



Andrea and David Wilson



# PSYCHOACOUSTICS AND MUSIC:

## A Report From Michigan State University

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The computational environment at Michigan State is evolving to serve both the composer and musically oriented psychoacoustician. Our main academic computer, a CDC 6500, houses MSU MUSIC. This program is an extension of the MUSIC V program developed by Max Mathews<sup>1</sup>. In addition to this versatile sound synthesis program, we have a package of acoustic analysis programs consisting of digital filtering and numerical spectrum analysis routines. We are linked via the MERIT computer network to the academic computation centers of the University of Michigan and Wayne State University.

As with many computer music installations we have had our share of difficulties in getting a digital-to-analog (D-A) and analog-to-digital (A-D) conversion facility developed. However, our problems appear solved and the future looks bright with respect to D-A and A-D conversion. Our College of Engineering and Department of Psychology have jointly contributed the funds for the D-A and A-D interface and the implementation of the hardware should be complete by the time this article reaches the presses.

Our interface provides for four channels of D-A conversion and a single channel of A-D. The digital samples are 12 bits and the D-A data rates are 25,000 samples/sec./channel in quadraphonic mode. The A-D and mono or stereo D-A system can accommodate rates upwards to 50,000 samples/sec. Those interested in D-A and A-D interfaces for CDC 3000, 6000, or lower Cyber series computers should contact Jack Peterson or Lynn Broski, the engineers who designed and constructed our interface. Write them care of The Computer Laboratory, Michigan State University, East Lansing, Michigan, Zip 48823.

### TIMBRE RESEARCH

Our psychoacoustic research has centered around the perception of tone quality or timbre and I would like to take a few moments to sketch some of the lines of research we are pursuing and assess their possible relevance to the composition of music.

First, timbre does not qualify as a well defined perceptual attribute like loudness or pitch. The various definitions of timbre are typically formulated in the negative as the collection of perceptual attributes that remain after loudness and pitch have been accounted for. It is certainly not clear what perceptual attributes, or how many, are involved in the perception of a given tone and at this stage of research it is quite difficult even to formulate a satisfactory criterion for what constitutes a perceptual attribute of timbre.

One approach we are examining is to consider the perceptual attributes as psychological directions in a geometrical representation that might be called a timbre space. The application of such a geometrical notion has considerable intuitive appeal. Two tones that sound very dissimilar might be thought of as very distant in the geometrical representation, whereas two tones that sound very similar would be quite close. Furthermore, this notion of distance in the geometrical setting seems quite compatible with many of the varied conceptions of contrast in music. A timbre space that adequately represented the perceptual dissimilarities could conceivably serve as a kind of map that would provide navigational advice to the composer interested in structuring aspects of timbre.

The sense of these formulations has been around in the musical arena for some time. Varese conceived of *Integrals* as a "spatial projection." Ligeti's work invites the application of spatial metaphors. And, of course, it has long been felt that a change in pitch implies a kind of spatial change. This richness of musical conception associated with the abstract geometrical framework is explored in a most illuminating fashion in a recent paper by Vincent McDermott.<sup>2</sup>

### AN EXPERIMENT

To get some idea as to whether or not this geometrizing would lead anywhere, Cindy Null and I performed what in behavioral science is called a multidimensional scaling experiment<sup>3</sup>. We made recordings of nine orchestral instruments each of which was played at the same pitch and duration—an E-flat (311 Hz.) approximately 1.5 sec. long. The recordings were made so that the instruments

sounded roughly equal in loudness on playback and were arranged on the tape so that the listener could conveniently judge the dissimilarity of each of the 36 possible pairs of different timbres we could form with the nine instruments. Ten listeners rated the perceived dissimilarities on a numerical scale on which small numbers indicated little dissimilarity and large numbers indicated great dissimilarity. We then submitted these subjective timbre dissimilarities to INDSCAL<sup>4</sup>, a multidimensional scaling program obtained from Bell Labs. This program arranged the locations of the instruments in a two-dimensional Euclidian space so as to best display, in the sense of maximizing a well defined goodness-of-fit criterion, the dissimilarity judgments given by the listeners. The resulting spatial representation is shown in Figure 1.



Figure 1. Two dimensional INDSCAL solution for dissimilarities between the nine instruments collected from ten listeners. Schematic sound spectrograms are placed just above the location of each instrument.

In order to facilitate an acoustical interpretation of this structure we sketched above each instrument a schematic representation of the results of a spectrum analysis of the onset and steady state regions of the tone. Within each spectrogram the horizontal axis represents time, the lines are the harmonics in ascending order, and the width of each line indicates the amplitude of the corresponding harmonic. The onset regions of the brass tones show that the low-order harmonics enter more rapidly than the high-order ones. The string tones, on the other hand, show a different onset pattern. In addition to an initial noise component, some of the high-order harmonics enter more rapidly than the low-order ones. These acoustical analyses, though preliminary, are in accord with other quite extensive analyses<sup>5</sup>. Thus, it is tempting to suggest that the horizontal direction in Figure 1 is a perceptual attribute determined by the nature of the onset process which we have known for some time to have a strong influence on timbre<sup>6</sup>.

The vertical direction might be interpreted as a perceptual attribute associated with the distribution of energy in the steady state region of the spectrum. The instruments at the top - trumpet, violin - have relatively more acoustic energy in the high frequency region than those at the bottom of the plot - French Horn, bassoon. This interpretation agrees with the observation that the instruments in the upper regions of the plot tend to sound "brighter" than those in the lower region. The fact that the bassoon is not quite where it should be along the onset direction is at present not too bothersome. As a general rule, it is not advisable to let the precise locations of the points in multidimensional scaling solutions outweigh, in the interpretation, the structure characteristic of the overall pattern. As a kind of informal validation of our interpretation we snipped off the onset and decay regions of the tones. The reduction in perceived dissimilarity between the strings, oboe, and trumpet was quite noticeable while the perceived dissimilarities within the class of brass instruments remained about the same as when the transients were present.

We certainly do not intend that these results be taken as a complete or even adequate account of the timbres of these nine instruments. The tones as stimuli were far removed from a musical context and, of course, a 1.5 sec. E-flat hardly seems representative of the wide range of timbres that each of the instruments can produce. Furthermore, even for this restricted set of nine tones, there must be more attributes than the two we suggest. For example, in the two dimensional solution in Figure 1 an attribute associated with the near absence of energy in the even harmonics of the clarinet is not brought forth. A three dimensional solution seems to capture this attribute but we are reluctant to infer anything about the meaning of directions in a three dimensional structure from information on only nine points.

In spite of the shortcomings, these results provide additional verification to the notion that the acoustical details of the onset



transient and the distribution of energy in the spectrum are strong determiners of timbre; more importantly, they place these physical properties in a conceptual scheme based upon subjective judgments. Furthermore, Figure 1 leads one rather naturally to aural speculation about the unfilled regions of the space. We are presently testing the validity of these speculations with MSU MUSIC instruments that synthesize tones with different envelopes for each harmonic. These instruments, which are practically identical to those used by Risset for the synthesis of brass tones, allow us to fill out the space and examine in a more rigorous fashion the manner in which onset and steady state properties are transduced and combined by the perceptual system in forming impressions of timbre.

## CONCEPTUAL STRUCTURES FOR MUSICAL MATERIAL

Our suggestion is that subjectively based spatial representations of musical materials such as those produced by multidimensional scaling programs might prove useful as conceptual aids in composition. We also wish to stress the importance of maintaining flexibility in the choice of representation scheme. The space need not be Euclidian or even Minkowskian. Perhaps a graph, hierarchical tree, or manifold structure would provide for more insight into the materials. The choice of scheme will surely depend on the context and preferences of the composer.

These extensions of spatial metaphor in music need not be limited to the domain of timbre. Rhythms, for example, are rather nicely characterized as hierarchical tree structures. Such a representation is in line with both musical and psychological analyses of rhythmic structure<sup>7</sup>. It would be interesting to represent each rhythm in a set of rhythms as a tree and then explore the properties of metrics used for obtaining distances between these rhythmic trees<sup>8</sup>. Selection of a tree representation and metric consistent with perceptual dissimilarities might allow for the construction of musically meaningful spatial representation of rather complicated rhythmic patterns. Research of this sort could conceivably provide new insights into rhythmic structure and these insights would have the explicitness required for the development of compositional algorithms.

The musical worth of these techniques, as with any music model or theory, must be assessed in terms of the extent to which the representations can be used to answer questions of musical interest. When the "real-time" music computers become available we foresee the possibility of composers structuring the results of their own perceptual judgments in an interactive fashion, tailoring their experimentation to specific musical contexts.

### Footnotes

1. Mathews, M.V. et al. *The Technology of Computer Music*, M.I.T. Press, Cambridge, Mass., 1969.
2. McDermott, V. A conceptual musical space. *Journal of Aesthetics and Art Criticism*, 30, Summer, 1972, 489-494.
3. Shepard, R.N., Romney, A.K., Nerlove, S.B. *Multidimensional Scaling*, Vol. I, II, Seminar Press, 1972.
4. Carroll, J.D., & Chang, J.-J. Analysis of individual differences in multidimensional scaling via an N-way generalization of "Eckart-Young" decomposition. *Psychometrika*, 1970, 35, 283-319.
5. Risset, J.C., & Mathews, M.V. Analysis of musical-instrument tones. *Physics Today*, 22, No. 2, 1969, 23-30.
6. Note the failure of electronic organs to convincingly mimic the instruments indicated by their stops.
7. Martin, J. Rhythmic versus serial structure in speech and other behavior. *Psychological Review*, 79, No. 6, 1972, 487-509.  
Cooper, G.W., & Meyer, L.B. *The rhythmic structure of music*. Chicago: University of Chicago, 1960.
8. Boorman, S.A., & Olivier, D.C. Metrics on spaces of finite trees. *Journal of Mathematical Psychology*, 10, No. 1, 1973, 26-60.

## "CULTURE: INTERCOM" AND EXPANDED CINEMA

### A PROPOSAL AND MANIFESTO By Stan VanDerBeek

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It is imperative that we quickly find some way for the entire level of world human understanding to rise to a new human scale.  
This scale is the world...  
The risks are the life or death of this world.  
The technological explosion of this last half century, and the implied future are overwhelming, man is running the machines of his own invention... while the machine that is man... runs the risk of running wild.  
Technological research, development and involvement of the world community has almost completely out-distanced the emotional-sociological (socio-"logical") comprehension of this technology.  
It is imperative that each and every member of the world community, regardless of age and cultural background, join the 20th century as quickly as possible.  
The "technique-power" and "culture-over-reach" that is just beginning to

explode in many parts of the earth, is happening so quickly that it has put the logical fulcrum of man's intelligence so far outside himself that he cannot judge or estimate the results of his acts before he commits them. The process of life as an experiment on earth has never been made clearer. It is this danger... that man does not have time to talk to himself... that man does not have means to talk to other men... the world hangs by a thread of verbs and nouns. Language and cultural-semantics are as explosive as nuclear energy.  
It is imperative that we (the world's artists) invent a new world language... that we invent a non-verbal international picture-language... I propose the following:  
That immediate research begin on the possibility of an international picture-language using fundamentally motion pictures.  
That we research immediately existing audio-visual devices, to combine these devices into an educational tool, that I shall call an "experience machine" or a "culture-intercom".  
The establishment of audio-visual research centers... preferably on an international scale...  
These centers to explore the existing audio-visual hardware...  
The development of new image-making devices...  
(the storage and transfer of image materials, motion pictures, television, computers, video-tape, etc.)  
In short, a complete examination of all audio-visual devices and procedures, with the idea in mind to find the best combination of such machines for non-verbal inter-change.  
The training of artists on an international basis in the use of these image tools.  
The immediate development of prototype theatres, hereafter called "Movie-Dromes" that incorporate the use of such projection hardware.  
The immediate research and development of image-events and performances in the "Movie-Drome".  
I shall call these prototype presentations: "Movie Murals", "Ethos-Cinema", "Newsreel of Dreams", "Feedback", "Image Libraries".

The "movie-drome" would operate as follows...  
In a spherical dome, simultaneous images of all sorts would be projected on the entire dome-screen... the audience lies down at the outer edge of the dome with their feet towards the center, thus almost the complete field of view is the dome-screen. Thousands of images would be projected on this screen... this image-flow could be compared to the "collage" form of the newspaper, or the three ring circus... (both of which suffice the audience with an abundance of facts and data)... the audience takes what it can or wants from the presentation... and makes its own conclusions... each member of the audience will build his own references from the image-flow, in the best sense of the word the visual material is to be presented and each individual makes his own conclusions... or realizations.

A particular example...  
to prepare an hour-long presentation in the "movie-drome" using all sorts of multi-plex images, depicting the course of western civilization since the time of the Egyptians to the present... a rapid panoply of graphics and light calling upon thousands of images, both still and in motion (with appropriate "sound-images"). It would be possible to compress the last three thousand years of western life into such an aspect ratio that we, the audience, can grasp the flow of man, time, and forms of life that have lead us up to the very moment... details are not important, it is the total scale of life that is... in other words... using the past and the immediate present to help us understand the likely future... endless filmic variations of this idea are possible in each field of man's endeavor... science, math, geography... art, poetry, dance, biology, etc...  
endless variations of this idea by each culture group and nationality that take it on as a project... to be presented in turn to each other culture group...  
The purpose and effect of such image-flow, and image density, (also to be called "visual-velocity"), is to both deal and logical understanding, and to penetrate to unconscious levels, the use of such "emotion-pictures" would be to reach for the "emotional denominator" of all men...  
the basis of human life thought and understanding that is non-verbal to provide images that inspire basic intuitive instincts of self-realization to inspire all men to good will and "inter and intro-realization".

When I talk of the movie-dromes as image libraries, it is understood that such "life-theatres" would use some of the coming techniques (video tape and computer inter-play) and thus be real communication and storage centers, that is, by satellite, each dome could receive its images from a world wide library source, store them and program a feedback presentation to the local community that lived near the center, this newsreel feedback, could authentically review the total world image "reality" in an hour long show that gave each member of the audience a sense of the entire world picture... the let us say world's work of the month put into an hour.

"Intra-communitronics", or dialogues with other centers would be likely, and instant reference material via transmission television and telephoen could be called for and received at 186,000 m.p.s... from anywhere in the world...

Thus I call this presentation, a "newsreel of ideas, of dreams, a movie-mural..."

an image library, a culture de-compression chamber, a culture-inter-com"... my concept is in effect the maximum use of the maximum information devices that we now have at our disposal...  
Certain things might happen... if an individual is exposed to an overwhelming information experience...

It might be possible to re-order the levels of awareness of any person... it certainly will re-order the structure of motion pictures as we know them...

cinema will become a "performing" art... and image-library.  
I foresee that such centers will have its artist in residence who will orchestrate the image material he has at his disposal... and will lead to a totally new international art form...  
That in probing for the "emotional denominator", it would be possible by the visual "power" of such a presentation to reach any age or culture group regardless of culture and background  
the "experience machine" could bring anyone on earth up to the 20th century.



As the current growth rate risk of explosives to human flesh continues, the risk of survival increases accordingly. . . . it now stands at 200 pounds of T.N.T. per human pound of flesh. . . per human on earth. There are an estimated 700 million people who are unlettered in the world. . . . we have no time to lose or mis-calculate. . . . The world and self education process must find a quick solution to re-order itself, a revision of itself, an awareness of itself. . . . that is each man, must somehow realize the enormous scale of human life and accomplishments on earth right now. . . . Man must find a way to measure himself, to simultaneously grow and keep in touch with himself. . . . Man must find a way to leap over his own prejudices, and apprehensions. . . . The means are on hand. . . here and now. . . . in technology and the extension of the senses. . . . To summarize: My concern is for a way for the over-developing technology of part of the world to help the under-developed emotional-sociology of all of the world to catch up to the 20th century. . . . to counter-balance technique and logic—and to do it now, quickly. . . . My concern is for world peace and harmony. . . . the appreciation of individual minds. . . . the interlocking of good wills on an international exchange basis. . . . the interchange of images and ideas. . . . a realization of the process of "realization" of self-education that now must occur before the "fact" of education. . . . in short: a way for all men to have fore-knowledge by advantageous use of past and immediate knowledge. . . . Mankind faces the immediate future with doubt on one hand and molecular energy on the other. . . . He must move quickly and surely to preserve his future. . . . he must realize the present. . . . the here and the now. . . right now. An international picture-language is a tool to build that future. . .

## HARRINGTON ELECTRONICS

Perceiving the world of digital and analog video machinery with refreshing newness is a major concern for Rick Harrington. Harrington started his own company less than a year ago after leaving the computer industry. Harrington Electronics is now deeply involved with developing 1/2" video equipment with broadcast quality. Harrington's philosophy of producing high quality digital and analog video equipment at low end-user cost is at the heart of his current endeavors.

An instrument soon to be completed by Harrington Electronics is the CHROMAGEN. This device designed especially for use in the 1/2" video studio provides synthesized color for black & white video. The color is added relative to the gray scale in an analog fashion. The gray scale reference is variable as well as the degree of color modulation and saturation. The CHROMAGEN also has a gen-locking capability incorporated in its design. This feature allows the user to add live video to already recorded tape. The gen-lock is necessary to implement this procedure because of the synchronizing problems encountered when trying to match the "sync" of the two different video sources. With this feature of the CHROMAGEN, many otherwise unattainable video effects can be realized.

Harrington first became involved with the visual art field when he designed and built a digital video synthesizer which produces rectangular patterns overlaid with a complex color structure. This piece of equipment was built to be a live-time "playable" instrument, with touch switch controls on the front panel. The synthesizer was on display at The Bloomfield Art Association in Birmingham, Michigan and The 1973 National Computer Conference in New York.

Future projects of Harrington Electronics include more machines, such as a time-base stabilizer, which would give the 1/2" video user the ability to produce broadcast stable material. In many cases these instruments are already on the market but are priced out of reach for the "small studio." Harrington feels this high cost is unnecessary and can be overcome, as he has already done with the economical design of the CHROMAGEN. For any further information write to HARRINGTON ELECTRONICS, 313 N. 7th, Ann Arbor, Michigan 48103, USA.

Barbara Wasneski

## AIMS AND MEMBERSHIP

The Society aims to encourage the creative use of computers in the arts and allow the exchange of information in this area. Membership is open to all at 1 or \$3 per year, students half price. Members receive PAGE eight times a year, and reduced prices for the Society's public meetings and events. The Society has the status of a specialist group of the British Computer Society, but membership of the two societies is independent.

Libraries and institutions can subscribe to PAGE for 1 or \$3 per year. No other membership rights are conferred and there is no form of membership for organizations or groups. Membership and subscriptions run from January to December. On these matters and for other information write to Alan Sutcliffe.

## BOOK OF COMPUTER POEMS

"Computer poetry is warfare carried out by other means, a warfare against conventionality and language that has become automatized. Strange as it seems, our finite state automata have become the poet's allies in this struggle, the long historical battle by which mankind pries into the surface of language to reveal its latent mysteries.

"At the beginning of this century, Stephane Mallarme published a slogan for modernism: A throw of the dice will never abolish chance. Chance is not abolished by the computer's randomizing power but is re-created in different terms. The poet-programmer finds this power a tool to create a new set of dice, multi-faceted and marked with elements of his own choosing.

"Yet the new battle to free language is fought on familiar battlefields: concrete poetry is reflected with a computer mirror in the poems of Leslie Mezei and Greta Monach; pure poetry of sound in the verbal orchestrations of Archie Donald and Noreen Greeno; imagistic poetry in the juxtaposition of the unfamiliar by Charles Forbes, James Runner, and Robin Shirley; syllabic organization in the poems of Marie Borroff, Pete Kilgannon, and Louis Milic. From all of these varied efforts a new convention has already arisen that allows poets like Edwin Morgan the scope to simulate computer poetry without recourse to the machine."

The preceding paragraphs are from the Preface of the book *Computer Poems* edited by Richard Bailey, Potagannissing Press, 1609 Cambridge Road, Ann Arbor, Michigan, 48104, \$2.25 postpaid for U.S. and Canada; \$2.50 other.

## BIO-FEEDBACK, A BRAINWAVE FOR ART

Aquarius Electronics is a very small R&D/manufacturing company. Our corporation is in some ways experimental: we are trying to develop a semi-communal high technology rural industry. Our area of interest is in exploring consciousness measurement and alteration.

Of all the techniques available for consciousness alteration, bio-feedback is the only technique which puts control of the process in the hands of the user. All other techniques such as behavior modification and drug use rely on external inputs for control.

Our instruments are being used by artists in several ways. First, to explore their own states of consciousness, second to measure changes in consciousness produced in viewers of their art and third as artistic techniques in themselves. An example of this third mode would be controlling a music synthesizer with one's brainwaves. Jean Mayo's brainwave controlled visual display is another example of this type of Art.

The field of bio-feedback is in its infancy and almost all applications of our instruments are experimental in nature. As our experience grows, we are designing increasingly sophisticated systems. Aquarius is interested in working together with researchers and artists to develop new instruments, systems and techniques. For further information write to AQUARIUS ELECTRONICS, Post Office Box 627 PA, Mendocino, California 95460.

## CERBERUS VIDEO

Cerberus Video is a non-profit organization of six artists working together in video and related visual information systems. These artists have particular interlocking skills in the fine arts and performance, video production, music, computer programming, and electronics hardware design. We believe that relevant art must involve the integration of the most advanced and expanding technologies with the creative conscience of society. With this realization we are evolving a synthesis of media consistent with the energies and consciousness of man in a cybernetic culture.

Cerberus works in a dimension where there is no tradition. Our medium is broadly defined as the cultural information space created and modulated by electronic communication and image technologies. Much of our concern is with live video configurations. Cerberus has performed works of dance and large screen projection of live and delayed video mix. The phenomena of dance/live activity with simultaneous live video projection has provided a radical experience in space-time perception. Cerberus also uses two digital video synthesizers which generate programs of color video patterns and colorize and modulate camera signals. These machines are revolutionary in the field of video image production. They are uniquely designed for live programming and to be used individually or in an audio-video system with mini-computer mediation.

For further information contact: CERBERUS VIDEO, 1008 Pontiac, Ann Arbor, Michigan 48105, USA.



## COMPUTER ARTS SOCIETY ADDRESSES

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New input channels to the US edited issue of PAGE are vitally needed. To establish the information connection for project descriptions, news items and/or articles please contact Kurt Lauckner, Mathematics Department, Eastern Michigan University, Ypsilanti, Michigan 48197, USA.



## COMPUTER ART EXHIBITION

April 27 — May 27 at the Bloomfield Art Association, 1516 South Cranbrook Road, Birmingham, Michigan 48009... open competitive and invitational exhibition

Co-sponsored by Cranbrook Academy of Art, the Bloomfield Art Association, the Computer Arts Society, Eastern Michigan University, and the University of Michigan with the support of the Michigan Council for the Arts.

## VIDEO EXHIBITION tapes by 50 artists

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7-13

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April 27 - May 27, 1973

# CIRCUIT



Kurt F. Lauckner Mathematics Eastern Michigan University Ypsilanti, Michigan 48197

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