Book Reviews

Science and Technology in the Fine Arts

Music from Mathematics. Played by IBM 7090 Computer and digital to sound transducer. J. R. Pierce, M. V. Mathews, D. Lewin, J. Tenny, S. D. Speeth, and N. Guttman. DL 9103. Decca Records, New York, 1962. 33⅓ rpm. $4.95.

Music from Mathematics, an exciting record that presages an area of endeavor likely to expand greatly in forthcoming years, is an excellent demonstration of some of the sounds, including singing, that can be generated by means of a digital computer. Some of the 18 short compositions are adaptations of familiar ones; some are new; some are in new idioms. Certain wave forms that can be generated with particular ease are reflected in those used: rectangular waves, sawtooth waves, trains of sharp impulses, sine waves, waves in which the amplitude of the first third of a note is four times that of the last two thirds, waves with various attacks or with attacks copied from orchestral instruments, waves in which the vibrato (frequency modulation) reaches a maximum in the middle of a note, and narrow-band and wide-band random noise. The square waves sound reminiscent of a clarinet; the sine waves, with a suitable attack transient, sound like a recorder.

Some of the sounds are like those produced by various electrical instruments invented during the past 30 years, but others are novel and not identifiable as combinations of the sounds produced by familiar methods. Complex rhythms and accents are easily generated and are illustrated by compositions involving three notes against four, five notes against seven, two simultaneous and different rhythms, and varying time intervals. Various sequences of frequencies are selected: Five octave glissandi (smooth changes in frequency), canons (two or more voices, usually at different pitches, duplicating each other exactly at different times), and 12-note rows are presented. (A 12-note row is in part a particular ordering of the 12 notes of a chromatic scale and generates the melody or harmony.)

In one example, the frequency of each note is the difference between the frequency of a note in a first voice and that of another note selected from this voice. In other cases, sequences having varying degrees of random selection are displayed. Nuances of vibrato and attack and long crescendos in which intensity, vibrato frequency, vibrato amplitude, and pitch increase are illustrated. Both percussive and nonpercussive sounds are created. "Frère Jacques," Orlando Gibbons's "Fantasia," "Bicycle Built for Two," and "Joy to the World" are used to demonstrate what may be done with a computer. These compositions were programmed to demonstrate the different sounds and effects that can be created. Despite the fact that the compositions were an experiment, they were given aural significance by the composers' awareness of rubato (perturbations in tempo), crescendos, and nuances of intensity and frequency. While these pieces have no serious pretensions, they comprise an excellent catalog of many of the sounds that can be created by a computer. Even if they are disembodied and not quite smooth flowing, the words of the singing generated by the computer are recognizable, a condition not always true nor required of more familiar means of singing. Original studies are presented by the composers Lewin and Tenny. Tenny achieves dynamics through the use of band-limited white noise, which has a more definite pitch the narrower the band width.

To those who are curious about things new in music and to those who wish to see some of the paths music may take, this record is highly recommended. It is not surprising to learn that musicians compose more convincing music than scientists, but it is also certain that scientists can contribute greatly to music through the creation of new knowledge and tools for the musician. While great effort is being expended on the analysis and synthesis of speech, often with the use of analog or digital information generators and processors, this record represents some of the earliest work involving music, especially that concerned with actual compositions by means of a digital computer.

L. Hiller and L. Isaacson (University of Illinois) use the digital computer to choose the notes of a musical composition by generating random numbers and accepting or rejecting the numbers according to a set of rules governing the game played by the computer. These numbers may determine the frequency, duration, or intensity of each note. The notes are printed by the computer and later played by performers, but they could be translated directly into sounds. In contrast, at Bell Telephone Laboratories the composer selects the notes and prepares a detailed list of instructions (subprogram) that governs the computer which generates sequences of 11-bit binary numbers. Each binary number represents the amplitude of a 100-microsecond segment of sound. With a number of subprograms available in a library within the computer, the composer needs only to instruct the machine which of the subprograms to use, when to use them, and how to combine the results of different subprograms (for example, by addition or multiplication). The binary numbers are processed by a filter that rejects all frequency components above about 4.0 kilocycles per second to remove noise and then by a digital-to-sound converter to make a tape recording. Additional details may be found in "Musical sounds from digital computers," by M. V. Mathews, J. R. Pierce, and N. Guttman [*Gravesaner Blaetter* **6**, No. 23/24, 119 (1926)] and in "An acoustic compiler for music and psychological stimuli," by M. V. Mathews [*Bell System Technical Journal* **40**, 677 (1961)].

The evolution of music spans all of written history; it is, therefore, reasonable to suppose that the art of using computers in music and the instrumentation itself will rise to much higher states. The enormous cost and the ratio of machine time to real time (1 to 2 to

1 for each voice at BTL) will undoubtedly be reduced by the rapid development of digital computers, and the composer will be given fast, flexible, direct control of a processor generating sounds in real time. Analog methods to generate music are much less expensive at present and much more widely available. Unfortunately, much more labor is required to exploit their flexibility, and they are being developed by very few people with most inadequate funds. Psychoacoustic information is badly needed by the composer, for he is no longer limited by motor performance but only by aural perception. Milton Babbitt has demonstrated that these limits are unknown. The composer must know what is perceptually significant and what is not so that he can create interesting tones of character. This subject can be illuminated by analyzing the tones of musical instruments to ascertain what physical invariants characterize these instruments and by synthesizing these tones to assess the aural importance of the invariants found. The present composers and scientists appreciate well the importance of low-frequency modulations—that is, subaudio spectra distributed about each of the audio spectra.

Except for such use of data processors, the development of artistically important musical instruments has nearly ceased during the present century, despite the much faster pace of technological developments. Is it possible that viable new instruments to be played by performers will not be developed because the evolutionary approach historically demanded of all successful instruments is lacking and that composers will, therefore, entirely bypass the performer and use devices developed for entirely different purposes and reasons? I hope not. How and when will men learn to spend an infinitesimal fraction of the effort they devote to developing devices for their own self-destruction on effort to make their lives more worthwhile?

The authors of this record have achieved considerable success in displaying the kinds of sounds and combinations of sounds that can be created by a computer; in my opinion they should be very strongly encouraged to expand their work. It will certainly be exciting to see where the work leads.

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Experimental Techniques

Neutron Physics. Proceedings of the symposium held at Rensselaer Polytechnic Institute, May 1961. M. L. Yeater, Ed. Academic Press, New York, 1962. xiii + 303 pp. Illus. $12.

This book is the transcript of a symposium on neutron interactions, which was held at Rensselaer Polytechnic Institute in May 1961. An evaluation of the book must be clearly distinguished from an evaluation of the symposium itself, since the two serve rather different purposes.

The principal value of the book, to most readers, lies in the numerous discussions of experimental methods for measuring cross sections and other nuclear constants of interest to reactor designers. Approximately three-fourths of the book is devoted to these topics, and the reader is able to make a good assessment of the relative merits and areas of applicability of various techniques, for example, fast choppers versus pulsed electron linacs as time of flight spectrometers. The discussions of experimental work are accompanied by current examples of the data obtained but the book, like the symposium, can serve as a source of this information only to the extent that it combines the work of several contributors into a convenient compilation.

The theoretical papers are devoted exclusively to topics related to neutron thermalization. The dynamics of the atomic motions and some of the problems of calculating thermal neutron spectra are discussed, without the detailed quantum mechanical treatment required for a complete presentation. For the theoretical physicist, this is a somewhat superficial treatment, but it provides a useful starting point for further study.

In addition to the useful information contained in the technical discussions, each paper is accompanied by references to the latest publications, which will be helpful in searching out many details that fall outside the scope of the papers.

At the request of the editor, the transcripts of each paper were reviewed by the authors for accuracy, but the papers were not rewritten. This retains the informal and sometimes extemporaneous nature of the original presentations. The inclusion of parts of the discussion periods has the same effect and also helps to point out interrelationships between the separate topics.

The contents would be more consistent with the title if the coverage included recent work on resonance absorption, neutron age, and neutron reactions in fast reactors, but this limitation was forced by the nature of the symposium itself.

In summary, *Neutron Physics* provides a useful and easily read compilation of background information, especially with respect to experimental techniques, and the book can serve as a good starting point for assessing the current status of work on the problems covered.

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Comprehensive Review

The Pyrimidines. D. J. Brown. Interscience (Wiley), New York, 1962. xxv + 774 pp. Illus. $40.

Research in the field of pyrimidine chemistry has been increasing at such a rate that it seems hardly possible for a critical, comprehensive, but reasonably current review to be written by one person. Nevertheless, this book, which represents a tremendous organized search and review of the literature, has some 56 tables listing all simple pyrimidine derivatives (approximately 4000 entries along with melting points and literature references) through 1957, and the text draws examples from the literature through mid-1960.

Brown intended the book to be a practical treatment dealing with synthesis, properties, and structures of the major classes of pyrimidines. Only a brief treatment of the extensive areas of nucleic acids and barbituric acid derivatives is accorded, and it is not intended to cover more complex natural products and fused pyrimidine derivatives.

The 29-page introductory chapter reviews nomenclature and gives the best *brief* review of pyrimidine chemistry available. Although theoretical aspects and mechanistic interpretations are not emphasized, the final chapter, "The ionization and absorption spectra of pyrimidines," includes a valuable and lucid treatment of the pK_a values of pyrimidine and its amino and