structure of a piece. For example, the piece *Piano Social* employed multiple recorded sounds fed into a configuration of switching circuits (designed by Paul Demarinis) such that the presence of one sound would trigger the occurrence of another. The action of the switching circuits highlighted details in the recorded sound in a way that would not be possible in a purely acoustic medium. This focus on the material nature of the medium is also typical of much of my work with computers [1].

My introduction to computers came about primarily through my association with James Horton, an experimental-music composer and theorist based in the San Francisco Bay Area, who introduced me to the KIM-1 microcomputer around 1976. The KIM-1 was a single board system designed around a 6502 central processing unit (CPU) with a built-in keypad and 6-digit light-emitting diode (LED) display [2]. Gerald Mueller, of the Electronic Music Lab at City College of San Francisco, also provided me with early opportunities to program in assembly language. After buying my own KIM, I started writing programs in 6502 machine code both to make solo pieces and eventually to play in computer-network bands with Horton and others [3]. In this article, I will focus on two examples of my solo computer work, both of which were also adapted for use in network bands at one time or another.

AUDIO WAVE

I composed *Audio Wave* (1978–1980) [4] for pianist Rae Imamura; she first performed the piece at 1750 Arch Street, Berkeley, on 30 May 1980. I wanted to create a live computer piece in which both of Imamura's hands would continually activate computer keypads instead of piano keys. I wanted her actions to influence an ongoing musical output produced by a computer rather than to initiate each sound as would be the case with a piano. To this end, I extensively modified an earlier random-tone-generating program that I had written for the KIM, ran it simultaneously on two KIMs, and made its behavior partially controllable by pressing keys on the KIM keypads.

The final version of the program, written in 6502 machine code, generates an 8-bit sonic output characterized by a continuous stream of highly modulated tones. Each tone starts as a simple ramp, triangle or random waveshape built up in memory in a wave table. At each audio cycle output, the waveshape is modified according to the following scheme: the value at a current point in the wave table is altered a number of steps toward a maximum or minimum and the current point itself is moved a number of steps toward the

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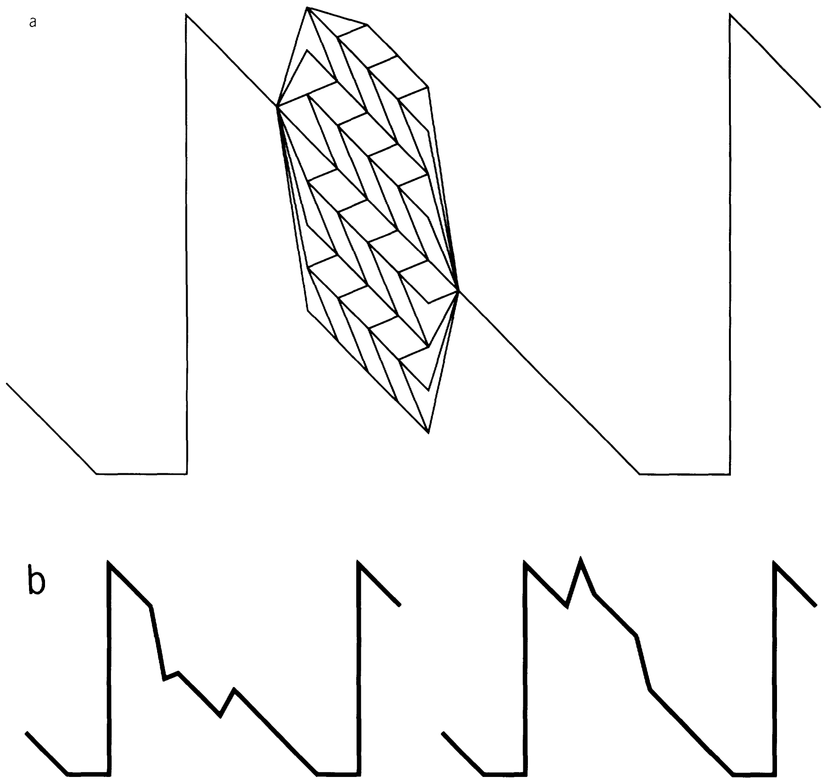


Fig. 1. Waveform modulation in *Audio Wave*. (a) An idealized superimposition of multiple waveforms, which are the result of approximately 80 cycles of modification carried out on a single ramp wave; (b) several typical waveforms extracted from (a).

beginning or end of the table. The result after many audio cycles is a continually changing waveshape that waffles around a given area of points in a repeating modulation pattern (Fig. 1). This technique creates tones with overtone spectra that expand and contract to varying degrees at varying rates.

An additional timbral effect arises from what might be considered a defect in my design: many program functions, including keypad scanning, wave modification, general housekeeping, are programmed within the main audio loop at the end of each waveform cycle. Before going to output the next waveform, the program executes these functions and therefore a flat portion is introduced into the waveshape between cycles (see Fig. 1). This 'dead zone' in each audio cycle fluctuates in length due to the varying number of functions that need to be executed. The fluctuation creates a kind of indeterminate pulse-width modulation that slightly perturbs both the pitch and the timbre of the tone. This unpredictable musical result came about as a direct consequence of an empirical programming style that relied on demonstrated effect rather than preconceived limits on what might be considered musical. Many of these effects became integral parts of the sonic character of the piece.

Occasionally, the flat portion of the wave is substantially lengthened by the insertion of 'key' functions into the flow of the program. The execution of a 'key' function is triggered when the performer depresses KIM keypads to influence the musical output of the program. The additional execution time required to process a 'key' function drops the pitch of the sounding tone noticeably. I retained this feature for its mechanical quality: through it, one can visualize the performer's keystrokes shaping the sonic output overall as well as leaving a mechanical impression on the course of each tone. The 16 key-function commands for each KIM include sustain current tone, change tempo, contract pitch range, repeat last 3 events and switch starting waveform.

The overall sonic effect of *Audio Wave* is one of unconstrained electronicism, an embracing of the electronic medium in its power to create a new voice. The nature of this voice is shaped by the limitations of the KIM-1 medium and my response to them. Its sound emanates from the speaker cone as a direct result of program control; each twist and turn of the program has an effect on the cardboard surface of the cone. The sound does not rely on simulation of acoustic instruments for its musical effects. Rather, its musicality derives from properties within the electronic system itself, which were discovered by empirical play with the medium. One can view the characteristics of this piece as uniquely electronic compensations for the absence of musical phenomena found in acoustic instruments:

- The onset of an acoustic tone, with its characteristic richness and complexity, is missing in *Audio Wave* and is made up for by modulation of the electronic tone throughout its length. It is as though the usual richness at the start of each tone is now spread out in time over its duration. Without the beginning, middle and end of the acoustic envelope, tones switch from one to another to form one continuous ribbon. The bending and warping of that ribbon are highlighted in *Audio Wave*.
- The age-old magic of an acoustic sound being struck into being by a human agent is replaced by the surging potential of a waffling speaker. There is a different quality of volition inherent in electronic sound. Motion starts from the individual in the acoustic realm and is inherent in the environment in electronics. The difference is something like the difference between standing on land and floating on water.
- The subtle imperfections of pitch and amplitude naturally occurring in a sustained acoustic tone are replaced by more methodical artifacts. In *Audio Wave*, small shifts in pitch occur as the result of unorthodox program design: the audio output

routine is not insulated from other program functions. As these functions are brought into play by the performer, the length of the output loop is altered and therefore both pitch and timbre are suddenly shifted. Also, the performer may switch the primary waveform in the middle of a sounding tone, which may produce sudden changes in position of the speaker cone. Often this will insert a pop or click in the sounding tone. These are welcome imperfections that become part of the character of the electronic instrument. Tones in *Audio Wave* are constantly revoiced in this manner, creating extended sequences of complex timbral articulation.

NEXT TONE, PLEASE

Next Tone, Please (1984–1985) [5] was written in the FORTH computer language on a Commodore 64 computer. Additional tone-generating hardware was added to the Commodore to give it a total of 12 oscillators, which make up the basic signal source for the piece. All enveloping was done externally with an analog synthesizer panel controlled by the computer [6]. I first performed the piece on 2 November 1985 at the New College Art Gallery in San Francisco.

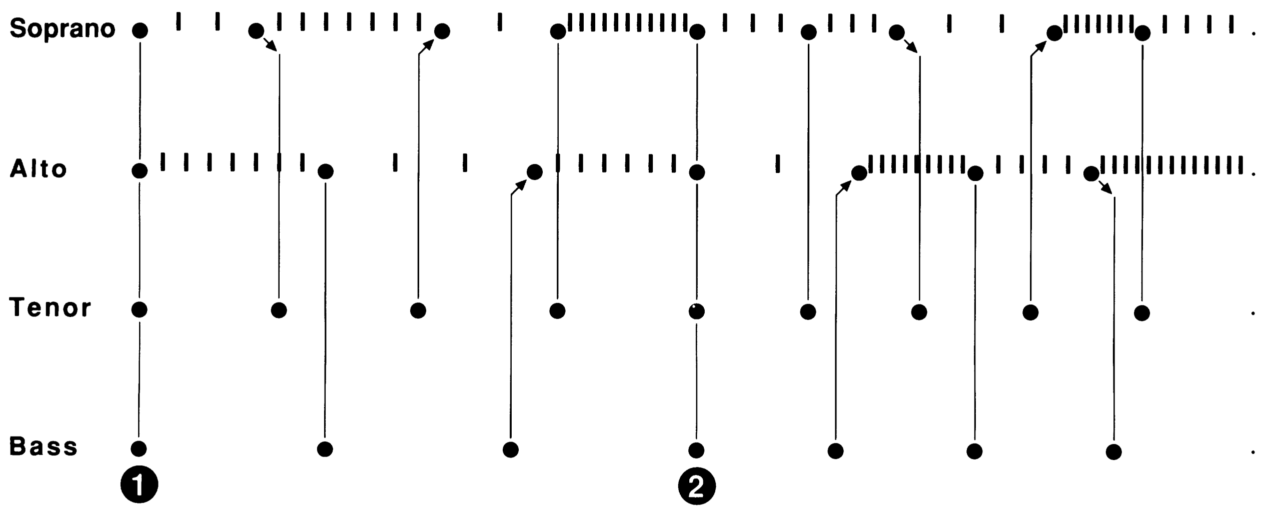
Next Tone, Please conjures a rarefied world of percussive block chords moving slowly across a phrase of fixed length. The chords are tuned to a subset of 31-tone equal temperament. Three different chord progressions were composed, each containing six chords of 12 notes. As the program constructs each phrase, it uses much of a given progression as needed; this factor varies depending on the primary rhythmic relationship selected for each phrase. In addition, a performer may activate embellishments of chords as the chords appear. The embellishments are fast reiterations of the chords just sounded at rates that fit strictly within the primary rhythmic units. Each phrase is built by the program according to the following steps, the order of which recapitulates my compositional process (Fig. 2): (1) A slow procession of primary chords (bass and tenor) subdivides the phrase into a simple polyrhythm (3 to 4, 4 to 5, or 5 to 6). This choice also determines the amount of the progression required, since more chords are needed, for example, in a 4-to-5 than a 3-to-4 relationship. (2) A layer of secondary chords (alto and soprano) fall slightly before, right on or slightly after the primary units. The precise placement before or after is based on higher number subdivisions of the phrase length (e.g. 24, 36). Additional secondary chords are inserted when the program finds the resultant proximity between the alto and soprano chords to fall within a given limit. The inserted chords are 'reflecting' chords: if inserted in the alto, they will echo the notes of the soprano chord just sounded or vice versa. (3) Reiteration of chords may fill the space between secondary chords if triggered by a performer.

Each successive layer was added to the piece after extensive listening to the previous layer(s). Particular attention was paid to the overall manner in which the music seemed to flow: if one rhythmic subdivision seemed too dominant, I tried to counterpoise it in the next layer. Each rhythmic component exerts its own gravitational pull on the listener—where multiple components are balanced, a single frame of reference is suspended and a kind of polyphony of forward momentum is allowed. The whole can be described in terms of each of the perceived rhythmic layers:

- The longest event is the phrase itself (15 sec), which in its strict regularity provides a fixed gesture within which the changing events occur.
- The primary chords (3–5 sec), which are locked in a slow polyrhythm, move a bit faster than the phrase. They unfold at a slow enough rate that their polyrhythmic relationship is just a step beyond the listener's constant awareness. They act as the fundamental points of chordal transition against which the other events are heard.
- The secondary chords occur at roughly the same rate as the primary chords, but act as attendants to the primary chords: appearing synchronous with or right next to the primary chords, they anticipate, reinforce or reflect the moments of primary transition.
- At the fastest level, reiterations (0.2–1 sec) fill the space between chords. This motion is fast enough to be assertively metrical and acts to methodically mark time between events.

Next Tone, Please methodically constructs an experimental style of musical momentum. The use of a polyrhythm

Fig. 2. A diagram representing two possible phrases in *Next Tone, Please.* Each dot represents a 3-tone chord in the range specified to the left. The primary rhythmic relation is the polyrhythm between bass and tenor (a relation of 3 to 4 in phrase 1; a relation of 4 to 5 in phrase 2). The alto and soprano are placed rhythmically right before, right on or right after the bass and tenor, respectively. The short vertical dashes in the alto and soprano represent reiterations of the chord just sounded.



as the primary framework for all other rhythmic placement grounds the sense of time flow on an essentially ambiguous phenomena. A polyrhythm is ambiguous because the listener can shift attention from one component subdivision to the other, each time shifting the reference for rhythmic activity. In addition, the slow tempo injects enough feeling of anticipation to make the arrival of each chord slightly unpredictable. Below a certain speed, metrical events tend to loosen their bonds while gaining an air of inevitability. Very slight delays are also introduced by program overhead (each upcoming phrase is calculated during the execution of the current phrase). These delays add further minute displacements to the positioning of each chord and lend to the music a slight feeling of effort that it would not otherwise have. Each phrase harmonically progresses with just a touch of forward momentum. Within the gestural sweep of a fixed phrase length, the shifting details of chord placement parse time in a patchwork of moment-to-moment arrivals and departures. This diffuses the sense of a discrete musical present and induces a more global experience of time.

Next Tone, Please grew out of my involvement with the music of Charles Ives, which was introduced to me by James Tenney [7]. After listening extensively to Ives's music, I have become particularly interested in his expansive sense of a musical moment. Ives stretches the definition of a moment to include such rambling arrivals and departures of tones and chords that the listener's sense of the present is widened to include a bit more of the past and future. A moment is experienced as an intersection of multiple paths that have suddenly gained additional meaning through close proximity. This potential resonance between rhythmically independent elements permeates Ives's music at many levels.

In *Next Tone, Please* the primary chord motion is surrounded by attendant chords and reiterations. I tried to fashion a musical context in which small shifts in placement around a fixed chain of events would generate surprising instances of musical meaning. The piece uses proximity as an independent musical parameter: chords become related by virtue of their simultaneous or near-simultaneous occurrence—the greater the distance, the weaker the relationship.

I think of these pieces as being sculptural because of the way they were written in software. Through the compositional process I have described, each piece gradually became a distinct musical entity. As I worked, I tried to peer into the behavior of the machine to see from where the next musical angle would come. My strategy was to accept the medium 'as is', using its confines as a possible avenue of discovery, rather than allowing myself to be distracted by the wish for a more perfectly plastic material.

References and Notes

1. See Tim Perkis, "The Future of Music" (compiled by Larry Polansky), *Leonardo* **20**, No. 4 (1987) p. 365.

2. For more information about the KIM-1 and its past use in the experimental computer-music scene in the Bay Area, see Curtis Roads, "Improvisation with George Lewis", in Curtis Roads, ed., *Composers and the Computer* (Los Altos, CA: William Kaufman, 1985) pp. 78–79.

3. The League of Automatic Music Composers, the first microcomputer network band, was active during 1978–1982 and, at one time or another, David Behrman, John Bischoff, Donald Day, Rich Gold, Jim Horton and Tim Perkis were active members. The group played music by linking their computers together into a computer network. Each program was designed to send and receive data over the network and to respond to incoming data in its musical output. The result was a multipart electronic music performance coordinated by paths of mutual influence defined by the network. See John Bischoff, Rich Gold and Jim Horton, "Music for an Interactive Network of Microcomputers", in Curtis Roads and John Strawn, eds., *Foundations of Computer Music* (Cambridge, MA: MIT Press, 1985) pp. 588–600; originally published in *Computer Music Journal* **2**, No. 3, 24–29 (1978). The Hub is a band that has continued to work in the network-music form since 1986, with members John Bischoff, Chris Brown, Scot Gresham-Lancaster, Tim Perkis, Phil Stone and Mark Trayle. See Mark Trayle and John Bischoff, "Paper Hubrenga", in *IS Journal #9*, Vol. 5, No. 1, 74–85 (1990). (*IS Journal* is published by International Synergy.) See Discography for recordings by both The League of Automatic Music Composers and The Hub.

4. For recordings of *Audio Wave*, see Discography.

5. For recordings of *Next Tone, Please*, see Discography.

6. The distinctive envelopes for *Next Tone, Please* were produced using Dual Transient Generators and Voltage Controlled Amplifiers made by Serge Modular Synthesizers, 572 Haight St., San Francisco CA 94117, U.S.A.

7. I studied composition and piano with James Tenney at the California Institute of the Arts, 1970–1971. See James Tenney, *Meta-Hodos* (Oakland, CA: Frog Peak Music, 1986).

Discography

Artificial Horizon (ART 1003), a compact disc (CD) of computer music by John Bischoff and Tim Perkis, available from Artifact Recordings, 1374 Francisco St., Berkeley, CA 94702, U.S.A. This CD includes performances of *Audio Wave* and *Next Tone, Please.*

The Hub (ART 1002), a CD of 9 pieces by the computer network band The Hub, available from Artifact Recordings.

Next Tone, Please, a cassette of six electronic compositions by John Bischoff, available from Frog Peak Music, Box 9911, Oakland, CA 94613, U.S.A. This cassette includes early performances of *Audio Wave* and *Next Tone, Please.*

Just For the Record (VR 1062), an LP by 'Blue' Gene Tyranny performing music by Robert Ashley, John Bischoff, Paul Demarinis and Phil Harmonic, available from Lovely Music Ltd., 105 Hudson St., New York, NY 10013, U.S.A.

Lovely Little Records (VR 101-06), six EPs of music by John Bischoff, Paul Demarinis, Phil Harmonic, Frankie Mann, Maggi Payne and 'Blue' Gene Tyranny, available from Lovely Music Ltd. John Bischoff's EP includes a selection by The League of Automatic Music Composers that was recorded in 1978.