
Composing *Clang-tint*

CURTIS ROADS

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Preface: a golden age

I am sure that the time will come when the composer, after he has graphically realized his score, will see this score automatically put on a machine which will faithfully transmit the musical content to the listener...Here are the advantages I anticipate from such a machine: liberation from the arbitrary, paralyzing tempered system; the possibility of obtaining any number of cycles or if still desired, subdivisions of the octave, consequently the formation of any desired scale; unsuspected range in low and high registers; new harmonic splendors obtainable from the use of sub-harmonic combinations now impossible; the possibility of obtaining any differentiation of timbre, of sound-combinations; new dynamics far beyond the present human-powered orchestra; a sense of sound-projection in space by means of the emission of sound in any part or in many parts of the hall as may be required by the score; cross rhythms unrelated to each other, treated simultaneously, or to use the old word, "contrapuntally" (since the machine would be able to beat any number of desired notes, any subdivision of them, omission or fraction of them)—all these in a given unit of measure or time which is humanly impossible to attain. – Edgard Varèse (1936)

Decades after the early experiments of the musique concrète, elektronische Musik, and tape music, a paradigm shift occurred. Around 1988, the means of production that pioneers such as Edgard Varèse could only dream of became readily accessible. This technological advance opened the door to new aesthetic possibilities. In effect, we crossed into a golden age of electronic music. What do I mean by a golden age? By contrast with the rare and expensive equipment available in Varèse's time, today a laptop computer can serve as a recording and editing workstation. Powerful software for sound editing, mixing, analysis, synthesis, and transformation is easily available, including much freeware. (1)

Let there be no illusion: this golden age of electronic music does not correspond to a golden age in the world at large: quite the contrary. But if we for a short period turn away from the incessant barrage of discouraging global news, we find that the conditions for creating electronic music are ripe, and the aesthetic and creative possibilities are enormous and exciting. The urge to create something beautiful is a healthy response to ugliness in the world.

To compose in the electronic medium is not an easy path. To begin with, the problem space of electronic music is much larger than that of traditional composition, due to its unlimited sound palette, wider range of operations, and the capability of organizing and transforming material on multiple time scales.

Vast uncharted territories remain. Precisely because the territory is wild, there are fewer rules to obey. Thus the composer is called upon to be a pioneer. Music training is based on tradition, so many composers are not comfortable in this role. Even the listener must be an explorer. The composer confronts time-consuming technical problems, and the work is often detailed and laborious. Each sound object in a musical architecture is a kind of miniature sculpture. Moreover, the composer must

take over a role previously delegated to performers: to form individual sounds and gestures. One is called upon to be both a composer and a virtuoso. For all these reasons, this is a formidable medium to master.

Unlimited sound palette

The most obvious difference between electronic music and acoustic instrumental and vocal music is the sound palette. The palette of electronic music is unlimited. A composer can use any sound from any source. The fountain of available sounds is endless, since new sounds are being made every moment. At the same time, we discover many synthetic sounds that are unique to circuits and algorithms. The artful deployment of pure sinusoids, pulse trains, filtered noise bands, modulations, convolutions, and granulations is integral to this practice. My music is a celebration of these materials.

Multiscale composition

The organization of a composition is intertwined with its materials and tools. The unique materials and tools of electronic music lead to new forms of organization. Recording meant that compositional material could include any sound possible. The tape recorder liberated time; it could be cut up, rearranged, sped up, slowed down, or played backwards. The digital sound editor gave us immediate access to all time scales and the ability to transform them—from an entire piece to a single sample—in one operation. The studio-based practice of *multiscale composition* applies these tools directly to the organization of a work—in the presence of sound and aligned with human perception (Roads 2015).

The multiscale approach is above all flexible and opportunistic as a strategy, intermingling top-down and bottom-up strategies for organization. Multiscale organization can be likened to a heterarchy of partial systems that come into being and go out of being. It can employ generative processes but reserves the right for the composer to interact, intervene, edit, and transform at any time. This was the methodology behind *Clang-tint*.

About this text

The genesis of *Clang-tint* was unusual. A commission from the Japanese Ministry of Culture (Bunka-cho) and the Kunitachi School of Music, it was conceived in 1990 and premiered in 1994 in Tokyo. From the beginning I combined composing with technical research and aesthetic theory. I documented the process in texts, photographs, and diagrams. I kept a written journal in a spiral-bound notebook, but also electronic notes.

An early draft of this manuscript dates to 1997. The occasion to finally finish it arrived at 10 PM on 31 December 2020, when I completed the manuscript of *The Computer*

Music Tutorial, Revised Edition for MIT Press. I had been working on the book continuously since 2017.

Meanwhile, Jan van Toorn had offered to release of *Clang-tint* in the form of a vinyl LP disc on his Slowscan label. With the *Tutorial* project done, it was time to prepare the master disc and finish this document.

Technological changes

The period around the realization of *Clang-tint* was a pivotal point in the technology of computer music. Prior to this, computer music was split into two camps. One camp consisted of institutions with research centers like MIT's Experimental Music Studio. These centers used research funding to invest in high-tech computer hardware and peripherals. The other camp consisted of individuals with a do-it-yourself approach to "homebrew" computing using early 8-bit microprocessors.

The personal computer revolution of the 1980s was a major shift in culture. By 1988, home computers could handle high-fidelity sound synthesis, processing, and recording formerly associated only with institutional centers. I purchased an Apple Macintosh II—the first Apple computer with software and hardware support for professional quality audio (16-bit quantization, 44.1 kHz sampling rate) thanks to third-party vendors.



Figure 0.1. The author in home studio, 1990, Somerville, Massachusetts. Apple Macintosh II computer with color display monitor, Studer-Revox PR 99 Mk III tape recorder, Amek TAC mixing console, Sony PCM 601ES digital recorder, Korg M1 sample player. Not seen is a Studer Dyaxis recording and mixing system, Lexicon 200 digital reverberator, Sony 2700 DAT recorder, B&W 801 Matrix loudspeakers, and Threshold S/500 amplifier.

Professional changes

The period around the initial version of *Clang-tint* from 1989 to 1996 was also a time of many changes in my professional life. At the beginning of 1989 I was employed at Hewlett-Packard corporation documenting a software development system. I owned a house on Walnut Street in Somerville, Massachusetts and had turned the living room into a studio (figure 0.1). At the same time, I was Visiting Lecturer in the Department of Music at Harvard University, teaching one afternoon a week the course “Advanced Composition in the Electronic Medium.” I departed Hewlett-Packard in August 1989. I had been invited to Tokyo as a consultant with F. R. Moore, David Wessel, and Cort Lippe to plan several new computer music studios at the Kunitachi College of Music. This memorable trip—my first to Japan—took place in December 1989.

In Winter-Spring 1990 I was Visiting Associate Professor of Music at Oberlin Conservatory, replacing a professor on leave. From January to March 1991 I had a residency in Tokyo, as I explain later.

In Spring 1991 I accepted a position at Ircam in Paris with roles as manager of the Documentation Service, instructor in the Pedagogy Department, and member of the Editorial Committee.

In 1993 I left Ircam to become Director of Pedagogy at Les Ateliers UPIC, invited by Gerard Pape. In Spring 1994 I returned to Tokyo for a month-long residency and the premiere of *Clang-tint*. Thanks to Professor Horacio Vaggione, in 1994-5 I was Chargé de cours (Lecturer) in computer music at the Université Paris 8. I taught a class of twenty-one students. In yet another transition, in October 1995 I began the doctoral program in Music Aesthetics, Science and Technologies of the Arts at Paris 8.

In 1996 I was offered a visiting faculty position in Music at the University of California, Santa Barbara. We launched the Media Arts and Technology (MAT) graduate program in September 1999. Since 2000 I have been a professor at UCSB.

Besides these changes of location and employment, I was also going through major transitions in my creative life. I had been working since 1979 on my textbook *The Computer Music Tutorial* for MIT Press. I finally finished the manuscript in Paris in May 1993. This was only the beginning of a process of proofreading and indexing. The book finally appeared in 1996.

After my piece *Field* (1981), which was released on a compact disc to accompany the opening of the MIT Media Laboratory, I did not work on composition for a decade, in order to concentrate on completing the *Tutorial*. I was also working full time. The 1991 commission for *Clang-tint* was an occasion to reawaken the composing part of my brain. Thankfully, this was a natural process and musical ideas started flowing as soon as I allowed them to manifest.

Acknowledgments

The realization of *Clang-tint* was an extraordinary once-in-a-lifetime experience. It was enabled by many kind people. I must extend my thanks first of all to Bin Ebisawa, then President of the Kunitachi College of Music (Kunitachi Ongaku Daigaku), and to the late Cornelia Colyer, then Director of the Center for Computer Music and Music Technology (CCMMT) at Kunitachi for their sponsorship of this project. I also express my appreciation to the Japanese Ministry of Culture (Bunka-cho) for providing the fellowship that brought me to Tokyo in 1991 and 1994. I thank composer Kuzika Kuryama for his assistance in Tokyo. Professor Sumi Gunji and her staff at the Gakkigaku Shirôkan kindly allowed me access to their amazing museum of instruments.

In Paris I was encouraged by my colleague Gerard Pape at Les Ateliers UPIC (later named the Centre de Création Musicale Iannis Xenakis or CCMIX). I would also like to thank Conrad Cumming and Gary Nelson for inviting me to teach at the Oberlin Conservatory, where *Clang-tint* was conceived.

Finally, I would like to thank Clarence Barlow, Yutaka Makino, Chris Jette, and Rodney Duplessis for helpful comments on this text.

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Point of origin



Figure 1.1. *Horse + rider of Artemision (Large)*, 1990, the Starn Brothers. The original is two meters wide and one meter in depth. From Grundberg (1990).

The point of origin of the composition *Clang-tint* can be traced to the sunny late afternoon of 9 December 1990. I was a 39-year old Visiting Associate Professor at the Oberlin Conservatory in Ohio. Several days before, on the local radio, I heard a *New York Times* art critic praise an installation of photographic works by the Starn twins at the nearby Akron Museum of Art. Intrigued, I decided to visit.

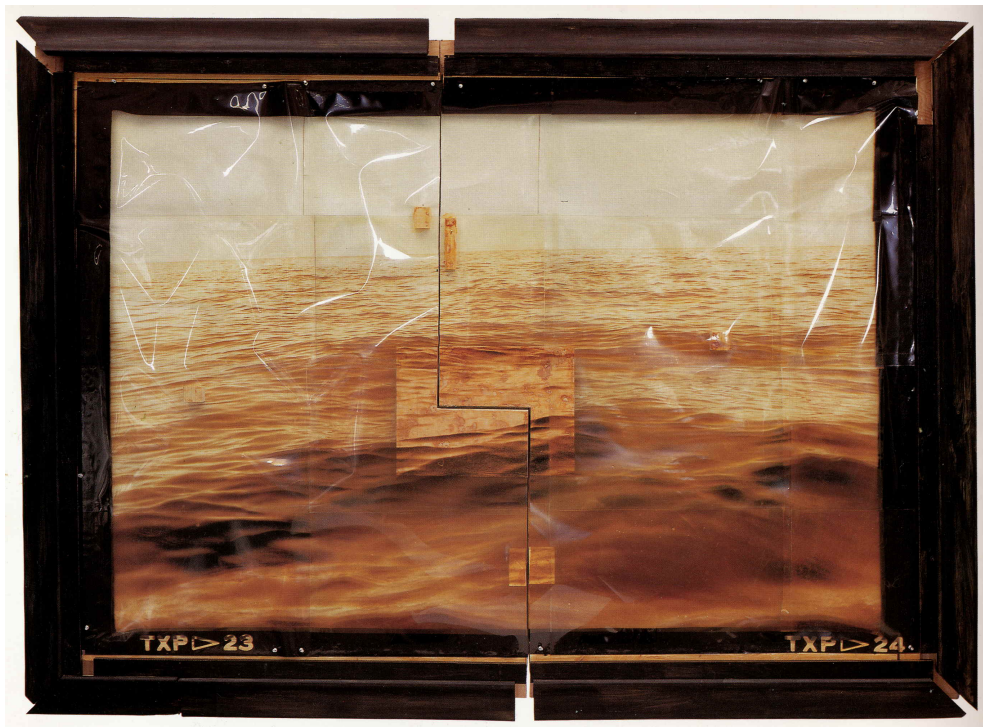


Figure 1.2. *Yellow seascape with film and woodblock, 1989*, the Starn Brothers. From Grundberg (1990).

These works, shown in figures 1.1 and 1.2, combined prints and large transparencies with wood, tape, metal, and other media to create three-dimensional sculptures (Grundberg 1990). Several aspects of this work struck me. These young artists integrated “sampled” (photographed) imagery with unusual materials and innovative methods of construction (tape, clear lacquer, pipes, and clamps). Image quality was treated as a parameter that could be varied from high to low within a single piece. The unconventional bending, cutting, and framing techniques spatialized their photography in three dimensions.

I was inspired. In the hour following my emergence from the gallery, I conceived a design for a new composition. It would apply aesthetic concepts that I experienced in the gallery to the realm of sound. The source material for the composition would include sonic “photographs” or sampled sounds, as well as synthetically-generated signals. It would exploit the contrast between pristine sounds and noisy signals. The spatial architecture of the work would be intimately bound with its inner form. The piece would be organized in four contrasting movements, each concerned with a specific theme, and each organized around its own sound materials.

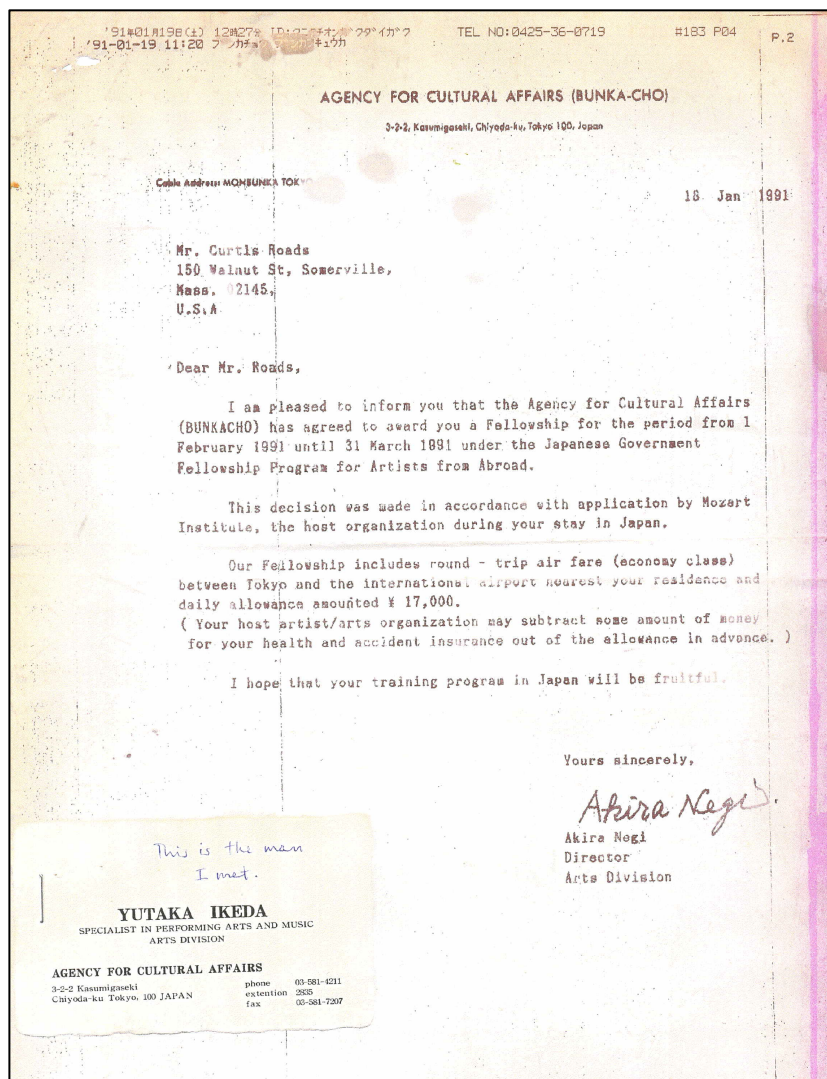


Figure 1.3. FAX from the Bunka-cho, offering a fellowship for a composition.

Shortly after this experience, I received an important fax message from Tokyo (figure 1.3). It was an artistic fellowship from the Bunka-Cho (Japanese Ministry of Culture) in support of a commission from the Kunitachi Ongaku Daigaku (Kunitachi College of Music). I decided that the realization of *Clang-tint* would be an ideal project for the commission.

The title *Clang-tint* was inspired by the book *SOUND* (1901, Third Edition) by the physicist John Tyndall. I discovered Tyndall's book in the Physics Library at Oberlin College.

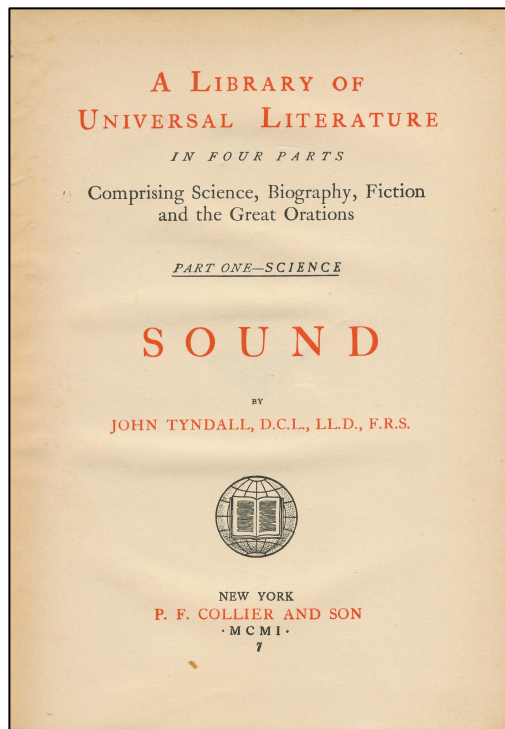


Figure 1.4. Title page of John Tyndall's book, third edition (1901).

SOUND is profusely illustrated with beautiful engravings of mechanical sound production devices. It describes amazing experiments from a bygone era (figure 1.4). Tyndall coined the term: *clang-tint*:

A compound [sound] color...is produced by the admixture of two or more simple ones, and an assemblage of tones, such as we obtain when the fundamental tone is the harmonics of a string sound together, is called by the Germans a Klang. May we not employ the English word clang to denote the same thing, and thus give the term a precise scientific meaning akin to its popular one? And may we not, like Helmholtz, add the word color or tint, to denote the character of the clang, using the term clang-tint as the equivalent of Klangfarbe?

Today, John Tyndall is best known for predicting the *greenhouse gas effect* causing global warming, where water vapor and carbon dioxide are absorbed into the high atmosphere by thermal radiation from the Earth, while solar radiation is transmitted to the Earth (Tyndall 1872).

Formal organization as four movements

I conceived *Clang-tint* in four contrasting movements. Each movement would express a specific theme or metaphor. This was a new approach for me. I had never designed a piece around a conceptual metaphor. The metaphors I conceived were *Purity, Filth,*

Organic, and *Robotic*. The concepts contain two opposing pairs: purity versus filth, organic versus robotic, providing a wide range of contrast.

A theme such as “purity” supplied a theme for the organization of the work and for the choice of its sound materials. What is purity in sound? If one sound is pure, then what sound is its opposite: “filth?” If “organic” sounds emerge from the living world, then what sounds correspond to the “robotic?” Determining the appropriate sound palette for each movement was a chore. Inevitably, I prepared much more material than I could possibly use, dozens of hours of sound.

Just as construction materials such as mud, wood, fiberglass, or steel have a strong influence on architectural design, so do sound materials imply different methods of musical organization. Each section of *Clang-tint* deploys its own specific set of sound materials, and each is organized in a particular way (Table 1.1).

Table 1.1 The four movements of *Clang-tint*.

Movement	Musical organization	Sound material
Purity	Melodic, harmonic, pulsating rippling	Pure sinusoidal waveforms in a microtonal scale; slow glissandi; slow modulation
Filth	Dense sound masses, irregular phrases	Granular synthesis; controlled distortion, fire and water sounds
Organic	Expressive phrases, cross-fading points of attraction	Bird, whale, animal, human, and insect sounds; pulsar synthesis
Robotic	Polyrhythms, metric versus ametric rhythms	Mechanical instruments, percussion, computer as drum machine

Research agenda

The realization of the first version of *Clang-tint* took place from 1991 to 1994. The work merged musical and technical research with composition itself. Among the research projects undertaken in the course of the composition were the following:

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Exploration of microtonal pitch organization—exploring the Bohlen-Pierce (BP) scale; constructing melodic and harmonic structures based on the BP scale; exploration of the continuum between harmony and timbre in the mixture of equal-tempered and microtonal scales.

Editing on a micro time scale—microfiltration, transient wave writing, micro-spatialization, microvariations in phase and delay. This research was enabled by high audio quality sound editors with graphical user interfaces, which had only just become available. (See Roads 2001b for further information.)

Composition with granular synthesis—exploring musical applications of new sound materials such as clouds of sonic grains. Developing software programs for generating synthetic grains and for granulating multiple soundfiles. In this period only two composers were using granular synthesis: Barry Truax in Canada and me.

Composition with pulsar synthesis—realizing a new approach to sound particle synthesis; applications of pulsar synthesis with convolution. This involved software development and experimentation.

New approaches to rhythmic structure—simultaneous polyrhythms; exploration of the continuum between metric (synchronous) and ametric (asynchronous) rhythms. Exploration of Varèse's idea of multiple asynchronous simultaneous rhythms with points of synchronization. Organization of rhythmic clusters around points of attraction, with sparseness around points of repulsion.

I address each of these topics in the chapters on the individual movements of the piece.

These are the research paths that produced positive results. It is important to note that I explored other research problems that did not yield interesting results, such as the unfinished movement *Robotic*. I consider experiments that result in dead ends to be an integral part of the creative process—definitely not time wasted. A creative artist must try an idea to see if it will work. Only by experimentation can we find the best path.

2

Sound materials

Sound is the product of immense energies of natural forces—thunder and lightning for example—as well as those created by human labor and tones synthesized by electronic means. In the first half of the twentieth century, Varèse (1971) advanced musical thinking with a new concept of music as *organized sound*. In this conception, any sound, from any source, can serve a musical function. This opens up composition to the entire universe of sound phenomena.

The organized sound approach emphasizes the initial stage of composition, wherein the composer gathers the sound materials to be engaged in a piece. This initial stage furnishes the palette of colors that will be used in the assembly of the meso and macro-layers of the composition. Moreover, the temporal morphology of the sound objects developed in the initial stage strongly suggests the musical context in which these objects can function. In effect, the sound objects shape the meso layers of musical structure.

In a multiscale approach to composition, mesostructure arises through human interaction with low-level sound materials. To shape materials into phrases requires mediation between the will of the composer and the inner nature of the sound materials. When the material will not bend, it is the composer who must be flexible. Either the conceived phrase must tend in a different direction, or the material must be discarded.

In each movement of *Clang-tint*, the chosen materials imply specific types of musical structures. In *Purity*, the source material is sinusoidal and pitch-aligned to a 14-note microtonal scale (the 13-note Bohlen-Pierce scale plus the octave interval), suggesting melodic and harmonic structures. In *Organic*, the cries of animals, birds, and insects suggested expressive phrase structures. In *Filth*, granular clouds of sound implied a mesostructure of crossfading sound masses. In *Robotic*, the percussive sound palette implied an organization based on asynchronous and synchronous events in complex patterns.

In toto, *Clang-tint* was constructed from a broad palette of eleven sources:

1. Human voice
2. Animal, bird, insect, whale sounds
3. Western orchestral instruments
4. World music instruments
5. Industrial and urban noises

6. Sounds of nature
7. Computer-generated speech
8. Electric instruments
9. Analog synthesizers
10. Digital synthesizers
11. Computer-generated pulses and grains

Sampled sounds

Sampled or *concrète* sound sources feature throughout the work. Chapter 4 describes the recording process at Kunitachi, where I sampled 45 instruments.



Figure 2.1. Transcribing insect sounds from phonograph to digital audio tape (DAT).

I transcribed animal, reptile, bird, insect, and aquatic sounds from various vinyl long play (LP) recordings I had collected over the years. For example, this included a 1958 field recording of frogs, an unusual 1960 laboratory recording of the sounds of insects, and recording of birdsongs from the early 1970s (figure 2.1). As figure 4.4 shows later, the sound archive of *Clang-tint*—mostly samples—originally spanned 23 DAT tapes. In the end, only a small fraction of the samples prepared for *Clang-tint* were used in the final composition.

Synthetic sounds: granular and pulsar synthesis

The theory of granular synthesis is described in Gabor (1946, 1947, 1952), Xenakis (1960, 1992), and Roads (1978, 1991, 2001b, forthcoming). My experiments with this research began in 1974 using a large mainframe computer at the University of California, San Diego (UCSD). By the time I began working on *Clang-tint*, I had coded two programs for granular synthesis using the Apple Macintosh II computer (Roads

1992a, 1992b, 1993b). I called these programs—written in the C language—Synthulate and Granulate, respectively. Synthulate generated synthetic sine wave grains. Granulate generated grains from sample sound files. My programs generated score files that were rendered by the Music 4C synthesis language. I modified Music 4C so that it could handle the large amount of data associated with granular synthesis. Music 4C (Gerrard 1989) was a C-language variant of the venerable Music IVBF language developed in the 1960s (Mathews and Miller 1965; Howe 1975). I continued to refine Synthulate and Granulate in Tokyo.

After moving to Paris in 1992, I modified the grain generator to work with new software instruments that I designed using the Csound synthesis language.

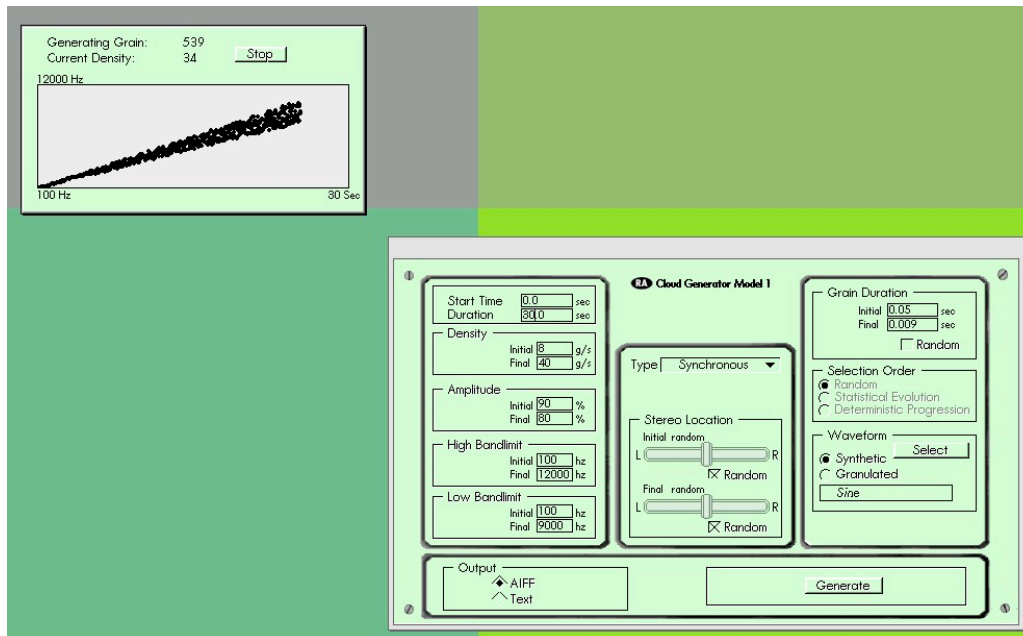


Figure 2.2. Screen image of CloudGenerator (bottom right) with a window displaying the formation of a cloud of grains in real time.

Synthulate and Granulate were text-based programs that I ran in a C development environment. For teaching purposes, John Alexander and I developed a granular synthesis program with a graphical user interface (GUI) called Cloud Generator (Roads and Alexander 1996b). The main features of Cloud Generator are: synchronous and asynchronous grain generation, synthetic or sampled grain waveforms, synthetic or granulated sample clouds, and graphical display of cloud formation (figure 2.2).

In the course of composing *Clang-tint*, I developed another experimental synthesis technique called *pulsar synthesis* (PS) (Roads 2001a). The original platform for PS was Synth-O-Matic, a programmable synthesis engine developed by James McCartney, who later created the SuperCollider programming language.

In its basic form, PS generates a family of classic electronic music timbres that are similar to those produced by impulse trains fed through a bandpass filter. Composers such as Stockhausen (1955, 1957, 1961, 1963) and Koenig (1959, 1962) used this technique as a staple in their electronic music studio craft. In its more advanced form, PS generates a world of rhythmically-structured crossbred sampled sounds.

The principle of pulse generation is well established. As Galileo observed in 1636, when the distance between successive impulses is less than about 1/50th of a second, we perceive the succession as a pitched continuum. When the rate of emission slows down below the infrasonic frequency threshold, the sense of pitch fades and we perceive each impulse separately in a rhythmic sequence.

Basic pulsar synthesis introduces two new elements to this principle:

- The pulse shape or *pulsaret* W is not limited to a rectangle; it can be any waveform
- The *duty cycle* O of the pulsaret can vary independently from the rate of pulsar emission P .

With this latter control the composer can simultaneously control both fundamental frequency (the rate of pulsar emission P) and a formant frequency (the period of the duty cycle O). Meanwhile the overtone spectrum of the pulsar stream, apart from the fundamental and formant frequencies, depends on the shape of W .

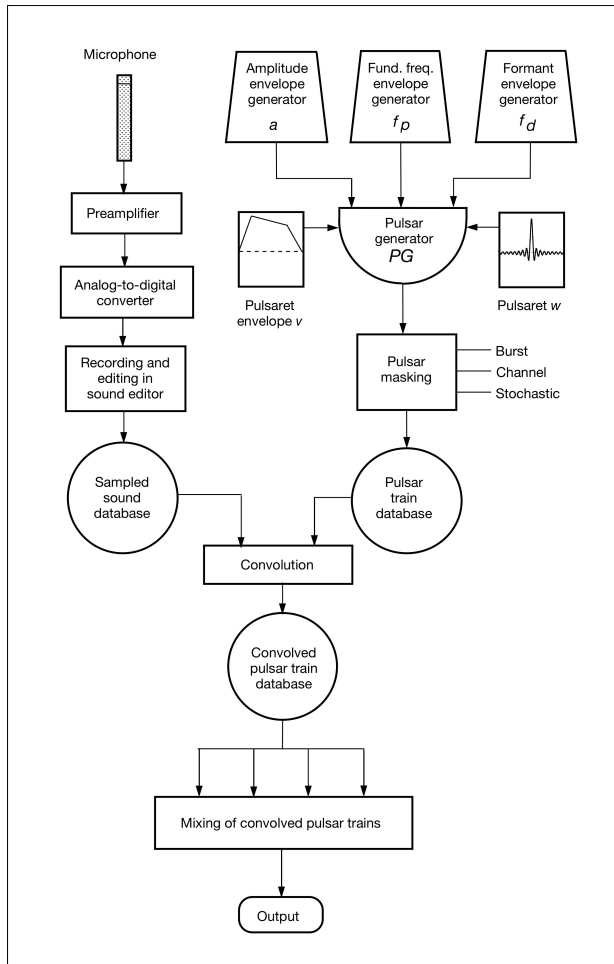


Figure 2.3. Schema of pulsar synthesis. A pulsar generator with separate envelope controls for fundamental frequency, amplitude, stochastic masking, and spatial position. In advanced pulsar synthesis, several generators may be linked with separate formant and spatial envelopes. A pulsar stream may be convolved with a sampled sound.

In the advanced technique of PS we introduce the possibility of *convolution* of pulsar trains with a database of sampled sounds (figure 2.3). Convolution is a well-known operation in signal processing (Roads 1993b, 1997). The convolution of a time-varying train of pulsars with a sound object causes each pulsar to be replaced by a filtered copy of the sound object. Three applications derive from this effect: *cross-filtering*, *rhythm mapping*, and *spatialization*, since each instance of the sampled object is shaped in spectrum, mapped in time, and projected in space according to the corresponding properties of a specific pulsar.

Such effects indicate a few of the compositional possibilities inherent in the advanced pulsar technique. While basic pulsar synthesis allows a composer to vary separately rhythm, pitch, timbre, and spatial projection of an arbitrary waveform sequence, the advanced technique extends this multilevel control to the broader universe of sampled sound sources.

Synthetic sounds: UPIC

I created some sound material using the UPIC system in the studios of Les Ateliers UPIC in Paris. The UPIC was a graphical sound synthesis system with hardware acceleration for synthesis designed by Iannis Xenakis and realized by engineers at the Centre d'Etudes de Mathématique et Automatique Musicales (CEMAMu) (Xenakis 1992; Marino et al. 1990; Weibel et al. 2020). The UPIC system combined various synthesis methods with a flexible graphical user interface to enable a unique approach to sound composition.

3

Sound Tools

This chapter focuses on the technology used to create and assemble *Clang-tint*. I have already mentioned the granular synthesis programs Synthulate, Granulate and Cloud Generator, as well as my program for pulsar synthesis and the UPIC system.

Clang-tint was created within an important period of technological change: the first use of personal computers with interactive graphics user interfaces (GUIs) in support of high-quality sound production. One could view sound waveforms, select a region, and play it back. Prior to this period, real-time interaction with computers consisted of typing command-line instructions such as UNIX shell commands.

The state of interactive GUIs developed extremely slowly during the 1970s and 1980s. In 1979 I was fortunate to be invited to a residency as a visiting researcher in the Department of Computer Science at the University of Toronto. There a team led by William Buxton developed an extraordinary computer music system. It was the first implementation of mouse-and-fader-based real-time graphical interaction with real-time digital synthesis. No other computer music system in the world could match these capabilities (Buxton et al. 1979).

By contrast, when I arrived as a researcher at the MIT Experimental Music Studio (EMS) in 1980, their system was based on old-style command-line terminals that displayed 24 lines of text. Thus I spent many hours at the MIT Artificial Intelligence Laboratory, where I had access to state-of-the-art Lisp Machines with modern GUIs (Roads 1980, 1985).

The original Apple Macintosh with its bit-mapped display, window system, and mouse was introduced in 1984. A major breakthrough occurred in 1986, when the Macintosh app SoundEdit written by Steve Capps featured a GUI for positioning audio clips on a timeline. This has become the paradigm for all digital audio workstations. By 1988 programs like Sound Designer and MacMix became available for editing professional 16-bit audio using proprietary audio hardware.

In this period, my personal studio was based around a Studer Dyaxis audio workstation with MacMix software and other equipment shown in figure 0.1. I purchased the Dyaxis system in 1989 when teaching at Harvard. The Dyaxis hardware consisted of a set of dedicated audio interface (16-bit digital-to-analog converters and analog-to-digital converters), an internal microprocessor chip for mixing, an external 300 Mbyte hard drive, as well as a circuit board with Motorola DSP56000 digital signal processing chips for filtering (Reson8 by Adrian Freed).

The Dyaxis hardware was powered by Freed's MacMix program. MacMix could mix any number of tracks, but not in real time, meaning that one had to wait for a mix to be calculated before one could hear it. The freedom to add tracks at will was essential in the montage of *Clang-tint*. In order to save time, one could limit the time range of a mix—for example, a 10-second transition—so the delay was often just a few seconds. MacMix was the one of the first mixing programs to use the paradigm of audio clips on a visual timeline, in which the clips to be mixed can be rearranged at will (Freed 1987).

With an unlimited number of tracks, one may be tempted by the possibility of layering dozens of sounds to create masses on a symphonic scale. With experience, however, one realizes that this capability actually pulls composition in the opposite direction: toward finer and finer temporal detail. It leads toward the construction of elaborately filigreed mesostructures that are the agglomeration of dozens of short segments merged into longer sections in a hierarchical manner.

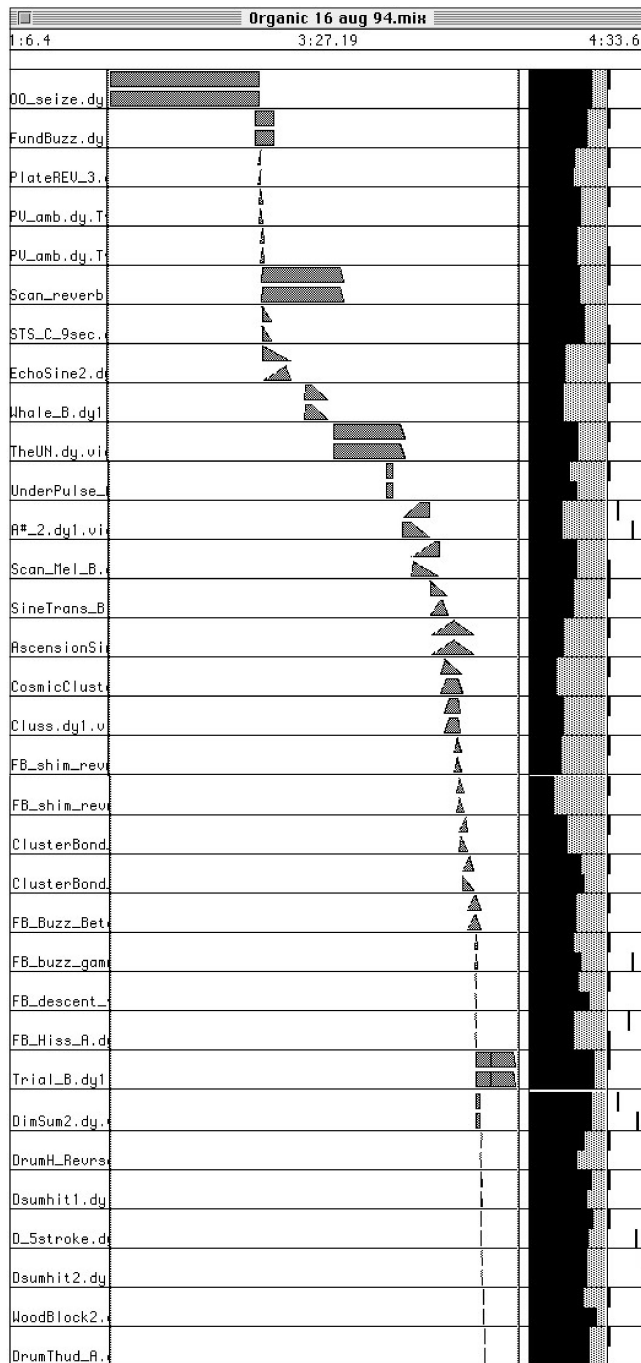


Figure 3.1. Macmix view of *Organic*, 16 August 1994 with the mix elements of *OO_seize* shown. The MacMix software aligns all mix elements in time order.

We can see this in the figure 3.1, which shows the state of *Organic* (one of four movements of *Clang-tint*) in August 1994. Each window shows a list of stereo tracks stacked vertically along a time line. Fade-ins and fade-outs are indicated by the shape of the track elements.

The mesostructural hierarchy becomes clearer when we examine the interior of a single stem or submix at the top of the previous mix, called *OO_seize*. Many tracks in

OO.seize are themselves constructed from other stems not shown. The final mix of this movement was ultimately a montage of hundreds of tracks previously combined in multiple submixes.

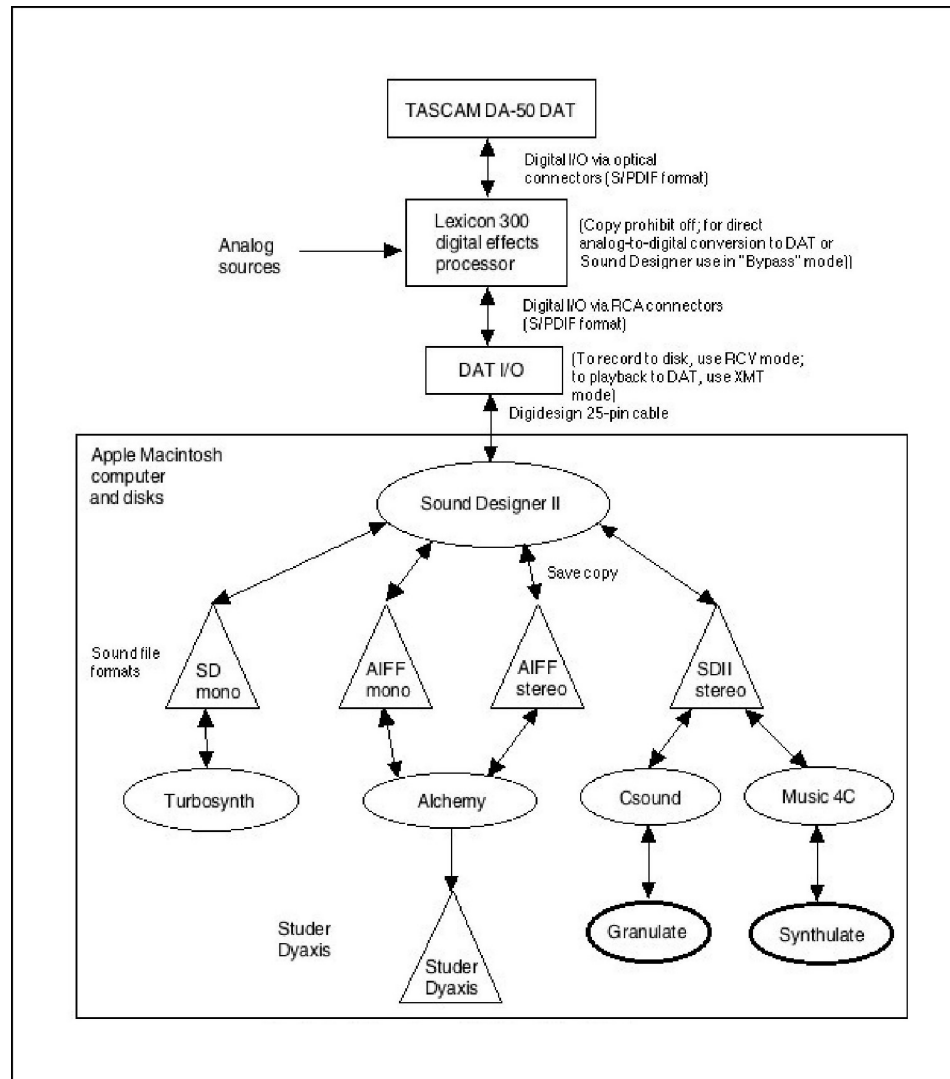
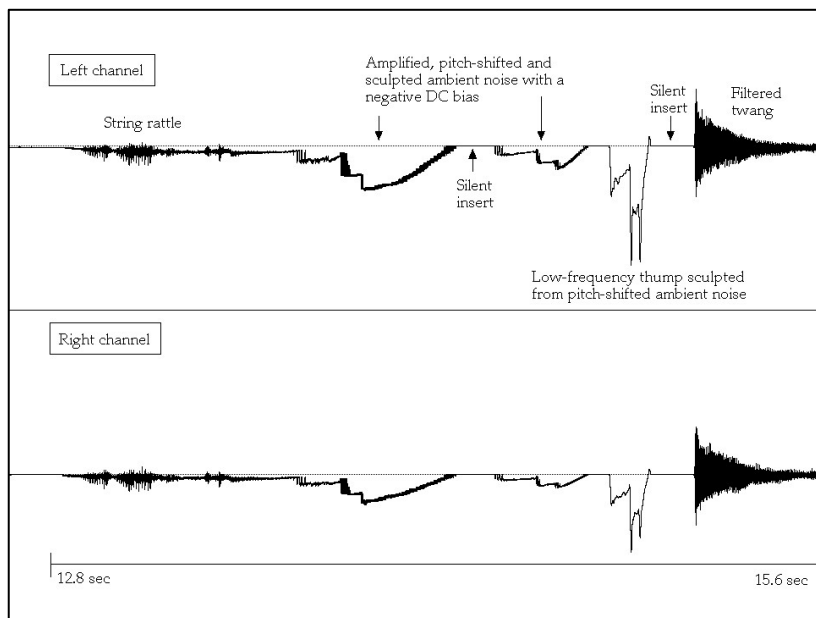


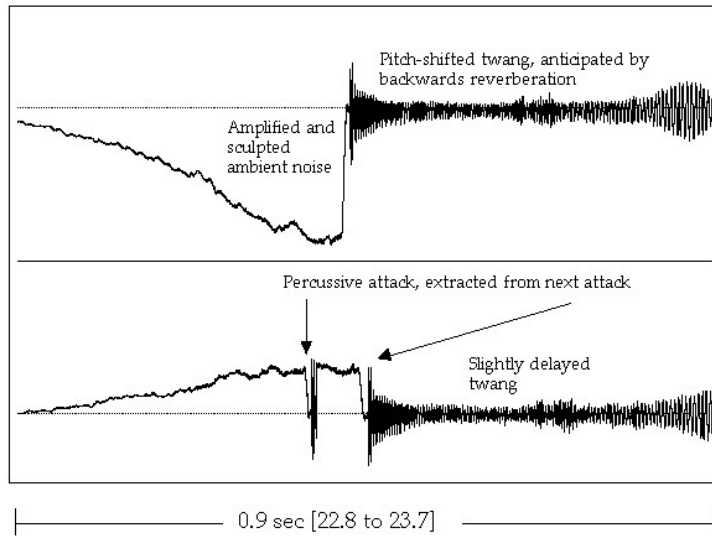
Figure 3.2. Tools used at Midori Studio, Center for Computer Music and Music Technology, Kunitachi College of Music, Tokyo, February 1991. In order to work with a sound using different tools, conversion between sound file formats (Studer Dyaxis, AIFF, SDII, SD mono) was a fact of life in this period.

Figure 3.2 shows software and hardware tools that I used to create and manipulate new sounds during my first residency at Kunitachi in 1991. The software included two sound editors with graphical waveform displays: Digidesign Sound Designer II and Passport Designs Alchemy. These were early waveform editing apps. Waveform displays revealed—for the first time—the intimate details of sonic material, permitting microsurgery on individual sample points as well as tiny grains of sound. I could edit the envelope of a sound object until it had just the right weight, proportion, and shape within a phrase. Zooming out still further, I could shape entire phrases and rearrange macrostructure.

Zooming in and out on waveforms and clips to operate on any time scale is taken for granted today. However, in the time period in which I began to compose *Clang-tint*, this possibility was entirely new. This simple capability—which now seems obvious and intuitive—changed the nature of electronic music composition, as it offered direct and immediate access to all musical time scales.

For sound synthesis I used the several tools: the Digidesign Turbosynth software synthesizer, my granular sampling and synthesis programs Granulate (which generated a Csound score) and Synthulate (which generated a Music 4C score). Using Alchemy I was able to convert files to the Studer Dyaxis format for later mixing in my home studio. I also used a Korg M1, a keyboard synthesizer that combined synthetic and sampled waveforms.





Figures 3.3a and b. Artificial waveforms created by editing. This shows the effects of waveform microsurgery on a recording of a Gopi yantra instrument. (a) The segment contains two ~300 ms insertions of digital silence. (b) In the middle the ambient room sound (normally 40 dB below the string sound) is amplified and sculpted into a percussive thump. At certain points the left and right channels are slightly asynchronous, which shifts the spatial image from one loudspeaker to another.

Graphical sound editing changed entirely the practice of working with sound. Sound editors let us perform microsound surgery to construct waveforms that would never be seen in nature. Figure 3.3a and b shows two highly artificial stereo waveform segments based on microsonic manipulation of a signal originally produced by a Gopi yantra I played at Kunitachi. This Indian instrument consists of a single string attached between a resonating gourd and a long neck. By bending the flexible neck as one plucks, one obtains a variety of expressive twanging sounds.

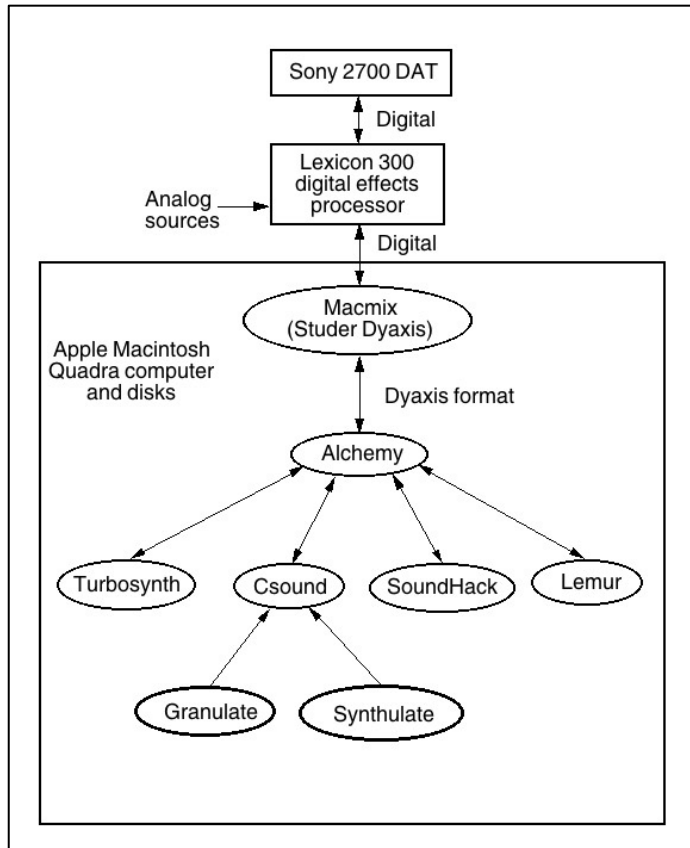


Figure 3.4. Software and hardware configuration of my studio in Paris.

Figure 3.4 shows tools in my home studio in Paris. Besides the ones already mentioned, we see the Lemur tracking phase vocoder and SoundHack, a multifunction signal processing app. Table 3.1 lists the software tools and their uses.

Table 3.1 Software tools used to create *Clang-tint*.

Tool	Use
Studer MacMix	Recording, editing, filtering, and mixing
Studer MultiMix	Recording, editing, filtering, and mixing
Digidesign Sound Designer II	Time-domain editing, pitch shifting, filtering
Passport Alchemy	Time-domain editing, continuous pitch shifting, filtering, re-enveloping; sound file format conversion
Digidesign Turbosynth	Synthesis of synthetic tones and noises; analysis/resynthesis of sampled sounds
Music 4C language	Asynchronous granular synthesis of synthetic grains
Csound language	Asynchronous granular synthesis of sampled grains (granulation)
Synthulate	Generation of synthetic grains from composer's specification
Granulate	Generation of sampled grains from composer's specification
Lemur (tracking phase vocoder)	Sound transformation
SoundHack	Sound transformation; sound file format conversion

The sound system in my Paris studio was based around a Threshold S/500 II amplifier and a pair of Bowers & Wilkins (B&W) 803 Matrix loudspeakers. A Mackie 1202 analog mixer controlled sound playback.

4

Realization

国立市 Kunitachi residency 1: 1991



Figure 4.1. The author at Sensoji Temple (645 CE), Asakusa, Tokyo.

The commission for *Clang-tint* involved an initial composing residency in Tokyo (figure 4.1).



Figure 4.2. Courtyard at Kunitachi outside the electronic music studios, 1991.

I began my stay in January 1991, working in the newly renovated studios of the Kunitachi Conservatory (figure 4.2). Besides the well-appointed computer music studios, I was particularly interested in an extraordinary facility at Kunitachi, the Gakkigaku Shirōkan (Musical Instrument Museum, or Institute of Organology). Thanks to Professor Sumi Gunji, Director of the Institute, I was granted sole access to the facility for a period of five days so that I could record the instruments.

I imported my own recording equipment to Japan. This consisted of a matched pair of Schoeps CMC5 condenser microphones with cardioid capsules as well as a two-channel Sontec MPA-1 microphone preamplifier. The output of the preamplifier was routed to the 64-times oversampling analog-to-digital converters of a Lexicon 300 digital signal processor. This in turn was connected via digital optical interface to a Tascam DA-50 (digital audio tape) transport at Kunitachi. The quality of the recordings was high.







Figure 4.3. Collage of photographs of recording at Kunitachi.

Alone in the museum, I played the instruments myself, since no instrumentalists were available. Over five days, I recorded 45 instruments, some dating back to 500 BC, and some as modern as a 1960 Ondes Martenot—an analog electronic instrument (figure 4.3). The instruments came from Zaire, India, Iran, Syria, Japan, France, Indonesia, England, Scotland, Germany, Switzerland, Burma, Papua New Guinea, Russia, Czechoslovakia, China, and the USA.



Figure 4.4. DAT archive of *Clang-tint*, including master mixes, sound examples for a lecture, sample transcriptions, and Kunitachi recording sessions.

The recording sessions resulted in a database of ten hours of sampled sound on Digital Audio Tape or DAT (figure 4.4).

1. Hyoshiban (wood block)
2. Garamut (large wood block)
3. Si (finger cymbals)
4. Rattle (shaken)
5. Bell
6. Napura
7. Kempli (Gamelan gong)
8. Trompong (Gamelan gong)
9. Reyong (Gamelan gong)
10. Tong gu (bronze drum)
11. Gong
12. Cymbals
13. Gender jegogan (metallophone)
14. Cog rattle

15. Music box Polyphon
16. Music box Symphonion
17. Harmonium (Indian)
18. Harmonium (German)
19. Nanhu (Erhu bowed string instrument)
20. Virginal
21. Double harpsichord
22. Sitar
23. Accordions (several)
24. Peruvian flutes (several) 11th to 15th century Chancay culture
25. Peru duct flutes (several) 400 B. C. to 200 A. D.
26. Tang Dynasty flutes
27. Small Chinese bells from 5th century B. C.
28. Positive organ
29. Hammond organ
30. Ondes Martenot
31. Zither (several)
32. Santur
33. Dulcimer (several)
34. Clavichord

Instruments 1-21 were cataloged in the book *The Collection of Musical Instruments* by Sumi Gunji et al. (1986).

国立市 Kunitachi residency 2: 1994

By 1994 I was Director of Pedagogy at Les Ateliers UPIC in Paris, a center designed around the technology developed by my former teacher Iannis Xenakis and his research colleagues (Weibel et al. 2020). For the second residency, I flew from Paris to Tokyo on 31 March 1994.

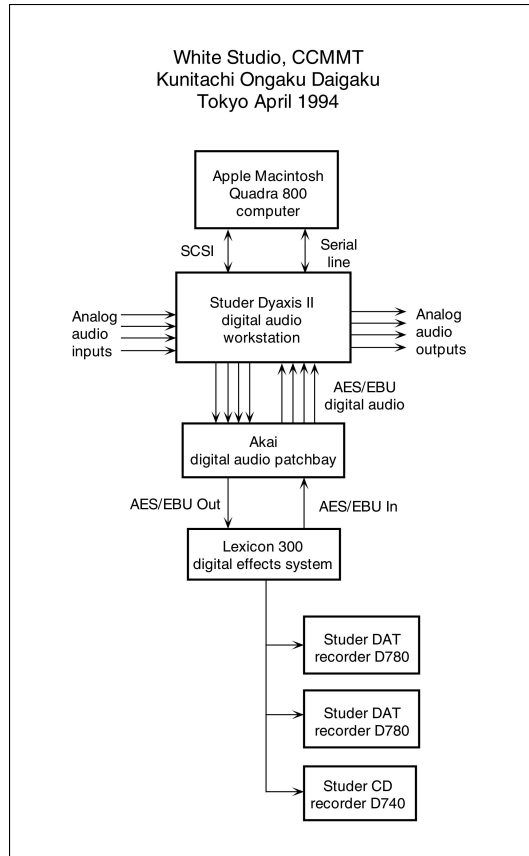


Figure 4.5. Configuration of the Shiroi (White) studio in 1994.

Purity was completed in Paris prior to my arrival in Tokyo. To finish *Organic* and *Filth* I had intensive marathon mixing sessions in the Shiroi (White) Studio (figure 4.5) at Kunitachi.



Figure 4.6. The author with the Studer MultiMix system in 1994 at Kunitachi College of Music, Tokyo.

My main tool for this work was the Studer Dyaxis II workstation running the MultiMix program (figure 4.6). In contrast to my own Studer Dyaxis running the MacMix program, the Dyaxis II was an advanced system, with dedicated disk drives and multiple Motorola DSP56000 processors. The Motorola chips sped up audio processing, so the system could playback and mix an arbitrary number of tracks in real time. Real-time mixing of an arbitrary number of tracks was realized by a clever method of invisibly submixing (with hardware assistance) all regions that overlapped in time. This happened whenever one moved a region on the time line in the mixing window. Thus every editing operation resulted in a newly rendered submix. Playback was then trivial, as the Dyaxis II only needed to play a chain of submixed stereo files.



Figure 4.7. Poster for the premiere of *Clang-tint*.

After seven weeks of studio work, I presented a lecture and a world premiere concert of three movements of *Clang-tint* on 20 April 1994 at the Kunitachi school (figure 4.7).

Period of Revision

I was not satisfied with *Organic* and *Filth* as presented in the premiere. Thus as soon as I returned to Paris I began revising these movements. Major revisions took place in 1994 and 1995. These revisions defined the final form of both pieces. From time to time I would revisit the work to make minor edits. The final version of *Organic* was finished in 1999. I remastered *Purity* for compact disc release in 2000. (See the section on *Purity* below.) I kept adjusting *Filth* until 2004.

The following chapters focus on the individual movements of *Clang-tint*.

5

Purity

The metaphor of *Purity* suggested high fidelity pure tones in a tonal context. The organization of *Purity* is based on a pulsating metrical structure and microtonal counterpoint.

Bohlen-Pierce scale

We seek new pitch schemes for their expressive potential. The pitch organization of *Purity* derives from the Bohlen-Pierce (BP) scale (Mathews and Pierce 1989). In contrast to the equal-tempered scale (12 ET) where each interval obeys the law: 12th root of 2, or 1.05946, the BP scale derives from the relation: 13th root of three, or 1.08818. Hence the BP scale has 13 tones. Note also that the cycle point of the BP scale is 3:1. It is called the *tritave*, in contrast to the equal-tempered scale's 2:1 octave. The equal interval of each semitone step in the case of the 12 ET is 1.05946. That is, a minor second interval represents a 5.9% difference between two tones. In the case of the BP scale, the chromatic step interval is larger, on the order of 1.08818.

I chose to use the BP scale not because of its numerological properties, but because of its intriguing sound. With its combination of intervals that were sweeter than 12 ET, together with others that were more sour, I saw strong potential for expressive melodic and harmonic structures.

Table 5.1. Bohlen-Pierce scale

Step	BP interval in cents	Frequency ratio	Closest 59-limit Just interval (decimal)	BP's difference in cents from 59-limit Just interval	Closest 5-limit Just ratio	Closest ET degree (cents)	5-limit Just difference in cents from ET degree
0	0	1	1/1	0	1	I	0
1	146	1.08818	27/25 (1.08)	-13		ii (100)	
2	294	1.18414	59/50 (1.18)	-8	6/5 (1.2)	iii (300)	+15
3	438	1.28856	9/7 (1.2857)	-3	5/4 (1.25)	III (400)	-14
4	585	1.40219	7/5 (1.4)	-3		Tritone (600)	
5	731	1.52583	38/25 (1.52)	-7	3/2 (1.5)	V (700)	2
6	877	1.66038	5/3 (1.666)	7	5/3 (1.66)	VI (900)	-16
7	1024	1.80681	9/5 (1.8)	-7		vii	
8	1170	1.96613	49/25 (1.96)	-5	2	VIII (1200)	0
9	1313	2.1359	21/10 (2.1)	-29		ix (1300)	-7
10	1463	2.32818	7/3 (2.333)	3		x (1500)	
11	1609	2.53348	63/25 (2.52)	9	5/2 (2.5)	X (1600)	0
12	1755	2.75689	11/4 (2.75)	-4		Aug XI (1800)	
13	1900	3	3/1	0	3	XII (1900)	0

One can summarize the most important facts about the BP scale by referencing Table 5.1. First the basic BP step of 1.08818 is a quarter tone broader than a major second, broader than the Pythagorean second (1.07). Several BP steps are very close approximations to Just intervals. Specifically, step 2 of BP (BP2) is close to a pure minor third (8 cents off) and BP3 is only 3 cents off from a pure major third. BP4 is very close to a pure tritone (3 cents off), while BP5 is very close to a pure perfect fifth (7 cents off, as opposed to 31 cents off for 12 ET). BP6 is very close to a pure major sixth (7 cents off, as opposed to 14 for 12 ET) and BP8 is close to an octave (30 cents off). BP10 is very close to a pure minor 10th (3 cents off) and BP12 is very close to a pure augmented 11th (4 cents off). BP13 is a pure perfect 12th.

Pierce (1999) viewed BP as a 9-tone scale (using steps 0, 1, 3, 4, 6, 7, 9, 10, and 12) beginning on any of the 13 chromatic steps, yielding 13 keys. Mathews and Pierce (1989) analyzed the harmony of the scale and showed its possibilities for quasi major and minor chords. My work, however, exploited the total chromatic range.

I programmed the BP scale on a Korg M1 synthesizer. The Korg M1 was tunable in cents, but was limited by its octave-based tuning system. This meant that retuning the middle C key (for example) also retuned all other C keys in higher and lower registers. Thus I had to divide the BP scale into two parts, BP I (the first nine steps of the scale) and BP II (the remaining steps). The M1 keyboard let me switch between them but I could not play them simultaneously except by overdubbing, which I did.

The ear is the most sophisticated sound analyzer we know, and it was by ear that I mastered the BP scale. This process of familiarization took many months.

Sectional organization

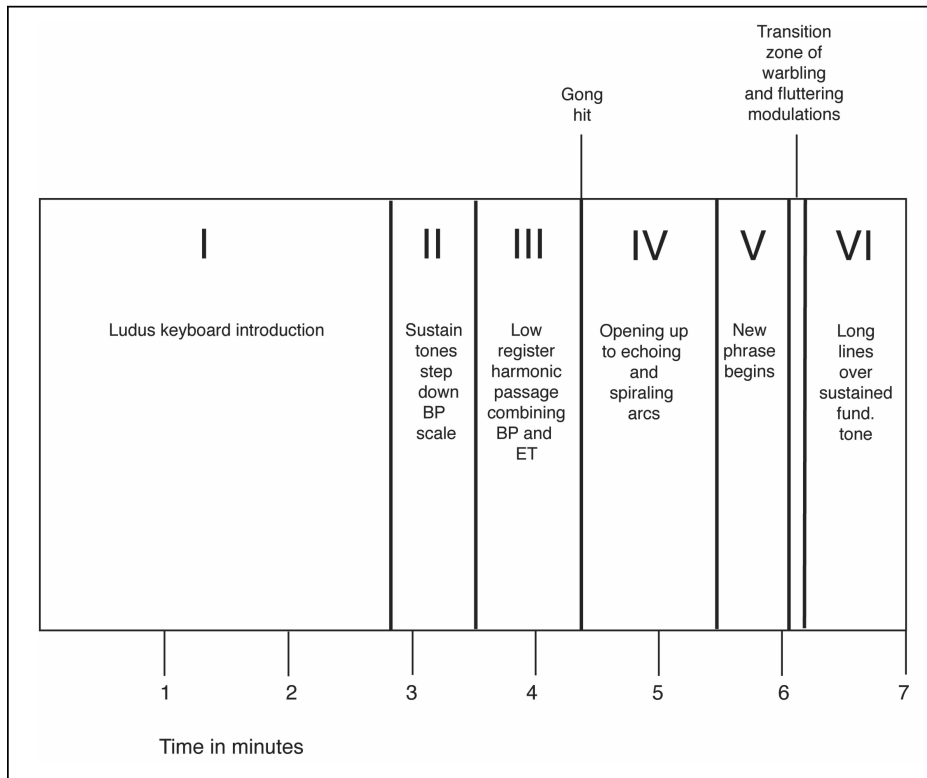


Figure 5.1. Sectional organization of *Purity*.

The overall form of *Purity* is strongly sectional, proceeding from a simple organ-like introduction and evolving into a “cosmic” glissando texture, made larger by deep echo and reverberation effects. On the last note, it returns to its organ origins. *Purity* divides into six sections, separated by transitions (figure 5.1).

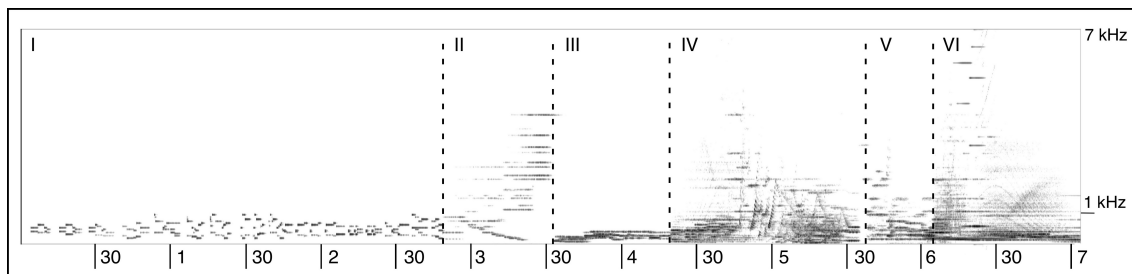


Figure 5.2. Sonogram with time on the horizontal axis and frequency on the vertical axis. Sections I-VI of *Purity* are indicated.

Figure 5.2 shows the same organization in a sonogram. Notice the contrast in spectra between section I and sections IV, V, and VI.

I [0:2:49] *Ludus*

I called the first section *Ludus* (Latin for play) because it began as an improvisation. As I played repeatedly with the material, however, I began to arrange the figures in a specific sequence. In the end, I performed a seven-minute keyboard performance using BP I on 24 January 1994 in Paris. It uses a sinusoidal voice (“Pur_Jan”) that I programmed on the Korg M1 synthesizer. The material divided into discrete two-voice phrases up to 2:14, then became more free. At four minutes the phrases play in the bass, and at 5:30, pitch bends entered in. I selected different parts of this performance, edited them, and spliced them into the opening of *Purity*.

II [2:49-3:33] *Sustained tones*

Long sustained notes (> 10 sec), bathed in reverberation. The texture simultaneously steps up and down the BP scale, reaching a single sustained tone in the high register.

III [3:33-4:20] *Polyscalar*

A warm harmonic section in the lower registers combines notes from both 12 ET and BP to create a hybrid progression, bathed in reverberation.

IV [4:21-5:35] *Cosmic opening*

Opens with a large gong sound recorded at Kunitachi. At 4:42 I introduce notes that spiral upward in frequency while also echoing, reminiscent of the radiosonic modulations of *Forbidden Planet* (1956) by Louis and Bebe Barron. Steady background tones maintain a tonal center leading to a resolution at the end.

V [5:35-6:04] *Bridge phrase*

A new bridge phrase begins after a cadence that resolves near to a pure tritone away from the tonal center.

VI [6:04-7:14] *Transition and Finale*

Warbling modulated tones signal a transition from the bridge phrase to the finale. The finale converges toward resolution at C, the tonal center of the piece. The last note is a positive organ sample that I recorded at the Kunitachi museum.



Figure 5.3 Cover of CCMIX CD.

In 2001 *Purity* appeared on a compact disc anthology entitled *CCMIX Paris: Xenakis, UPIC, Continuum* on the New York-based MODE Records label (figure 5.3). This album won the “Coups de Coeur” award from the Académie Charles Cros in Paris and was named “One of the Top Five of 2001” by *WIRE* magazine in the UK.

6

Organic

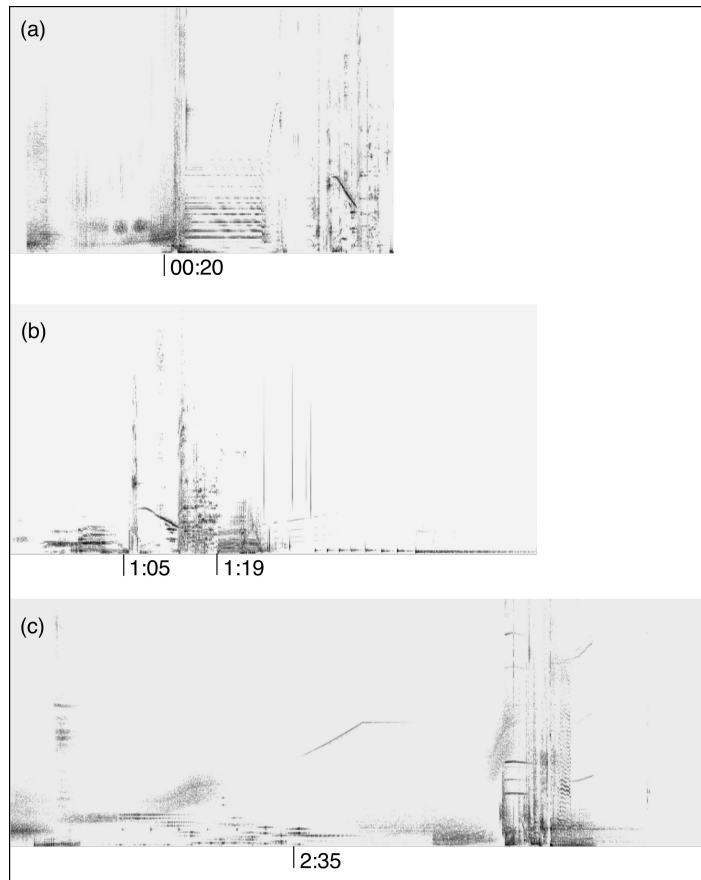


Figure 6.1. Sonogram of the three sections of *Organic* with time on the horizontal axis and frequency plotted to 7000 Hz on the vertical axis.

Organic lasts 3 minutes 22 seconds and can be divided into three sections:

Section I [0:00-0:48] *Beginning* (figure 6.1a)

Opening pulsar cluster salvo. Zone of attraction at 20.5-23 seconds.

Section II [0:49-1:55] *Middle* (figure 6.1b)

Murky beginning. Pulsations emerge. Expressive gopi yantra phrases enter at 1:05 including pitched tones made by Korg M1. Pulses going up and down in frequency begin at 1:19.

Section III [1:56-3:22] *End* (figure 6.1c)

Gasp opening onto a natural soundscape. Pulsar cluster. Slow contra-pulsations. Rising tone at 2:35 leads to climax and finale.

The acousmatic question

Organic draws sonic materials from the world of living creatures: animals, birds, and insects. These are merged in natural combination with electronically-generated pulsars and sine waves. Indeed *Organic* is the first piece in which I used pulsar synthesis. Pulsations function as a common thread throughout this movement.

The *acousmatic* question has long been part of the discourse of electronic music (Schaeffer 1977). A composer can choose to reveal the provenance of a sound, or its source identity can be obscured. This can be done by transformation or by syntactic arrangement (juxtaposition, intermixing, masking, etc.). My initial plan involved a variety of recognizable source sounds, following the example of the Starn brothers use of “quoted” portraits. However, after experimenting with recognizable sounds, I found them to be distracting. These sounds can evoke narrative allusions that resist attempts to configure them into the kinds of compositional structures I was seeking.

Thus I transformed the recognizable sounds so that animate and inanimate sources are often indistinguishable and can function together within the design of the piece. The ultimate aim was to extract the sonic essence of the source, rather than paint a portrait with recognizable sounds. At the same time, I used the expressive power of samples at key moments such as the end of section II and the beginning of section III, where synthetic pulses open onto an obviously natural landscape.

Tape echo feedback

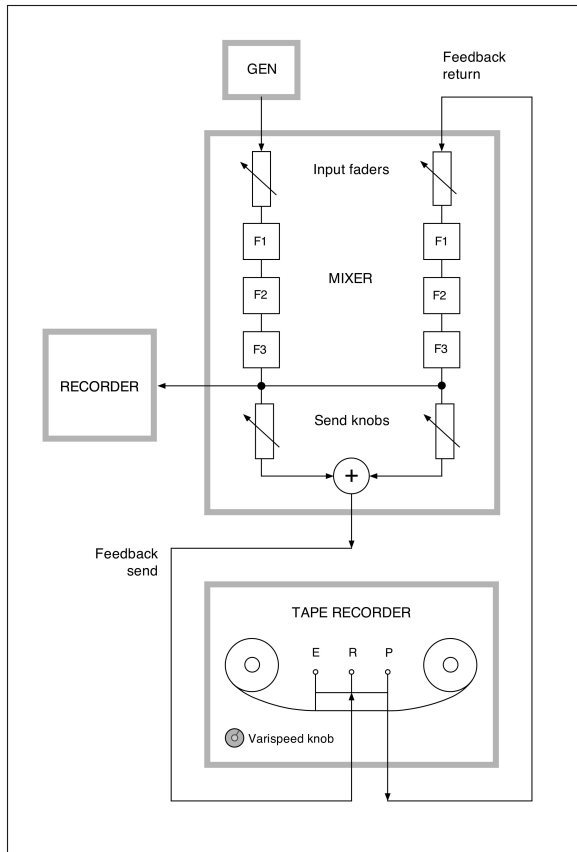


Figure 6.2. Tape echo feedback circuit as used by the author. GEN is an impulse generator, but any other sound source could be used. F1, F2, and F3 are filters. E is Erase head, R is Record head, P is Playback head. Note that all signals are two-channel. In order to create a ping-pong echo effect the left send goes to the right input on the tape recorder.

Organic makes use of *tape-echo feedback* (TEF). TEF was originally developed in 1951 by Dr. Werner Meyer-Eppler, Stockhausen's teacher (Ungeheuer 1992). Stockhausen and his assistant G. M. Koenig used this technique extensively in the realization of the opus *Kontakte* (1960). My interest in recreating this lost sound world has led me to explore this technique in several compositions. Figure 6.2 illustrates the technique. It requires an analog chain consisting of a two-track tape recorder with a varispeed control and a mixing console with an equalizer section. The rate of echo is controlled by the varispeed knob but also by the amount of feedback. More feedback brings in more echoes. Filtering focuses the feedback in specific formant regions of the audio spectrum. It is easy to induce a self-sustaining feedback, which can lead to long and evocative phrases. For *Organic* I recorded the resulting mix in real time on a digital audio tape.

Attraction and repulsion as an organizing principle

In this movement, I first tested the principle of *attraction-repulsion* in composition. Varèse hinted at this idea when he observed:

When new instruments will allow me to write music as I conceive it, taking the place of the linear counterpoint, the movement of sound masses, or shifting planes, will be clearly perceived. When these sound masses collide the phenomena of penetration or repulsion will seem to occur.—Varèse (1936).

In *Organic*, sounds gravitate around designated zones of attraction. Sounds scatter around zones of repulsion. One zone of attraction is the period from 20.5 seconds to 23 seconds. Dozens of brief sounds burst in a cluster within this zone. A sparse zone of repulsion appears at 55 seconds. I made a second zone of attraction in the region between 3:00 and 3:06, the finale of the work.

7

Filth

The sound material of *Filth* derives from a morass of crude waveforms, raw transients, irregular sound globs and grains, industrial noises, and distorted tones.

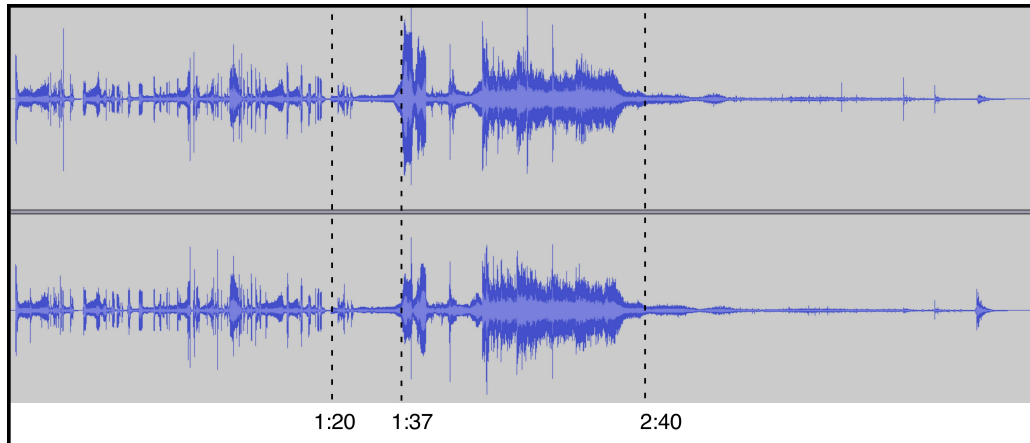


Figure 7.1 Waveform view with markers indicating the formal organization of *Filth*.

Filth can be divided into four sections indicated in figure 7.1.

- I [0-1:20] *Opening*
- II [1:20-1:37] *Transition*
- III [1:37-2:40] *Distortion and climax*
- IV [2:40-4:16] *Finale*

The final section consists of soft sounds in layers. Running throughout most of the last section is a recording of burning embers of wood, which I called *fire song* at the time. This burnt ember recording was extensively edited. In order to even out the amplitudes I altered or excised many transient bursts. Then it was filtered and ring-modulated at 246 and 470 Hz to situate it within a specific spectral band.

Granular synthesis

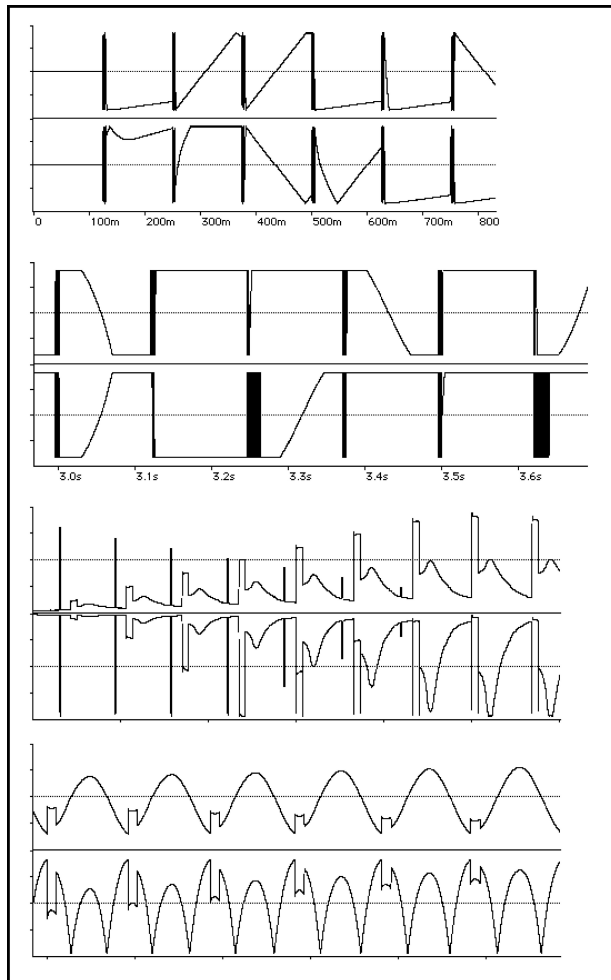


Figure 7.2 Unusual waveforms generated by granular assembly.

One of the techniques deployed in *Filth* is granular synthesis (Roads 1991, 1995, 1996b). Granular synthesis generates short-duration grains of sound (typically less than 100 ms). It is one of a number of methods of *microsound synthesis* (Roads 2001a, 2001b). The grains can be generated *synchronously*, i.e., one immediately after the other, *quasi-synchronously* (jittered in time), or *asynchronously* (randomly in time) to produce different types of textures. For example, the emission of several synchronous grains can result in a sound object on the time scale of a typical note. By contrast, thousands of asynchronous grains can produce dense clouds of sound of arbitrary length. The grains can be generated by algorithm or by manual editing (*micro-montage*) (Roads 2001b). Figure 7.2 shows some of the unusual waveforms I assembled in the course of making *Filth* (figure 7.2).

After the premiere of *Clang-tint* in April 1994, I returned to Paris, where I was working at Les Ateliers UPIC. As I was not satisfied with *Filth*, I began revisions. During this same period, John Alexander and I developed the Cloud Generator program shown in chapter 2 (Roads and Alexander 1995). Specifically, I coded the grain generator, and

John Alexander wrote the graphical user interface (GUI). The GUI uses the metaphor of a laboratory signal generator. The primary features of Cloud Generator are:

- clouds of synthetic waveforms or granulated samples
- synchronous and asynchronous granular synthesis
- waveform drawing or imported waveforms
- random, statistical, or deterministic timeline algorithms
- graphical display of cloud formation
- high-resolution interpolating oscillators
- stereo file output
- text output for use with plotting programs.

Distortion

In audio recording, distortion has been viewed as something to be avoided. At the same time, vacuum tube distortion became a signature sound of the Chicago blues. As a young musician growing up near Chicago, I was quite familiar with this sound, which amplifies the impression of intensity.

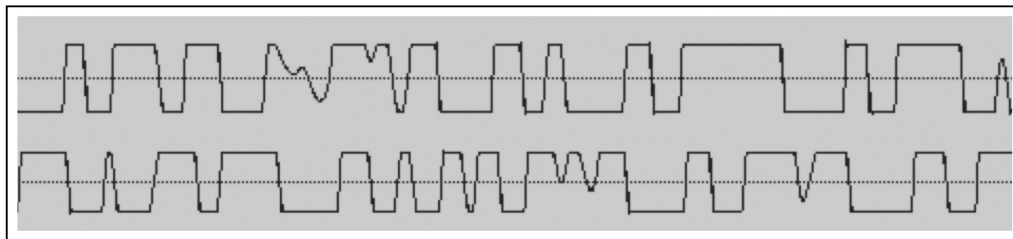


Figure 7.3 Distorted waveforms created by extreme filtering.

A goal in making *Filth* was to develop techniques of distortion that would not be perceived as harsh. In electronic music we have myriad techniques to distort sounds (compression, waveshaping, wavefolding, quantization, noise modulation, etc.). Section III of *Filth* applied extreme equalization to this end. I used the hardware-accelerated MacMix graphic equalizer to boost certain spectral bands by 24 dB, causing overload saturation (figure 7.3). This is heard in section III of *Filth* where I applied distortion to a battery of explosive sounds.

8

Robotic

Robotic is the unfinished fourth part of *Clang-tint*. It was conceived as an opposite to *Organic*, in the same way that *Purity* and *Filth* are opposites.

The original idea behind *Robotic* was to harness the rhythmic energy of machines. Machines often express their mechanical nature by emission of metrical and synchronous sounds. With metrical rhythms as the core of the work, the main question was how to organize the structure of the work on multiple time scales. *Robotic* was planned as a study in polyrhythms. It was to proceed from asynchronous rhythms of sampled acoustic percussion toward increasingly synchronous (metrical) mesostructure, realized by synthetic percussion instruments.

Like the other parts of *Clang-tint*, the concept was a research challenge. Initial results were not compelling. It was clear that it would require much experimentation to make a successful piece of music. As time went on, the call of newer projects eventually led me to abandon this one.

9

Aesthetic reflections

In my student days, I recall a talk by a composer who spoke for more than an hour about a single composition. He said he could go on at much greater length. At the time I thought: how much is there to say about any one piece? Documenting *Clang-tint* taught me that one can say a great deal!

Clang-tint was a milestone in my compositional process. I set goals at the beginning with the explicit aim of expanding my technique. I also set out to design this work using conceptual metaphors as an exercise to expand my intuition.

Clang-tint reflects its zeitgeist. In the 1970s the production of electronic music synthesizers was a cottage industry. Companies like Moog, Arp, EMS, and Buchla sold modular synthesizers by the hundreds. By the 1980s innovation shifted to Japan. Japanese corporations industrialized production and marketing of electronic instruments. Synthesizers by Yamaha, Korg, and Roland were sold by the hundreds of thousands. Viewed as a cultural artifact, *Clang-tint* can be seen as a product of the early 1990s in Japan—the era of the Japanese “economic miracle”—a period of impressive prosperity and social cohesiveness. I recall neatly-dressed elevator operators everywhere in Tokyo, a sign of full employment—not something one would see elsewhere.

In Tokyo, I was fortunate to meet Xenakis’s former student and colleague, the composer Yuji Takahashi, who gave an extraordinary live electronic music performance. He sat cross-legged onstage as if meditating in front of an Apple Macintosh computer, generating sound while a butoh master danced. One could never witness such a culturally-specific performance outside of this exclusive venue.

The extraordinary series of Kunitachi commissions (several other non-Japanese composers also received support) was a sign of emergence of Japan as an international cultural force in the field of electronic music. Since that time there has been much more exchange, with Japanese electronic music artists becoming well-known internationally.

The technical context of this work is also significant. This was the first piece that I realized with graphical editing and digital multitrack mixing techniques, as opposed to analog tape editing and mixing. The ability to view waveforms and edit on a micro time scale was a revelation. This capability enabled a process of multiscale planning (Roads 2015). Whereas the emphasis in computer music in the 1970s and 1980s was on

programming and synthesis techniques, the 1990s was an era in which interactive editing moved into the forefront of working methods.

One of the aesthetic goals of *Clang-tint* was to demonstrate that a broad and heterogeneous sound palette can be integrated into a coherent compositional structure. Despite their contrasting sound palettes, the movements of *Clang-tint* are united through their phrase-structured discourse. Finding a way to organize a musical narrative was the most important lesson for me. A style emerged from this process that would echo in my later works.

Notes

Chapter 0

1. Varèse died in 1965, around the time of early computer music experiments at Bell Telephone Laboratories. For example, the modular synthesis program Music V by Max Mathews and J. Miller first appeared in 1966 and his book about it appeared in 1968 (Mathews 1968). In 1982, the equipment cost to start a computer music studio could easily exceed \$200,000. The introduction of MIDI and real-time digital synthesis (Yamaha DX-7) in 1983 was a major breakthrough, but it was not until around 1988 that low-cost (<\$2000) professional quality analog-to-digital and digital-to-analog converters became available for personal computers.

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Appendix: Early presentations on *Clang-tint*

March 1991. Kunitachi College of Music, Tokyo. Lecture on the work-in-progress.

June 1991. Pontificio Istituto di Musica Sacra, Rome. Lecture on the work-in-progress.

April 1992. Tempo Reale, Florence. Lecture on the work-in-progress.

September 1993. International Computer Music Conference, Tokyo. Poster on the work-in-progress.

April 1994. Kunitachi College of Music, Tokyo. Lecture on the premiere.

June 1996. "Materials and montage in *Clang-tint*." Académie de Bourges 1996.