# AUTOMATED COMPOSITION

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by

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This book is dedicated to Lejaren Hiller and John Myhill

Table of Contents

# PREFACE

This book surveys techniques of composing music by computer. It is a truly interdisciplinary book, not only drawing upon compositional practice (traditional and otherwise) but also drawing insights from probability theory, statistics, information theory, the mathematical theory of games, some number theory, theoretical linguistics, cognitive psychology, and computer science. The book assumes a reader who is:

1. mathematically sophisticated enough to handle modular arithmetic, exponents and logarithms (no trigonometry or calculus);

2. conversant in programming languages, particularly FORTRAN '77;

3. capable of reading musical notation; and

4. familiar with elementary musical theory.

Though intended primarily as a guide for composers, this book should also be of interest to artists in disciplines other than music, to musical theorists or analysts, and to computer scientists. It is organized in a topical format suitable for use as a textbook, either for self-directed study by readers knowledgeable about programming languages or for guided study under a computer-literate instructor. The book is comprehensive enough in its scope to remain of continuing value both as a historical reference and as a sourcebook of model procedures and programs.

This book would not exist without the unflagging support and encouragement I received from Lejaren Hiller and John Myhill during my graduate and postdoctoral years at the State University of New York at Buffalo. I would also like to express my gratitude to Stuart Shepherd and Thomas DeLio for their penetrating comments on the manuscript in its various drafts.

The Eleven Demonstrations reproduced in this book are dedicated to clarinetist James Perone. They were first performed by him during courses in automated composition which I taught in conjunction with Hiller and Myhill at the State University of New York at Buffalo during the spring and fall semesters of 1983. Perone also gave the set its first public performance on April 12 at the 1984 North American New Music Festival in Buffalo.

It is in the nature of a project like this book that many long meetings, phone conversations, and letters have had to be

## NOTE TO THE READER

Each chapter concludes with a list of recommended readings. The following books in particular should be available for reference:

1. Hiller, Lejaren, and Leonard Isaacson 1959. Experimental Music (New York: McGraw-Hill). Reprinted 1979 (New York: Greenwood Press).

2. Lincoln, Harry, editor, 1970. The Computer and Music (Ithaca, New York: Cornell University Press).

3. Schillinger, Joseph, 1941. The Schillinger System of Musical Composition (New York: Carl Fischer).

4. Xenakis, Iannis, 1971. Formalized Music (Bloomington: Indiana University Press).

For readers lacking background in musical matters I recommend:

1. Erickson, Robert, 1975. Sound Structure in Music (Berkeley: University of California Press).

2. Perle, George, 1962. Serial Composition and Atonality (Berkeley: University of California Press). Third edition, enlarged, 1972.

3. Piston, Walter, 1941. Harmony (New York: W.W. Norton). 4th edition with Mark DeVoto, 1978.

4. Roederer, Juan 1973. Introduction to the Physics and Psychophysics of Music (New York: Springer-Verlag). Second edition, corrected, 1979.

5. Schoenberg, Arnold 1963. Preliminary Exercises in Counterpoint, Leonard Stein, editor (London: Faber and Faber).

Theoretic background is useful, though one must always remember that even the best theory is always second-hand; it can never substitute for a direct awareness of musical works.

There are many usable books on FORTRAN '77 programming. The one in greatest sympathy with my own attitudes is:

Wagener, Jerrold 1980. FORTRAN 77: Principles of

Programming (New York: John Wiley and Sons).

A useful and well-written set of guidelines for disciplined programming can be found in:

Kernighan, Brian W. and P.J. Plauger, 1974. The Elements of Programming Style (New York: McGraw Hill). 2nd edition, 1978.

A comprehensive reference for advanced programming, often consulted by the author, is Donald Knuth's three volume set, The Art of Computer Programming (Reading, Massachusetts: Addison-Wesley). The volumes are:

1. Fundamental Algorithms, 1968. Second edition, 1973.
2. Seminumerical Algorithms, 1969.
3. Sorting and Searching, 1973.

Many sections of Knuth's books require substantial mathematical background; however, he organizes his text in such a manner that these sections may be skipped over without great harm by less ambitious readers.

An equally wide range of books are available on mathematical topics pertinent to automated composition. Background on continous functions such as exponential and logarithmic curves may be found in any book on "elementary functions" or "pre-calculus", for example, chapters 1-5 of:

Flanders, Harley, and Justin Pierce 1973. Elementary Functions and Analytic Geometry (New York: Academic Press).

Insights from probability and statistics are explained where necessary in this book; should further background be desired, a standard reference is:

Feller, William, 1950. An Introduction to Probability Theory and Its Applications, in 2 volumes (New York: John Wiley and Sons). Third edition, 1967.

Other mathematical disciplines which provide relevent but non-crucial insights include set theory, linear algebra (the study of "vectors" and "matricies"), mathematical logic, and calculus. A comprensive and highly readable history of mathematical concepts which has proven an invaluable source for the current book is:

Kramer, Edna E., 1970. The Nature and Growth of Modern Mathematics (Hawthorn Books). Corrected 1981 (Princeton, New Jersey: Princeton University Press).

distilled into short paragraphs or less; many valuable insights have found their way into background material for which it would become extremely tedious to provide specific citations. For this reason, I give my warmest thanks here at the outset to several important contributors to the field who have supplied crucial information to me directly for this book: Herbert Brun, William Buxton, Thomas DeLio, Emmanuel Ghent, Gottfried Michael Koenig, Otto Laske, Larry Polansky, Curtis Roads, Laurie Spiegel, James Tenney, Barry Truax, and Iannis Xenakis.

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