Music and computing: the present situation*

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Perspective

There may be those who find that the terms music and computing form an unlikely pair. We remind them that the monochord, a device usually associated with music, was one of the first scientific measuring instruments. We need not stop there. In virtually any historical period one finds an interaction between music and science and mathematics. With respect to the seventeenth century, for example, Claude Palisca has observed:

> *In any discussion of science in the seventeenth century, among the names that inevitably arise are those of Galileo Galilei, Marin Mersenne, René Descartes, Johannes Kepler, and Christian Huyghens. It is no mere coincidence that these . . . were all trained musicians and authors on musical subjects . . . because music until the seventeenth century was a branch of science and held a place among the four mathematical disciplines of the quadrivium beside arithmetic, geometry, and astronomy.*[1]

The interaction has not been uncontroversial. In the fourth century B.C. Aristoxenus, one of Aristotle's most eminent pupils, took issue with the Pythagoreans, who maintained that the science of harmonics, regarded as central to music, was based upon numerical relations. Aristoxenus asserted that a rational interpretation must take into account the more basic factors of sense-perception and memory. This view was echoed by the celebrated mathematician and encyclopedist, D'Alembert, in the preface to his treatise on Rameau's theory of music:

> *One can consider music either as an art, the purpose of which is to provide one of the principal pleasures of the senses, or as a science by which that art is reduced to principles.*[2]

A nineteenth-century scientist took a simpler view (and one perhaps substantiated by the current commercial musical product):

> *I conclude that musical notes and rhythms were first acquired by the male or female progenitors of mankind for the sake of charming the opposite sex.*[3]

Although the association has sometimes been ludicrous or even fraudulent, the point is that some aspects of music have long been involved with science, mathematics, and technology in some way. It is not at all strange, therefore, that a significant segment of contemporary work in music theory and composition should be concerned with logic, mathematics, and machines. Indeed, a natural synthesis of these seemingly divergent enterprises is even now taking place in computer-implemented music research and composition.[4]

This trend is especially evident in recent work in this country, much of which has been inspired by the theoretical formulations of Milton Babbitt[5] and set in motion by the pioneering efforts of Lejaren Hiller and his associates.[6] It is now evident that an intellectual climate exists—albeit in a very small group—such that one can predict with some degree of certainty that computer-implemented music research and composition will continue to extend and will produce significant results.

Because of the diverse applications that have been made or proposed, it would be pretentious to imply that a comprehensive view of the present situation can be given here. Nonetheless, an attempt will be made to indicate those directions and activities that are currently visible. Much of the work is long-range and experimental. Accordingly, it is necessary to say, once and for all, that we are still in a pioneer stage.

Sound-generation by computer

Sound-generation by computer involves the computa-

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tion of waveform samples at a specified sampling frequency and the conversion of these to an output waveform through a digital-analog device, a low-pass filter, and an amplifier.[7] For "real time" generation, which presumably is to be preferred to the "off-line" situation where digital computer output is converted to analog form by a transducer separate from the computer, speed and storage capacity are critical factors. It appears that more effective use of the computer for sound-generation must await hardware improvements, since the "off-line" situation requires an excessive amount of machine time for the production of complex sounds, while real time generation necessitates compromises in the form of limitations upon obtainable sounds.

At present, the generation of sound by computer affords the researcher and composer at least three interesting possibilities: (1) experiments in auditory perception—characterized by Babbitt as "the most refractory of areas";[5] (2) the study of musical "grammars"; (3) the development of original compositions. The greatest amount of activity has occurred in the latter category. Early credits go to Max Mathews and the MUSIC IV program for sound-generation and to Lejaren Hiller at the University of Illinois. More recently, computer generation has been carried out at Princeton (by James Randall,[8] Godfrey Winham, Hubert Howe, and others), at Yale (by James Tenney), and at M.I.T. (by Ercolino Ferretti[9] and by A. Wayne Slawson).

The second category (study of musical grammars) is relevant to contemporary work in music theory. Is it possible to write a computer program to produce new music in a familiar style? The serious issues and problems involved here have been obscured, unfortunately, by the occasional efforts—dutifully recorded by the press—to produce music that "sounds like" Mozart, Bach, Irving Berlin, etc. To my knowledge, no such effort has been successful. (It should be remarked, in this connection, that actual sonic output would not be required. For example, the computer might produce or display a score in complete music notation.)

Music research

Under this heading come a variety of applications: information retrieval, style analysis, study of musical systems, and the development of music representations for computer processing. (Most of the projects cited below are described in more detail in the compilation by Edmund A. Bowles listed in the references.[10])

In the information retrieval category perhaps the most impressive project is the important RILM (Répertoire International de la Littérature Musicale), directed by Barry S. Brook, that is being carried out at New York University Institute for Computer Research in the Humanities.[11] The long-range goal of this project is bibliographic control of the scholarly information about music past and present.

Several eminent scholars are interested in pattern-recognition, with a view to codifying style-characteristics for a particular corpus of music. Among these are Arthur Mendel (the vocal works of J. S. Bach), Lewis Lockwood (the masses of Josquin), Jan LaRue (Haydn symphonies), and Harry Lincoln (Frottole repertory). This work is characterized in part by what might be called "overlay" procedures, the comparison of variant texts for relevant similarities and differences, and thus has an affinity to certain work being done in literary research.

Research in what may be called, loosely, musical systems has been undertaken by Stefan Bauer-Mengelberg and Melvin Ferentz,[12] by Michael Kassler,[13] Hubert Howe,[14] and by the present writer.[15] These projects are characterized by a concern with combinatorial problems, complex decision structures, and non-statistical mathematical models.[16]

Both in style analysis and in the study of musical systems a distinction can be drawn between "numeric" and "non-numeric" processing. If the researcher deals indirectly with music, that is, if his data consist of numeric sets representing some musical property or properties, information-loss is assumed and the problem is usually solved in a straightforward way, using available mathematics. If he deals more directly with music, however, the question of input data and information-loss becomes central. What is to be the object of study? Bauer-Mengelberg[17] maintains that it is the score and makes a cogent case for a syntactic representation that is complete for any composition. Other researchers take a more casual view and are content with incomplete or *ad hoc* representations. The issue is interesting and significant, for it may ultimately affect the viability of a research project.

The question of music representation is but one of many we are beginning to cope with. Interpretation of output, which involves criteria of parsimony and significance, formalization, and the development of efficient algorithms is a matter of immediate concern. The question of appropriate high-level languages and their natural data-structures is also in the foreground for those of us who are active in computer-implemented research.

A look ahead

We confine our remarks here to music research, although some of them are probably relevant to composition as well.

To a large extent the future of music research vis-a-vis the computer depends upon education. If computer-implemented research is to have a significant effect it must be undertaken by more scholars than are now active in that area. They must be scholars of the highest rank, well versed in subject matter and sufficiently competent to be able to program fluently and to supervise programming, where that is desirable and feasible. It might be noted here that the Harpur Seminar on Music Research and the Computer, a two-week summer course directed by Professor Harry Lincoln, represents a pioneer effort to effect a rapprochement of music scholar and computer.[18] For younger scholars—mature graduate students in particular—the problem is simpler. They must be taught to use the computer as a normal part of their formal education. This is especially important for those in the area of music theory, but is probably also essential for scholars whose main interests are historical—on the assumption that even though the scholar's historical interests might be confined to the period from 1601 to 1603 he lives in the 20th century and presumably should have access to contemporary research facilities.

It is wise to remember that many problems in music are complex. The extent to which data-processing technology will render solutions more accessible than do traditional procedures remains an open question. For example, it now appears that computer-generated graphic displays offer new resources for the editing procedures that are central to much work in musicology. Yet, a great deal of work must be done before machine-implemented editing can cope with the notational systems of various historical periods or with such a complex representation of the human creative process as a page from a Beethoven sketchbook. In attempting to cope with such problems, however, we can expect that traditional music scholarship will obtain insights that may determine extensive critical revisions of conventional methods and criteria.

REFERENCES

1 C V PALISCA
Scientific empiricism in musical thought
In Seventeenth Century Science and the Arts edited by H H Rhys Princeton University Press 1961

2 J D'ALEMBERT
Élémens de musique
London 1772

3 C DARWIN
The descent of man
London 1872

4 A FORTE
Computer-implemented analysis of musical structure
In: Papers from the West Virginia University Conference on Computer Applications in Music West Virginia University Library Morgantown 1967

5 M BABBITT
The use of computers in musicological research
Perspectives of New Music vol 3 no 2 Spring-Summer 1965

6 L A HILLER L M ISAACSON
Experimental music; composition with an electronic computer
McGraw-Hill Book Co New York 1959

7 JAMES C TENNEY
Sound generation by means of a digital computer
Journal of Music Theory vol 7 no 1 Spring 1963

8 J K RANDALL
A report from Princeton
Perspectives of New Music vol 3 no 2 Spring-Summer 1965

9 E FERRETTI
The computer as a tool for the creative musician
In Computers for the Humanities?; A Record of the Conference Sponsored by Yale University on a Grant from IBM January 22-23, 1965 Yale University Press New Haven 1965

10 E A BOWLES comp
Computerized research in the humanities; a survey
ACLS Newsletter, Special Supplement June 1966

11 B S BROOK
RILM répertoire international de la littérature musicale
Computers and the Humanities vol 1 no 3 Jan 1967

12 S BAUER-MENGELBERG M FERENTZ
On eleven-interval twelve-tone rows
Perspective of New Music vol 3, no 2 Spring-Summer 1965

13 M KASSLER
A sketch of the use of formalized languages for the assertion of music
Perspectives of New Music vol 1 no 2 Spring-Summer 1963

14 H S HOWE
Some combinational properties of pitch structures
Perspectives of New Music vol 4 no 1 Fall-Winter 1965

15 A FORTE
A program for the analytic reading of scores
Journal of Music Theory vol 10 no 2 Winter 1966

16 J ROTHGEB
Some uses of mathematical concepts in theories of music
Journal of Music Theory vol 10 no 2 Winter 1966

17 S BAUER-MENGELBERG
The truth, the whole truth, and nothing but the truth
Paper read at The Computer and Research in the Humanities a conference held at the University of North Carolina Chapel Hill March 1967

18 J PRUETT
The Harpur College music-computer seminar: a report
Computers and the Humanities vol 1 no 2 Nov 1966