. . . to hold discourse —at least— with a computer. . .

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Composers who attempt to compose music with the assistance of computers, and who, instead of keeping their mouths shut, respond to the request to tell why and how they propose to breed immortal beauty for all of us by marrying mere technical logic to fertile inspiration, these composers have to override such exalted expectations with a careful report on the notions, theoretical and otherwise, on which they base their various interests for experimental research in music. I shall attempt to do that now.

Anyone who attends either a concert of new music or a lecture on speculative ideas concerned with new music may occasionally come away with a question in mind. Was this music? Is that music? Did they mean “music”? Did all this even have anything to do with music? In the attempt to do justice to these questions as well as to the events which provoked them, I usually come to a full stop having reached the big question: What is music?

Three cases may arise:

1. A question is answered, and dies. The discussion stops.
2. Or, a questions survives all its answers. The discussion then absorbs the answers and continues from there.
3. Or, a discussion survives the already answered question. This is unpleasant to behold and therefore best skipped over with a charitable smile.

Noone can, under all circumstances, be quite sure with which of these three cases one *is* confronted. Noone, however, can avoid implying by word, gesture, and stress of choice, which case one *assumes* it to be. I would even go one step further and say which case I *want* it to be. And reasoning may be brought to bear on it. If I say that the question “What is Music?” survives all its answers, then it is because I have a vested interest in music, being a composer, and because I know that once we know what music *is*—there *won’t* be any. We may delve into the well of the past and inquire what people then thought music could be and come up with useful documentation as to what music *was then*. Useful, because without it, we, today, would know only what music *was today*. We then can go to the composers and ask them. And if they know their profession, they certainly know what music *was*, but if they begin to say what music *is*, something flips, and turns their good intentions into advertisements of what music *is to be*.

Still, there must be something that allows us to use the general term music, if only to be able to set it off against the general terms “acoustical phenomena” and “aurally perceivable sensations”. That something, of course, can not *be* music, but it can be found *in* all music, can change continuously and tremendously while remaining the same thing. I am speaking of a ratio, a rational relationship. In all music there is manifestly implied the rational relationship between the chaotic image of an unlimited, unconditioned and disordered universe of all audible phenomena and a tentatively defined image of an equally disordered but artificially limited and conditioned sub-system that we at a given time consider our temporary acoustical ALL. Every composer of music has testified to this relationship, knowingly or unknowingly measured it, and the composer's work reports on what the composer was able to measure up to. If today we try it with computers, nobody can possibly say whether any result of this attempt will correspond to what has up to now been called a "work of art", or whether it will define what from then on will be called a "work of art", or whether it will miss altogether that function in society which makes some creative communication a "work of art". The contemporary relevance and significance of a composition should be achieved in that it does not appeal to existing means of understanding music but rather creates new means for musical understanding. It not only will show noticeable changes in the concept of the acoustical system, not only propose new schemes of organization, but also provoke the creation of new circuits in the listener's mind. This provocation is the aim and purpose of all creative and scientific projects. It is in this sense that the cooperation of composer and computer is for here and now considered to be a natural idea. Whether it will lead to "music" or to "electronic brains" or to a new aspect of both is a question fascinating enough to render fascinating all attempts at a satisfactory answer.

Compared to these somewhat lofty ideas, the work on and for their implementation proceeds in rather small steps and no one at this moment has yet been given a chance ever to justly evaluate whether these small steps stumble in the right direction. The first step I took was to envisage both, the computer and what I call music, as two different systems, and to explore the possibility of their mutual compatibility. I use the term "system", whenever I mean to speak of a collection of elements wherein each element can be in either of at least two different states and where the change of state in one element results in a change of state of the whole collection. The term "element" I use when referring to something as a whole that I do not consider as made up of a set of elements. Indeed, it frequently depends on observers and their particular purpose at a given time whether they regard an object as being a system or as being an element. A composer may at one time consider the piano to be a system which can adopt as many states as about 88 elements will allow, each of which, and any number of which, can be "on" or "off", at least. At another time the composer may think of the piano as an element which changes the state of a system called orchestral timbre. I hope composers frequently consider all possible ways simultaneously, but think it vital that they know which way of looking at them determined their final choice.

Dependent on the number of elements in a system and on the number of states which each of these elements can adopt, each system has a definite number of states in which it can appear. This number of possible states of a system I shall call its information potential. As this is an important notion for my purpose, I shall express it as follows: If I am faced with a certain state of affairs, be it in music, language, politics or family, I will, for the purpose of understanding and evaluating, not only need to know the precise present constellation of all the elements, but also the number of possible states out of which this particular one which faces me had been selected. If you play several little tunes on a recorder, you will find that not only is the system called "recorder" able to be in as many states as the tunes demand, but that the tunes exploit the system "recorder" to the limit. One can say that here two systems simulate each other almost completely, they even imply each other. No number of little tunes played on a piano will ever define the large system called piano for you. This means that each message which we receive has to be investigated in respect to two questions:

1. What kind of a source-system does this message imply?

2. How much of that system did the message exploit?

Every musical composition is in this sense a message. In order to hear the musical events as they are being carried to you by acoustical events, it is necessary to find out as much as possible about the originating system before you can be sure you have heard what actually had been played and that it was music. For how is anyone to say whether what one heard was music or not, as long as the listener is not even sure as to what "it" was that was heard? And in order to even begin to know what it was that was heard, the listener must be able at least to estimate how many "similar" acoustical events the choice of each particular one eliminated. Not only the results of the composition but also the processes of composition are parts of this message. Here, one can see that we noticeably approach that concept of musical composition which considers the interrelations and interdependencies that join acoustical events together as even more important for musical meaning than the acoustical events as such alone. Every decent analysis of a musical work will try not only to state the kind, form, and quantity of acoustical events in the piece, but, more than that, will try to find out as much as possible about the schemes, plans, processes, and logics which the composer may have employed for making decisions. These last mentioned methods of bringing a specifically planned order into a system of generally possible orders I shall call "the algorithms" by which changes in the system can be controlled. And I call them "algorithm" because this word has both a rather general and a quite specific meaning. It does not specify any one particular method; it does not imply any particular degree of complexity or convenience or efficiency. But it is specific in one point: It means any set of instructions which will control the changes of state in a system in such a way that from a given initial state to a given final state, each intermediate state generates its follower. If we now call an algorithmically controlled change of state a "transformation", then we can say that an algorithm produces an uninterrupted chain of transformations between a given initial and a given final state of a system. Or, the other way around: If two states of a system appear to be connected by an uninterrupted chain of transformations, then we may assume the presence of a controlling algorithm. Now, it is rarely the case that there is only one lonely algorithm responsible for what we hear, see, or otherwise perceive when we look at systems. Usually there are many simultaneously active. But, also usually, they are active in a kind of hierarchic power distribution. There are the little algorithms which control counting, addition, multiplication, etc. They may obey an algorithm which tells them when to go into action. This may be controlled by an algorithm which controls the relative dimensions of sequences and thus may direct a "lower" algorithm to eliminate its product and to start again from another given state. And so on and so forth.

Let us cut this promising excursion short and say that we now have all I need in order to make the following statement: A system is defined by its information potential and by those algorithms that can control this particular system. Two systems are compatible with each other when they are similarly defined. The degree of compatibility of two systems determines the degree to which they can simulate each other, to which one system may behave in analogy to the other. We are interested here in three main degrees only: fully analog, partially analog, and not analog at all. The system called "Thermometer" is fully analog to the system called "Temperature", partially analog to the system called "The Weather", and not at all analog to the system called "Language". An analogy is a chain of transformations in one system simulating a chain of transformations in another system. Communication is based on analogies, on degrees of compatibility between different systems.

The largest, most general and thus most flexible systems we can control today are found among the electronic high speed digital and analog computer installations. The number of states representable by such machines is enormous; the elements, simple and semantically uncommitted, can stand for almost anything enumerable, quantizeable, measurable; the network potential offers the conditions for nearly any algorithm one can think of. Thus, it is a system especially designed for utmost compatibility with all kinds of other systems, large or small, simple or complex, open or closed, numerical or logical. It is, therefore, up to the computer users to find or to construct the system in which their problems can be expressed and solved, in which the processes they desire to observe and to test can be seen as chains of transformations. Once the users have defined the system they need, they are able to plant it as a subsystem into the computer. This “planting” procedure is usually referred to as “programming”.

A computer program is a set of instructions. If fed into the computer system in an appropriate code, the program communicates to the computer the structure, size, dimensions, rules, algorithm, etc. of a system which the computer system is to simulate. Under the control of such a program, the computer system will act as an analogy to the system which the programmer had in mind when writing the program. It is quite probable that not all composers think of their activities as being operations on and in systems, that not all processes leading to the final appearance of a musical work take place in only one or in any system. However that may be, the computer has to be programmed in order to be of any assistance, and programs can only be written by users who consider at least part of the work, the processes and the data with which they are concerned, as changes in and states of a system that they had defined.

If the term “composition” is taken to mean “programmed operation on given data”, then a computer can “compose” music. If, on the other hand, the providing of the “given data” is taken to be an important part of “composition”, then the computer only executes a program, for it can not “give data” as yet. An apparent middle-of-the-way concept of composition programming offers itself: Let all of the data which the composer provides define the initial state of the computer system; let one part of the composer-written program instruct the computer to adopt this initial state and then operate on it, so that the results of this operation can be used as “given data” by another part of the program; under control of a third program segment, every now and then, let some state of the system be interpreted and operated on as the next initial state; finally, let a fourth section of the program select from system-states lying between these “initial” ones those that are to appear as results in the output. This section also instructs the machine as to the format in which the output is to appear.

Here the composer defines a point of departure and the various processes and algorithms by which “given data” are to be generated and operated upon and by which results are recognized and notated. It is quite correct, in such a case, to say that the computer generates the result of the composition, the piece, but rather careless to conclude that the computer composes it. Even without a machine, the composer working at a desk with pencil and paper on a musical score, generates the finally notated result under control of some rules, conditions, stipulations, premises, liberties, memories, changes and so forth, all of which interact in ways that reflect a system, known or not known as such to the composer, which is considered by the composer as the plan and idea of composition. This compositional concept initiates, accompanies, controls and eventually stops the process of generating data and results, but is not identical with it.

Every musical idea implies the system in which its acoustical realization may become its structural analogy. The compositional process begins with an analysis of the implication and continues with a search for, or with the construction of, a system with the appropriate generating potentials. It may just as well be stated here that every generating system also implies the musical ideas which it can represent. Bad composition usually results from some failure in compatibility between idea and generator.

A programmed computer can be a suitable generator if the program has been determined by those composers who are aware of the implications of their musical ideas and of the implications of computer systems. The most important step toward a correct recognition of such sometimes vague and “never heard of” implications is taken when composers, through knowledge or deliberate stipulation or both, determine the invariants which significantly define their ideas and which should be preserved in the generated analogy. Most readily preserved in analogies, and thus by computers, are proportions, relationships, quantities, weighted probabilities, functions, statistics and multivalent simultaneous hierarchies of either permissive or restrictive rules and conditions. In fact, it would mean by-passing the possibilities offered by the machine system if a program were to instruct the computer merely tautologically to code a specified set of determined, discreet data, fixed point by point; one would thus actually degrade the computer to the redundancy of a glorified typewriter. It is admittedly not always absolutely clear to composing programmers whether, at any given moment of the work, they happen to be programming analogies or only tautological coding and bookkeeping procedures. Nor can those composers who compose without computer assistance always know whether they are creating a coherence of sound where this did not exist before, or whether they just keep on using an existent one to fill preplanned, plausible slots in an orderly fashion. The difference being that it is usually easier to inspect and to correct programs than to inspect and correct composers without getting painfully involved with their "personalities".

It is necessary, at this point, to mention that all composers who work with computers continue writing "pencil and paper" pieces which however show that the knowledge of immense possibilities they learned from machines keeps encouraging them to look for a "like richesse" in their own minds. No matter how artificial we may make the systems we wish to work with: their conception, their response, and the wealth of unpredicted questions they raise in our minds as we contemplate their potentials are certainly not at all artificial, but genuine results of a feed-back which provokes visions of unknown territories for research and creation, edging us on to ask for more, while the little conservative skeptics and the big official guardians of culture can only cry yea or nay, their only feed-back being the cud they chew.

The composer's program must contain, in one form or another, a set of instructions which not only tell the computer when the execution is finished but also what to do with the results. Depending on the composer's specifications and, of course, on equipment available to a particular installation, the output of a computer may appear in any one or all of the following forms:

1. Printed on paper pages in a code of symbols and characters stipulated by the programmer, and easily translatable into a written musical score by a copyist. (To have the computer print out the final score immediately is a purely technical refinement, which could be implemented if and when it should be deemed necessary, useful and, last not least, worthwhile.)

2. Punched cards that could be fed as data, for instance, into a sound synthesizer which might again be a computer with a digital to analog conversion attachment.

3. A digital magnetic tape, which will store the information obtained in a nearly indestructible form, and which could be used again as input data for another program or computer or even for the analog equipment of any electronic music studio.

4. A graphical representation of the resultant data, either as a printout of the computer or, more refined in format and detail, by a computer controlled "Plotter", which can draw anything that the composer is able to specify in the program.

5. Audio tape (see 2) on which the output voltage of the computer system is recorded at a rate of up to 40,000 samples per second so that a play back would potentially contain a noisefree representation of the auditory frequency range.

There are more possibilities available and every day new inventions are being announced. In any case, it should be noticed that the output format envisaged by a composer represents one of the important factors which ought to determine the nature of the composed program. While one kind of musical idea requires the generation of a detailed score for a specified number of instruments (which are to play precise pitches of determined durations at exactly indicated time points), another kind of musical idea would be sufficiently notated by a generated graphical display of special symbols, their position and size on the page, thus leaving undetermined the number and kinds of instruments which are to be used in performance. Quite different from both preceding alternatives, and to be considered and programmed quite differently, would be a musical idea which is to be realized directly by synthesized sound on tape.

It should be obvious: the composer who wishes to work with a computer system has to think about, decide upon, and find solutions for the same problems that face the composers who write a piece at a desk with nothing but pencil and paper and an occasional table of numbers on the side and a history of music in their past. But there is a difference. The composers at a desk generate the piece step by step, witness the process in every detail and thus can add or withdraw consequences, redundancies and the like, can audaciously, bitterly, moodily or lazily modify everything by direct, point by point inspection of what they had just written or of what they were just about to be write. In other words, they edit while they work. The composer who writes a program has to predict all of that, is then out of the game while the computer executes the given instruction, and can only edit the whole program after having carefully inspected the output of a computer run.

The difference has among many consequences one that could be stated by a sentence which, if not entirely valid at all times, at least expresses an observed tendency and furthermore clearly gives away the position taken by the author of this paper: The prevalent compositional proposition of a composer, in a particular work, may either be to have that which was defined as elements generate the structure of the piece, or to have the stipulated structure of the piece, which the composer sees as a system, generate the elements. The latter is definitely the alternative most appropriate to the conditions under which a system of digital and analog computers will assist a composer in creating music of contemporary relevance and significance. The programming composer composes the structures of systems in which the elements function as variables, each according to its temporary context, as potential carriers of meaning, unprejudiced by semantic or mythical traditions. Such systems may often be analogies to present day social systems, (not as they are seen, but as they are) or to a possible future social order. The musical result of structural composition would thus participate in society's self-representation: a self-critical gesture of communication.

Communication with and within society is an eternal and thus constantly present and forever fluctuating problem because it depends on the fulfillment of too many demands: A system of practically unlimited information potential needs innumerable at least partially analog systems which could simulate the significant transformation chains in the larger system. Furthermore, it is not at all easy to know which algorithms are in control, even though one notices their presence. Thus a system called listener may analogically follow the changes of state in a system called music, but at the same time be unable to trace the algorithms that would establish as an uninterrupted chain of transformations that which the listener experienced as arbitrary randomness. The easy way out, of course, is to assume that actually all systems are sufficiently analog, so that a decrease of communication could only be due to some mistake, error or malicious obscurantism in the source-system which emits the undecipherable message. This assumption claims the invariability, the absolute consistency of systems. I claim that this assumption not only is unfounded, but that it actually prevents the solution of communication-problems.

The composition of music is an analogy to communication with and within society in the following sense: It refers to a practically unlimited system, namely the acoustical universe. It chooses more or less strictly defined fields of this system as its working ground. It decides on the algorithms which are to control the changes of state in this system. It determines whether a musical message is to consist of interrupted or uninterrupted chains of transformations, whether all the controlling algorithms are to be made known or whether some are to be kept hidden and elusive. But the most important point is this: A composition of music attempts to be only *analog* to a communication. It does not attempt to *be* one. It has all the necessary makings; it obeys all the demands, it adheres to all the rules of communication; but it does not communicate anything but itself. Thus it expressly intends to simulate that which we usually define as “not intended messages”, as “manifestations of circumstances”, as “natural processes”, only that this simulation is intended, and thereby represents and implies a criticism and a correction of conditions as they appear to be, and a proposition and plan for conditions as we would rather have them be.

In this sense, the composition of music is much more difficult than one might think at first and, furthermore, will always be just as difficult again the next day. For nothing is sooner lost than new ways and new languages. . .

To conclude: It simply is not the computer that threatens to replace people, the human brain, the composer. Much rather it should be asked whether these three could eventually learn how to understand and to handle the systems which they themselves have valiantly conquered from chaos; whether we could and eventually would learn how to have discourse with music, with society—or, at least, with a computer, so that it may slowly dawn on us where, in reality, substitution does threaten. With such knowledge, we then might successfully try to make ourselves once again, even briefly, appear irreplaceable.