

# Musical Ideas for Synthetic Sound

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A lecture given by Brün around the time of composition of his *Sonoriferous Loops*. This must have been given for a somewhat technical audience, given its material. I've edited some trivial mistakes that may have entered in from the original typing. [A.C.]

## *Introduction*

Time is running short. So let me be concise. Brevity may cause omissions. Gaps caused by omission can be filled in later. If you have questions, remember them. After I have finished lecturing, I shall try to answer the questions you then will ask.

First let us hear something of which nobody should be able to say immediately and with sure conviction whether it is music or noise. Nor do you have to come to any such conclusion right now. You are going to hear it again later. Maybe we shall then come to some kind of agreement as to what this is that I make you listen to now.

## *CSX-1*

Some people know more about computers than others. Some people know more about music than others. And even those people who know something about either or both usually are not in complete agreement. As I can not remedy this probably deplorable situation in one hour or even two, and as I do not wish to address myself only to those who know more or at least think so, I have to ask you all to agree with me, for the time of this lecture, in adopting a so-called "working hypothesis" as to what a computer is to a composer and as to what music is to a composer who desire the assistance of a computer. Under this working hypothesis both, music and computer, appear as systems, and all I now have to do is to explain briefly, what I mean with the word "system", whereupon we shall all have the same point of departure, and equal nu-

cleus of knowledge, from which to proceed together.

The world is full of audible events, of acoustically perceptible events. Let us quickly divide all that one can hear into two distinct classes. If you walk, one can hear your steps. If you suddenly step on the brakes, one can hear your car screech to a halt. If you pay attention, especially in the evenings, you can hear the town; or if you live in the country, you can hear the wind in the trees, or the breath of silence in the plains.

In all these cases, you will agree that what you hear are sound events which are by products of something else. These sounds just accompany certain goings on, which may be motions of man or things; goings on that go on without having sound as a purpose. So let us call our first class of audible events: unintended sound. Obviously, our second class of audible events will contain all intended sound. Intended sound is the result of some action which has been chosen for the purpose of producing sound. Usually it is very easy for even only slightly intelligent humans to discern, when they hear something, whether it was intended sound or unintended sound. Occasionally though, one has to think. If I slam a door because I wish to close it as fast as possible, the slamming noise is unintended. If I slam the same door to express my feelings, you can be quite sure that the noise is very much intended. If you hear only the noise, you can not know which it was. You would need more information about me, for instance, to see my face or to know the context in which I slammed that door, in order to understand the sound as intended or not.

Intended sound is the material of music. I underscore the material. While all music is heard as intended sound, not all intended sound is heard as music or even necessarily meant to be music. Speech for instance. Applause. The Metronome. Audible signs and signals like: Sh—, tsk-tsk, foot stamping, etc.

So, I am sorry to say, we must subdivide our second class of acoustical events, the class of intended sound into two groups: Intended acoustical events and intended musical events. To discern between these two groups is always very difficult; frequently it seems almost impossible, at least for a while. Unfortunately it is just as impossible to be a music listener as it is to be a composer, if one does not perceive the difference. To be quite fair I have to make two statements: The problem is far more difficult to solve for the listener than for the composer. In fact, the composer is a person who makes it his profession to turn acoustical events into musical events. By the time he presents his work as a musical composition to the listener, the composer, if he is not just an arranger of old stuff or simply a fraud, has already solved the problem, and knows precisely what he has intended and what not, whereas the listener now has to begin to find all that in what he hears.

On the other hand, just therefore the listener should not jump to conclusions, but rather give himself a chance by giving himself a little time in which he might detect, by and by, that especially among the most forbidding sounds of new pieces more acoustical events did indeed turn music than first meets the ear. It should not surprise any listener that music sounds strange if it consists of sounds and sound constellations which had never been music before.

How does the composer turn acoustical events into musical events? Well, one might think, that innumerable answers to this question exist, just as many answers as there are composers and composition teachers. But I assure you that if all these people could never agree on almost anything, they will agree to this very general answer: If you select from all possible acoustical events a specific set and stick to it; if you impose rules and restrictions on the possible permutations of the elements of that set and stick to these rules;

and if the order in which the acoustical events thus finally appear it not only of acoustical interest but also of significance as an organization, as changes of state in a system, as an event in time, analogous to other events in time that deserve attention, then at least these selected acoustical events become intended musical events. If you can hear in a performance of these musical events something that either is or should be of importance to you, something which is analogous to or reminds you of what has importance and meaning for you, something which causes you either to think or to cry or to laugh or all of it at once, then, if you can hear it, you are hearing music. If you hear it for the first time it is new music for you. New music for you may be from any period, composed long ago or recently. If what you hear is music for the first time, then it is new music for everybody, including the composer, and can only have been composed in our time. Composers of music need not always be composers of new music. It is of great interest, artistic and personal, to try and turn already musical events into different musical events. But it is, of course, of great commercial interest, to turn already musical events into the same musical events, or even to turn new musical events like electronic sound into old musical events by having them play *Yankee Doodle* or TV science fiction tunes. It is always disastrous when composers dabble in customer research, asking the listener, the publisher, the critic for advice. In any case, and whatever a composer may choose to do, he at least ought to know what it is that he does.

The computer is used by composers who are searching for new acoustical events (we call that "research in synthetic sound generation"), for new ways of turning these new acoustical events into musical events (we call that: "research in compositional logic and logistics"), and for an appropriate notation of possible music results, as the traditional music notation occasionally seems unsuitable.

All this was to affirm that the pursuit of musical composition requires, on the one hand, full dedication to a steady and unchanging idea: namely the idea of transforming into music what otherwise would remain merely acoustical, and, on the other hand, full

preparedness, even the desire, for constant changes, to the point of radical abruptness with regard to possible materials and methods.

The use of the computer does not reflect any change of idea, but rather a considerable change in the concepts of materials and methods.

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Some people know more about computers than others. Most people know something about what the computer can do. Let us forget all this for the moment. I wish to describe the computer to you as I as a composer see it, as anyone can see it, so that we all can share one image of it, independent of previous knowledge. In the course of this description my use of four all-important words, and what I mean by them will be explained: System, Algorithm, Compatibility, Analogy.

In my first musical example you will hear in one minute nearly 4000 sound events. Each is defined by a frequency out of a repertoire of 120 different frequencies, and by a duration out of a repertoire of 1000 different durations. All the sounds were produced at one and the same dynamic level and represent one and the same wave form, namely the square wave.

#### *Example 1*

What can anyone make of such a thing? I shall show a little later, what I made of it, but first let us take a sober look at the proposition and at some ways of placing it. We have a small but fast and accurate computer at the University of Illinois, which is called CSX-1. When it was built on campus, an engineer had the idea to incorporate into the machine a square-wave generator with an excellent amplifier and a good loudspeaker. Many computers possess similar facilities, but none good enough for my purposes two years ago. CSX-1 filled the bill at that time, in what it would represent each state of that system called computer with a different and very clear tone. Thus the technicians were able, after a short briefing in ear-training, to locate malfunctions of the circuitry by ear. Soon, and with the help of computer engineers and programmers, the somewhat arbitrary repertoire was, so to speak, "musically" reordered, so that in the

end I could handle the computer just like an instrument. Or, in other words: I could operate on and with the states of that system called computer. I did, and the example you just heard, was the result, played by the computer. Now let us quickly compare the two systems, the music I had in mind and which you heard, with the computer I used. Let us count, how many states of a system were necessary to represent all the events in my examples: 1 for rest, 1 for play, 120 for frequencies and 1000 for durations. As no changes were planned for the waveform and for the dynamic level, they did not need to be operated on and thus did not mean anything in the system.  $1000 + 120 + 1 + 1 = 1122$ . The CSX-1 on the other had offers me 65536 different states.

In recording the output of the CSX-1 Computer, I converted each state of a system called electromagnetic fields and impulses on a tape. This was possible because of the high degree of compatibility between the two systems. This tape you heard. Now I took the tape to the Electronic Studio, which I had previously prepared to represent a system of circuitry, that would change its state in analogy to the changes of state on the tape. My second example first repeats the tape, you have heard before, and then presents the analog behavior of the Electronic Studio. Note please, that here the information on the computer tape acted in the analog equipment of the studio as an *algorithm*. The studio equipment does not computer or control its own changes. Thus my studio equipment plays only the *analogy* to what in this case is the real thing, the computer output.

#### *Example 2*

The CSX-1 computer tape examples, which you have heard, are fragments from a piece I composed, and which is called *Sonoriferous Loops*. It consists of four sections to be played by instruments: flute, trumpet, double bass, xylophone, marimbaphone, and percussion. The four instrumental sections alternate with three interludes of synthetic sounds on "two-channel stereo" tape. At the end the media share in a very brief Coda.

Some years ago Hiller and Baker at the University of Illinois had begun to write computer

program routines, each of which would represent one of the numerous algorithms, every composer might wish to use. By now, this program package contains more than 50 routines of various size and refinement, many of them contributed by users. The name of this library is MUSICOMP and in my programs for *Sonoriferous Loops I* made extensive use of MUSICOMP.

I programmed the computer to choose pitches, durations, and instrumental densities out of a specified repertoire and under the restraint of specified rules. The repertoire for instance gave the computer a choice of 12 different pitch classes, four different octave registers, 18 durations, 5 instrumental parts, etc. A rule would specify for instance, that, for the first 913 choices, the flute was to play 74% and to rest 26% of the times it was chosen. After 913 choices the rule would be changed, so that the second section of the piece differs from the first, among other things, also in the frequency distribution of instrumental timbre.

In short: The program for the instrumental sections instructed the computer as to what system it was to simulate: the number of elements, the number of possible states for each element, and the various algorithm which were to control the proceedings that I wanted to have take place. The program furthermore defined the initial and the final states of the system, that is, where the proceedings were to begin and where and when they were to stop. Finally, it was to give me a readable printed output, from which I then could copy the score in a code legible by human instrumentalists.

The program for the electronic interludes, similar in many respects, but more complex in some, was to give me as an output a tape. Well, you heard such a tape and you know, that the last step here was taken in the electronic studio.

*Sonoriferous Loops* lasts 13 minutes. It took two months until I was happy with my program, and then three minutes for the computer to follow my instructions and print out the whole piece in one run.

In the recorded performance, part of which you will hear in a minute, I conducted six students of our music department. They play so precisely and beautifully, that you get a true and exact picture of the computer's execution

of my orders.

### Example 3

There is one dignified way, by which the computer might be made a musical instrument, without making it a redundant simulator of orchestral treasures. A computer, that can be programmed to generate acoustical phenomena, that the existent instrumental body could not generate, would be an asset. Thus steps have been taken to find out about these possibilities. Bell Telephone Labs was the leader in this field. Others have followed. Among them, the Experimental Music Studio of the University of Illinois. As usual in research, first steps are mostly concerned with the question, whether the well known can be simulated, before embarking on the attempt to control the yet unknown. The basic idea is, that a program which will instruct the computer correctly how to generate a well-known sound, is a good program, to experiment with. If, without changing the algorithms, one only changes the initially given data, one may expect, that the resultant sound, though hitherto unknown, will accurately reflect the intentions of the programmer, who thus will learn authentically, what his intentions meant. That is exactly where we stand right now. I admit, that the spectacular seems still far away, but I wish to communicate to you, that what you will hear in the next examples, has proved a great number of preliminary points to us, that is to those, who have learned the hard way, how slow and difficult the realization of an idea can be.

Let me play for you just a few tones, single unassuming tones, which were generated by the computer, inside the computer, under programmed instructions. I desired to hear, what would happen if a sine tone of 300 cps were to restart 200 times per second, while the amplitude fluctuates 100 times per second between piano and forte (or -30 and 0 dB).

Here it is:

### Example 4

To get this, I punched a card, containing in the appropriate columns by data: 300, 200, and 100. The digital computer, instructed by our program for sound synthesis, uses by data

to computer 40,000 samples for each second of sound. These samples which are, numbers closely fitting the curved representations of the desired sound waves, were then fed into an analog converted which converts numbers into voltages. These voltages get to you by means of audio tape, amplifiers and speakers in the form of sound.

Observe, that I had programmed in my card the frequency of the sine wave, the frequency of its restarts and the frequency of amplitude changes. I had not programmed the overall slow intensity envelope, the crescendo and decrescendo of my tone. This came as a surprise, a gratuitous present. And it gave us to think. I now tend to speculate that this macro envelope must be a function of my three given parameters, and thus I enjoy the idea of having there an envelope of the timbre rather than of the constituents of the tone. By permuting the three numbers 100, 200, 300 among the parameters, I received the following six tones:

#### *Example 5*

It is here, and with examples of that kind, where synthesis works into the hands of analysis. At least it has led me to start an investigation, by which I hope to find out, to what extent the so-called internal life of a sound, the timbre and character of a tone are due to pseudo-random interference and interplay of all its constituents, rather than to a determined path of each. Or with other words, I should like to find out, whether noise, today noted as a rebellious component in music, has not at all times been a legitimate component of music, that particular disturbance, commonly called the intrinsic beauty of a tone.

To give you some impression of how our computer plays these days, here is one of Gary Grossman's *Studies*. Being a typical research product, it does not present you with complex composition or "way out" explorations, but rather rigidly controlled and extremely restrained variations on basic material. Inasmuch as it makes for pleasant listening, it does so in spite of its usefulness for our attempts at evaluating our program.

#### *Example 6*

In the meantime, our equipment has become quite sophisticated. The CSX-1 and

its square-waves have been replaced by a Digital/Analog and Analog/Digital Conversion system and we have written programs, which allow us to have the computer generate and play for us a great variety of sounds of many simple or complex waveforms.

Let me show you a little experiment which was to serve as a preliminary test of a program, which finally is to be part of a major project. Tests have to be simple. But occasionally it happens, that the result of simple test are rather complex. Here I have an unassuming sequence of triads.

#### *Play!*

First I desired to hear, what would happen, if these triads were to be played so fast, that for each tone there would be time enough for once cycle of vibration only. The "A" (which vibrates 440 times per second) was to last 1/440 of a second, the "C" = 262 cps, 1/262 of a second, the "F" = 349 cps, 1/349 of a second, and so on. Then the sequence was to be repeated, each time allowing more cycles per tone, and I wished to find out, how many cycles would be necessary for each tone to communicate its pitch to my ears, so that I could hear my original sequence. Please do pay some attention to the changes in timbre, while you wait for the pitches to appear.

#### *Chorale*

The obvious next step consisted in turning this thing upside down. For the last example, the components were given and the results found. For the next example I gave the results and had the computer compute the components. I instructed the computer to find for each tone of my sequence a different Trio of components, which, lasting one cycle each, would add up to one period of my given tone. the result is rather surprising, but I should think, that it allows you to see the possibilities, which this method, once it were systematically developed and controlled, might offer to the composer.

#### *FUTHIS I*

#### *Additional Text*

#### *Musical Ideas for Synthetic Sound*

Let me demonstrate for you one instance of this. Last year, I wrote a composition and programmed it for the computer CSX-1, which can reproduce the contents of its registers in the form of square waves. My input instructed the computer to play a great number of square wave tones at specified pitches, specified durations, and in a specified sequence. Lest anyone justifiably, might accuse me of having degraded the computer to an automatic organ, I hurry to assert, that this "playing" of the computer was but the last and least dignified of a series of stages, in which the computer had been active and helpful at it's most noble best. The average duration of a tone in this composition is 0.25 seconds, 1/40 of a second. The longest duration is 1 seconds; the shortest duration, and that you have to either believe me or not, for you cannot hear that fast, the shortest duration is 0.000038 seconds, a little less than 1/25,000 of a second. Please listen:

*Example*

There were three musical elements, which I judged to be missing in this acoustical analogy to my composition: There were no rests; no wonder! I had not programmed any rests. there was, to say the least, and insufficient variety of timbre. No wonder again. The CSX-1, being a digital computer, has but one wave-

form to offer, and is therefore almost as limited, as any old musical instrument. If treated like a violin or a clarinet, who knows, but it might sound like a Hammond organ. There also was a lot in the audible output, that, by sheer dint of speed, remained inaudible. So I took the recorded tape containing the computer output you just heard, and two further sets of the same program, into the Studio in Stiven House, where I had the equipment, the possibility and the control facilities necessary to fill those three gaps. What you'll hear next, contains in essence all of the computer output. Nothing was suppressed, lost or cut out. Rests were added, timbre was added, and speed was converted into timbre, pitch and dynamics of attack and decay. From three computer outputs, the following three *Interludes of Sonoriferous Loops* were derived. Since at this moment I really am far from proposing or requesting any aesthetic considerations, allow me to draw your attention to the small wiggles, to the micro-sonic inner structure of the acoustical events, allow me to ask you to prevent familiarity with the apparent event from deterring your awareness of the speedy accumulation of numerous items that made the events appear. Please listen:

*Example*