Music for an Interactive Network of Microcomputers

John Bischoff, Rich Gold and Jim Horton
Berkeley, California

INTRODUCTION

In the following article we describe the music presented in concert on July 3rd, 1978 at the Blind Lemon, a small new music gallery in Berkeley, California. In Section I of this article we will give an overview of the piece. In Section II, each of the three composers will present a brief description of their individual program and how that program accepts and sends information to and from the other computers. In Section III we will collectively give our comments on micro-computer network music, a new and useful development which we consider to be a radical departure from traditional music, either of an instrumental or electronic nature.

SECTION I – An Overview of the Piece

Music over the milleniums, traditionally, has involved more than one person, either in its composition, in its production or both. In fact, it seems to be one of the most social of the artforms. While there has been individually produced music as well, computer music, until very recently, because of its nature, could *only* be individual, solitary music. However,

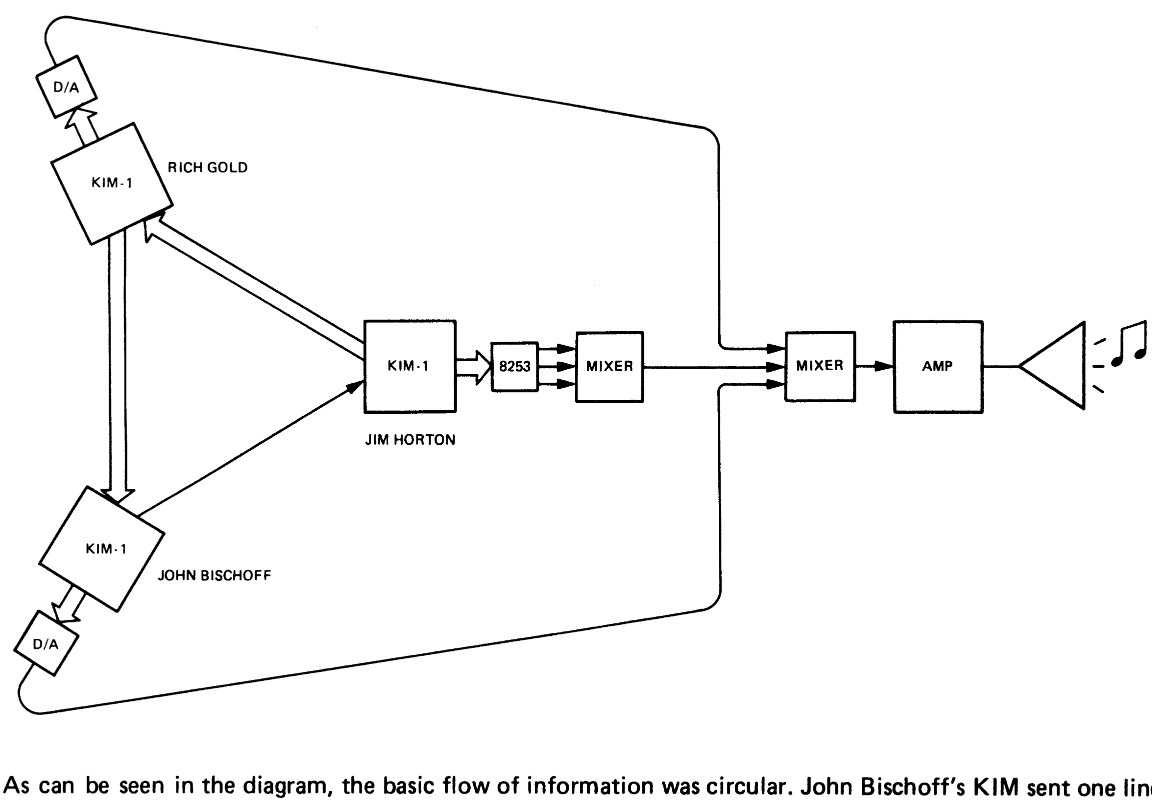

Figure 1. As can be seen in the diagram, the basic flow of information was circular. John Bischoff's KIM sent one line of serial information (which served as both interrupt and data line) to Jim Horton's KIM. Jim Horton placed four bits of parallel information onto a latched data line for the use of Rich Gold's KIM, while Rich Gold gave information to John Bischoff, also on a four bit latched data line. Each of the three KIMs had their own musical output: Jim Horton's machine featured digitally controlled circuits; Rich Gold and John Bischoff's outputs were both direct D/A conversion. The three musical outputs were summed together and played to the audience at a goodly volume.

with the introduction of microprocessors at a reasonable cost. Composers can now own their own computers, and, operating free from major institutions, true computer bands are possible. While such bands can take many forms, network music seems best suited and the most contemporary.

All three composers performing on July 3rd owned KIM-1 microcomputers, though other than simplifying many of the I/O problems the similarity between machines was not significant. Each composer had programmed his computer individually with a music program that was by itself able to produce music; however, the programs were also able to input data that would affect the musical content and output data that would affect another computer's program. Each computer had its own musical output, either D to A or digitally directed electronics.

It was decided that for this first concert a simple formation would be used, in this case, each computer sent data to one other computer and received data from one other computer so that a circular data structure was effected. How the received data was used and what data would be sent was the individual composer's choice, though the bus structures were mutually agreed to by each pair of composers. The final musical output was mixed together and broadcast over a high fidelity music system.

The exact configuration used during the concert was the following: John Bischoff sent data to Jim Horton; Jim Horton sent data to Rich Gold and Rich Gold sent data to John Bischoff. The nature and the use of this data will be described in more detail in the following section.

SECTION II – The Individual Programs

John Bischoff's Program

John Bischoff's program was originally composed for a performance with Phil Harmonic at *WORKS* Gallery in San Jose in February 1978. The performance environment was casual, attentive and allowing of social interaction, and the music was designed around the idea of long moments of rest interspersed with computer tones. The occasional tones generated by the KIM served to punctuate the ongoing life of the performance. The periods of rest between tones lasted up to one minute and as Phil Harmonic pointed out, one could even forget that KIM was running. As heard in the network, the program played somewhat the same complimentary role but with more emphasis on the ensemble music properties of the three parts moving in relation to one another.

All the choices in the accompanying flowchart are based on a continually renewed string of random numbers. The output waveforms are routed through an 8-bit D to A converter and are of a constant amplitude. There is no predetermined sequence of pitches as each run-through of the program involves one rest period followed by one pitch event. There are four possible waveforms: sawtooth, triangle and two types of random waveshapes. The random waveshapes generate particularly striking timbres and noticeable sidebands during pitch slides.

In April 1978 Jim Horton modified his program so as to accept data regarding the specific frequencies that John Bischoff's computer was putting out. John Bischoff altered his program to enable it to send that data each time it was ready to produce a tone.

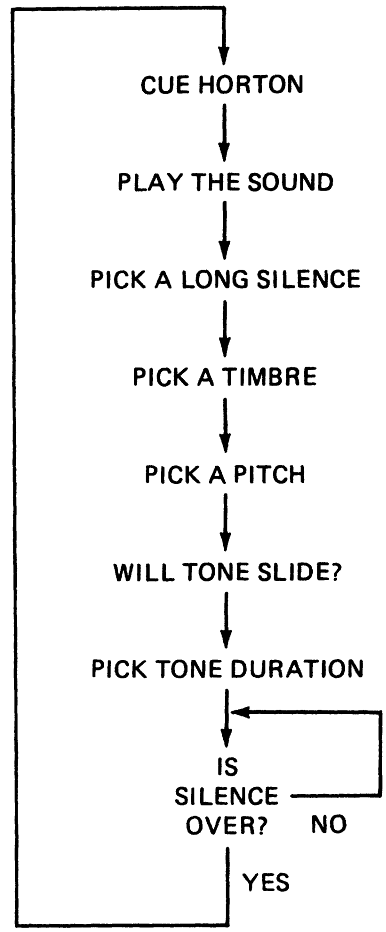

Figure 2. The musical flow of John Bischoff's program.

A single line was connected between the two computers to act both as an interrupt line and a serial data line. Before each tone and before each rest an interrupt was sent followed by one bit of data which acted as a flag to indicate the upcoming event. In the case of a tone a floating-point representation of the frequency was then transmitted, serially, following the flag bit. On receiving that data, Jim Horton's computer calculated and played pitches which were in justly intoned harmonic intervals to the note that it had received. His program jumped back into its independent mode when it received an interrupt followed by a "rest" flag. John Bischoff's computer was also connected, by four parallel lines, to Rich Gold's computer, the information from which was either used to influence frequency, rest duration, both, or was ignored.

Rich Gold's Program

Given the following equation:

$$f(x,y) = z$$

where x is the latitude and y the longitude of a traveler on a fairly smooth, basically continuous surface, and where z is the altitude of that traveler, and where the traveler exhibits a continuous, closed motion about the surface; then z can be shown to exhibit periodic wave-like properties where the frequency of the wave (z_w) is determined by the length of the traveler's closed walk *and* the speed of the walking, while the timbre of the wave, including amplitude, is determined by the hills and valleys of the land. The problem would become far more complicated if the traveler could move at more than one speed, but, since in Rich Gold's program he can move at only one constant speed, frequency is determined by the length of the walk only. Further, if that traveler moves at a speed such that the periodicity of z_W usually falls between 20-20,000 Hz., and given the appropriate transducers, there is music.

The entire program, save a latched output port and a simple D to A converter, was contained within KIM's 1 K of memory. The surface f was modelled in a 16 by 16 matrix, occupying page 3, and behaved like a land on a torus. The continuous closed motion of the traveler was produced in a Lissajous-like fashion using two software up-down counters (e.g., triangular outputs). While the rate of update of the two counters remained constant, the four end-points (a top and bottom for each counter) were under program control. It should be noted that not merely the length, but the relationship between the lengths of the two up-down counters determined the fundamental frequency of z_W. Further, since the pattern could be relocated anwhere on the surface f, there was a way of altering the timbre of a given pitch.

The end-points of the up-down counters were determined by four up-counters, one controlling each of the four end-points. These were updated at the beginning of each new note or sound. The end-points of these four up-counters were controlled by data input from Jim Horton's machine. The "tune" was determined by the series of end-points generated by the up-counters given that at the beginning of each note they were all incremented by one and wrapped-around (i.e., rotated) upon reaching maxima. The length of each note, the number of notes in each "song," and the length of silence between songs was determined from information coming from the surface. It was the durational information that was sent to John Bischoff's machine (as a four bit word). All updating and housecleaning, due to the constraints of real time music, took place, imperceptably, between the notes.

The program, nominally called "The Terrain Reader," was part of a broad piece entitled "Fictional Travels in a

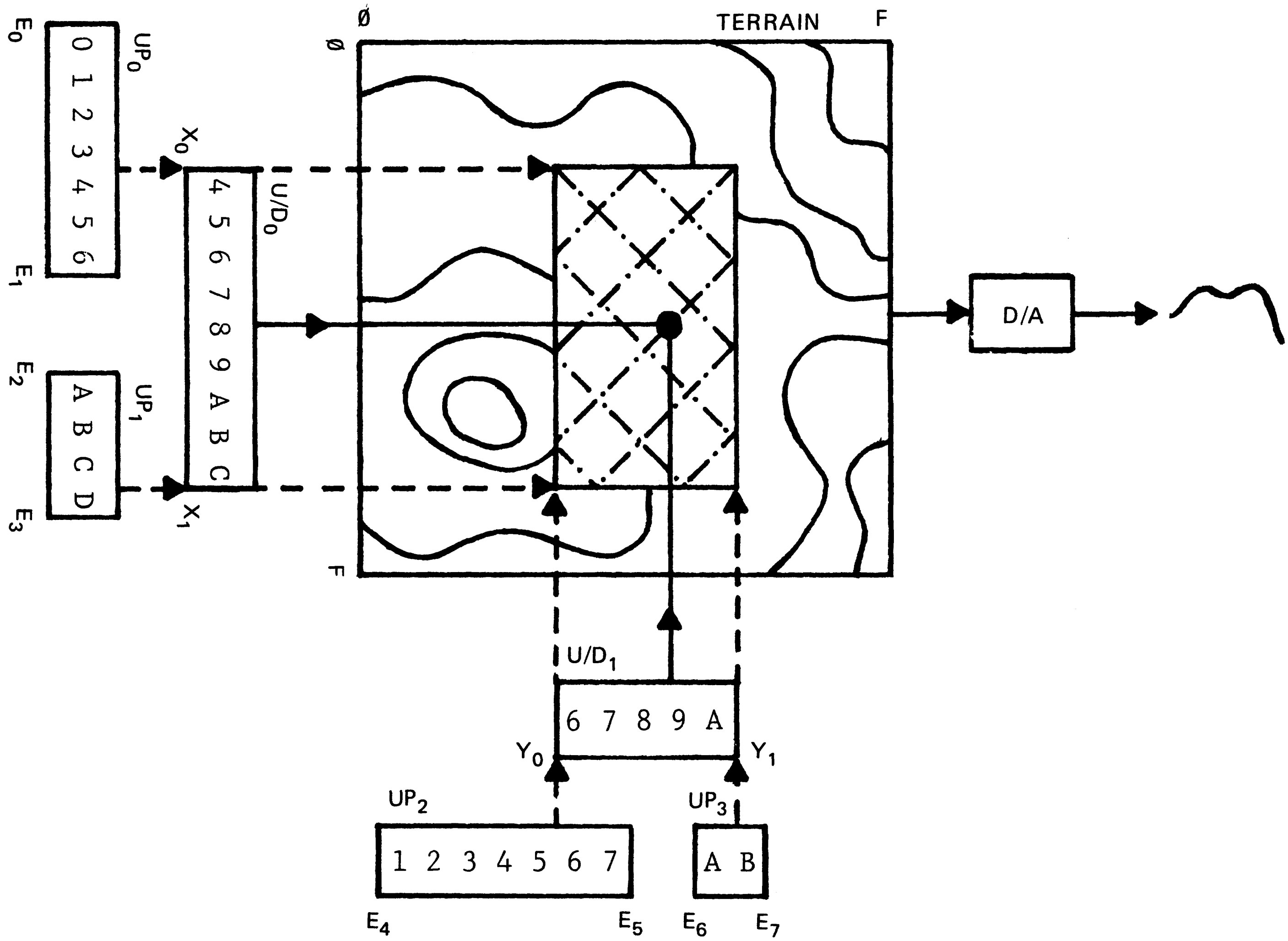

Figure 3. A block diagram of Rich Gold's Terrain Reader. Each of the four up-counters controls one of the four end points of the two up/down counters. The up-counters are updated at the beginning of each new note. The up/down counters count at audio rates and specify a point of the surface or Terrain, which is held in one page of memory. The value of the point specified is sent to the D/A. The tune, or the series of notes that results, is determined by the eight end points of the up-counters which are set, in this version of the piece, by the information flowing from Jim Horton's computer.

Mythical Land." What the Terrain Reader reads *is* the land, the shape of which was determined by the general Myth from which the entire Fictional Travels piece was derived. That is, the program was not intended to be a general purpose music program, but rather, an integral part of the piece itself.

Jim Horton's Program

Jim Horton's program did two separate but related things, one harmonic and the other melodic. The melodic program was written out of curiosity in order to listen to an aspect of Max Meyer's psychological theory of melody (*Contributions to a Psychological Theory of Music*, Max Meyer, Ph.D., The University of Missouri Studies, Vol. I, editor Frank Thilly; University of Missouri, 1901). Meyer's empirical investigations led him to conclude that no tone is in a specifically melodic relation with another unless the interval between them can be represented by one of the ratios: 2-2, 2-3, 2-5, 2-7, 3-7, 2-9, 2-15, 5-7, 5-9; or else they are both related to a third tone by one (not necessarily the same) of these ratios. Meyer's notation represents classes of ratios, for instance 2-3 indicates 3/2, 4/3, 3/1, 8/3 etc. because according to his observations, octave transposition does not make any difference in the kind of relationship perceived.

Meyer defines the "complete musical scale" as "the series of all tones which may occur in one melody, however complex this may be." He shows that according to his theory it "is represented by the infinite series of all products of the powers of 2, 3, 5, and 7." However, in his extensive analysis of existing melodies, including those of the highly chromatic music of his contemporaries, he found that 29 tones suffice for a complete description. None of these tones has a factor of $2 > 2^{10}$, of $3 > 3^6$, of $5 > 5^3$ or of $7 > 7^1$. This 29 to the tone octave scale is shown in Figure 4, arranged so that with a little perusal the melodic relationships are evident.

The program works by randomly selecting a note from the scale and calculating whether or not it and the note already sounding form an interval that falls within one of the ten melodic classes. Phil Harmonic has commented on this system by saying, "It usually seems right on the edge of breaking into a recognizable tune."

Range, tempo, "rhythmic pattern" and density of rests are determined by simple algorithms whose parameters can be changed while the program is running. This is done by switching in or out subroutines or by changing values in memory. The program is designed so that any constant or parameter that might conceivably be changed is located in page 0 (00–FF hex). A section of the program allows the player to use a hex keyboard and LED display to inspect any location in zero page and to enter new data into a buffer. The player can then transfer the contents of the buffer to a memory location at the right musical moment.

Whenever a new note is played, data about the current "rhythmic pattern" is latched into an output port for the use of Rich Gold's program. Audio is obtained by using an LSI device, the 8253 programmable interval timer. This chip contains three 16 bit down-counters and a control-word register. Each counter is configured as a square-wave rate generator whose frequency is set by dividing a one megahertz clock by a number supplied to it by the computer.

Any counter is always at the same pitch as the others but at a slightly different frequency. One is played at the scale frequency, another offset from the first by a small fixed amount and the third is offset by a randomly-determined amount. The three components of the sound are mixed together to produce precisely controlled flanging.

3^6			
3^5			
$\boxed{3^4}$	$3^4 \cdot 5^1$		
$\boxed{3^3}$	$\boxed{3^3 \cdot 5^1}$	$3^3 \cdot 5^2$	
$\boxed{3^2}$	$\boxed{3^2 \cdot 5^1}$	$3^2 \cdot 5^2$	
$\boxed{3^1}$	$\boxed{3^1 \cdot 5^1}$	$\boxed{3^1 \cdot 5^2}$	$3^1 \cdot 5^3$
$\boxed{2}$	$\boxed{5^1}$	$\boxed{5^2}$	5^3

Figure 4. Meyer's emperically derived, 29 tone per octave scale arranged by fifths vertically, by major thirds horizontally and by septimal minor sevenths perpendicular to the page (i.e. $3^1 \bullet 5^1$ should be read as $3^1 \bullet 5^1$ lying on the page and as $3^1 \bullet 5^1 \bullet 7^1$ floating just above the page.) In order to project these tones into an octave they should be multiplied by some power of 2 so that they fall within the range 512-1024. Each pair of tones can be seen to form two intervals with each other (i.e. $3^1 \bullet 5^2 \bullet 7^1 / 3^2 \bullet 5^1 \bullet 7^1 = 5/3$, a major sixth, and $3^2 \bullet 5^1 \bullet 7^1 / 3^1 \bullet 5^2 \bullet 7^1 = (2^1) \bullet 3^1 / 5^1 = 6/5$, a minor third.) Only a subset of pairs falls within the class of the ten melodic intervals.

SECTION III – A Discussion of Network Music

(The following section was written using a technique very similar to the process used by the three computers in the Network Piece discussed in this article.)

The event of three composers making music together using ideas and structures developed independently without thought of future collabaration now seems a natural musical process due, in large part, to the work of John Cage.

Because nobody is only an ear, the *sound* of music, bracketted apart from the projection of socially relevant images and meanings, is, while often quite interesting, not necessarily the main focus of a composer's work.

Very high technology is *about* working together in large scale teams, e.g., the space program. It should be no different for modern music.

Independent simultaneous activities viewed as one single activity always bring to mind the idea that groups can work wonderfully together without the anxiety of control structures that supposedly insure success.

Yes! What a pleasure to play and be part of a dynamic musical cybernetic process! To explore catastrophy hypersurfaces in the relative safety and comfort of involvement with one's friends and neighbors!

At each stage in the development of the network the music changed unpredictably. It became clear that it was impossible to tell beforehand where the music was going to come from.

At this stage in the development of the experimental tradition it is thought well to develop a personal, even idiosyncratic, approach to music. To find such an approach is not always easy. The advent of not-very-expensive microsystems can help free the computer musician from the pressure to conform to the mores of highly-structured business and academic institutions.

It seems obvious that three composers would write different music for subroutines in an IBM than for micros they personally own in a network. I suppose that if we hooked these routines together and the result was a Bach fugue with perfectly synthesized strings, we'd have to re-write the programs.

Although the network seemed to have a sound more characteristic of one active musical intelligence, it could be viewed as three people making music and listening to each other continually along the way.

To bring into play the full bandwidth of communication there seems to be no substitute, for mammals at least, than the playing of music live.

For music exhibits the properties of both gyroscope and steering rocket for a society.

For instance, having one's one microcomputer reduces the need for contact with institutions just to do one's music, while at the same time encourages collaborative work between artists. This latter situation is created by the possibility of everyone on the block owning roughly the same device.

It was John Cage who pioneered an important form of collaborative music, that is of the simultaneous playing of compositions. An extension of that idea is to write "reactive" compositions which can interact with one another as well as with their players. This approach makes possible a collective style of music while allowing each composer the opportunity to invent and play complete designs not necessarily subordinated to other parts or wholes.

There are many ways of handling form other than putting the largest and fewest structures at the top and the smallest and most numerous at the bottom. In this case forms were distributed fairly evenly throughout.

Computers seem to start from such a low level of musical intelligence (unlike the impression that synthesizers give immediately) that the potential of modeling musical intelligence using computers appears promising.

However, at present, the philosophies guiding the development of general purpose software systems and programs can be questioned. For instance, why the great effort to synthesize the sound of the violin and the piano? Why not the koto, the accordian, the Peyote ceremonies' rattle? For that matter, how many composers are really committed to the idea that art should imitate nature anyway?

Music has that wonderful ability that when you have three pieces of music working together you still have music.

Though synthesizers always offered the potential of multi-synthesizer group music, and there are some nice examples, micro-computers seem to fit the group music situation even better. One can literally show up at a rehearsal or performance with little more than computer in hand. Microcomputers are conceptually both a module and an entire system.

And ideally music should contain within itself all the information most important to a culture. An orchestra especially should have a structure which exhibits the best types of socio-political arrangements imaginable.

Though a single computer, micro or macro, is regal in nature with its hierarchy of registers, a network of them isn't necessarily.

(Live concerts always seem to have a shared feeling between the performers and the audience that makes all the startings and stoppings enchanting.)

"The patterns of control in a system tend to reproduce the organizational chart of the institution that designed the system." Hierarchical design derives from the myth that militaristic kings are better at getting things done. The theory of heterarchical and anarchistic systems design has been under-explored, although experimental musicians have been engaged in the processes for years.

John Cage set up a new minimum, on the potential plane of music, away from the classical music valley, but close enough to draw composers away from it, which allowed for the direct modelling of contemporary ideas (if we want to talk about networks we build a network) and the use of the available technology for sound production.

The inexpensive microcomputer is a decentralizing influence on the way art involving technology is structured in society. This might help to balance the inherently centralist tendency of the arts and music in general.

Since computers are now as portable as other musical instruments it is easier to think about grouping them into bands and orchestras.

In our band each computer contained the program of one composer and produced a sound of its own. Furthermore, all three computers played those programs simultaneously and in the same real-time. Beyond that, they were interactive in that each affected the next. That is to say the piece unabashedly manifested all major trends in music composition of the last 5000 years.

The sound of the piece as a whole is characterized by sudden overlapping sonorities and converging and diverging lines. There are moments of tuned correspondence where the three voices seemed to listen to each other while at other times they appear to be independent. There are also instances of odd grandeur.

When the elements of the network are not connected the music sounds like three completely independent processes, but when they are interconnected the music seems to present a "mind-like" aspect. Why this is so or why we can perceive some but not all activities as the product of an artificial intelligence is not understood.

I had different modes of attention—sometimes listening to one line, sometimes to one line that was really two, sometimes to the counterpoint which was unforeseen and sometimes to the large changes which swept through the system as a whole.

The non-hierarchical structure of the network encourages multiplicity of viewpoints and allows the separate parts in the system to function in a variety of musical modes. This means that the moment-to-moment form the music takes is the combined result of the overlapping individual activities of all the parts with the coordinating influence of the data exchanged between computers.

Since mistaken concepts and "bugs" seem inevitable, and plans of any complexity usually break down, it is heartening to note the mystery that where several errors intersect they very often make an interesting pattern.

But how do you get three modern composers to work together? Micros with their simple structures provide an answer. On the other hand large computer facilities and large electronic music studios seemed to be an extension of the older romantic idea of the individual composer writing notes in isolation of audience and other musicians.

The structure of a circular system satisfies the desire for a symmetrical interactive network where the flow of influence emanates evenly from each point in the system.

Because musicians, since time immemorial, have been playing together, music has developed into a wide variety of "naturally occurring" parallel processing systems.

We created an interesting creature and spent an evening, in public, listening to it.

(continued from p. 15)

GMK Faster sometimes than technology, I think. It takes years to develop electronic music studios according to the demands of a given time and then its always too late! The moment the studio is developed up to its original standards, the composers are miles away.

CBR What programs and technical devices need to be built? Exactly what systems then do composers need today?

GMK The composers of the past, by that I mean the last ten or twenty years, would not have been able to build their own hardware, or design their own studios, or to write their own software. So they had to accept anything that was prepared in their respective studios and institutions. But in the future, composers will be educated in a different way or at least will have other possibilities of being educated, in terms of mathematics, sound synthesis techniques, linguistics, artificial intelligence, or what have you. Also the prices of digital hardware are decreasing. So I could imagine a future situation in which a composer would not wait for the Institute of Sonology to make things, but would rather buy his own computer, to design their own software in a much faster time period than the past. Even the technology of designing programs is progressing.

CBR Do you then see a situation of decentralization?

GMK I think so.

Collaboration Amongst Computer Music Centers

CBR What about an intermingling among centers for computer music now? Do you forsee any of this? What are the difficulties or advantages of collaboration?

GMK But music is made by individuals. Composers compose alone. They don't form teams. Places like IRCAM or this Institute or others are more-or-less centered around individuals who design the basic principles.

CBR And yet is not musical research—by the definition of what is scientific—socially communicable? Is it not something that should feed together to create a common body of knowledge that everybody can draw from?

GMK That's a very steady but slow-growing process; everybody talks about better communication between studios—one should come together more often, have conferences, and the like. The computer music conference is now established but it's in only one place in the world, and for Europeans it's harder to get to the States. On the other hand, if it were held in Europe it would be the same problem. You can't telephone all day to everybody, its too costly and you don't have the time. So its a theoretical wish that people have—to get together more frequently to exchange ideas and knowledge. I would think that its not really that necessary to make an effort to bring people together more often, because certain ideas lie in the air, so to speak. Some things are developed independently of each other at different places. You discover that it wasn't really necessary to consult because you know actually what the present-day problems are.

On the other hand the exchange is difficult. Even the exchange of computer programs seems to be difficult. Systems are different and approaches are different. So collaboration is a little hypothetical.

The nice thing about different institutes is that you can have different approaches to the same problem. Suppose we would try to imitate what the French are doing in Paris, or they would try to imitate what we are doing here. Then you would have the same institute twice. On the other hand, if you are an individual walking in your own direction then you want to know what's around you but you don't want to follow the others. Exchange is sometimes necessary but it doesn't always solve your own problems.

CBR You see more of a collaboration on the level of ideas?

GMK Yes, and there are periodicals in which ideas and developments are described. If you really are in need of certain knowledge, then you can do as people have for centuries—just travel to the place and study the problems there.