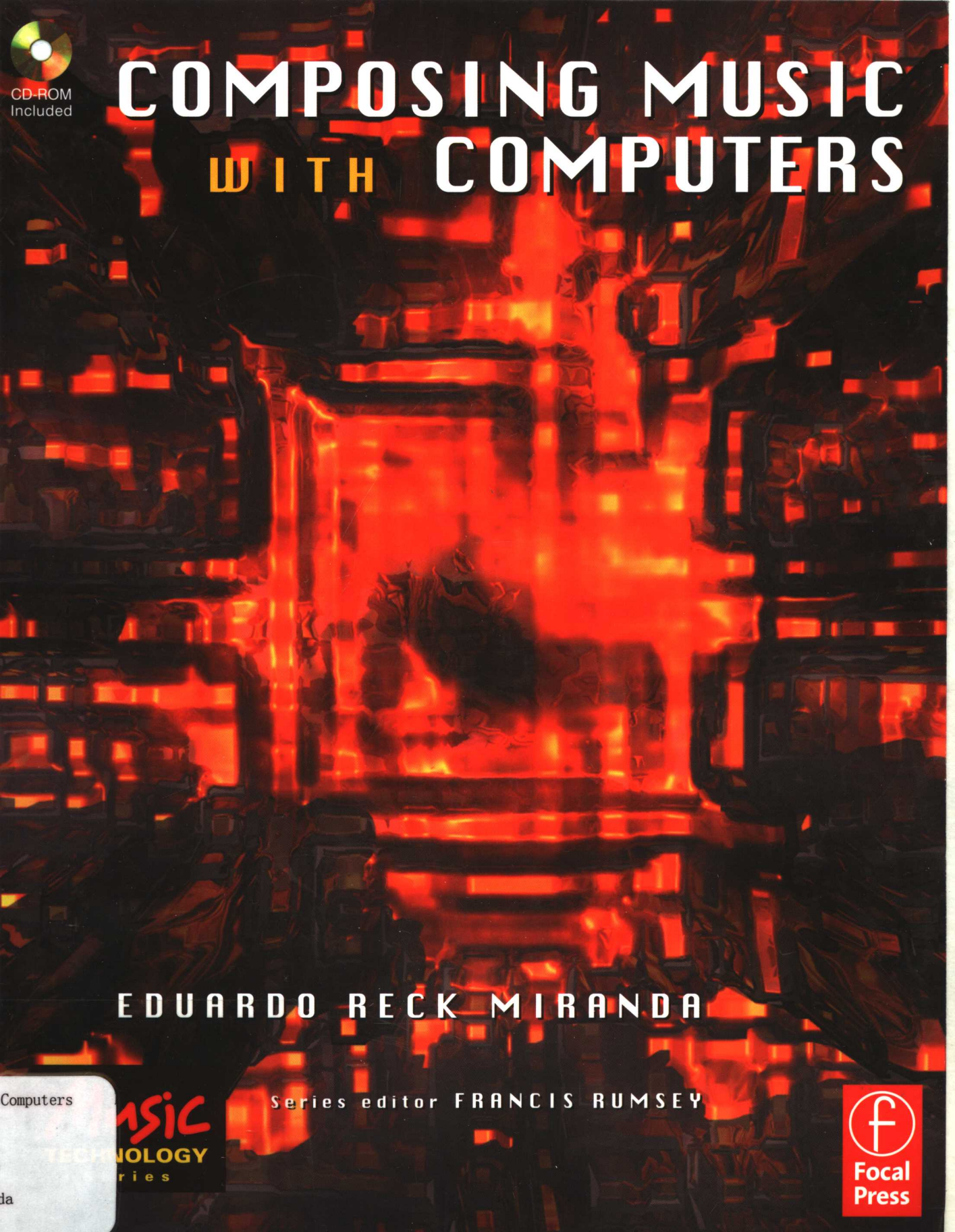

Composing Music with Computers

Eduardo Reck Miranda

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Series introduction

The Focal Press Music Technology Series is intended to fill a growing need for authoritative books to support college and university courses in music technology, sound recording, multimedia and their related fields. The books will also be of value to professionals already working in these areas and who want either to update their knowledge or to familiarise themselves with topics that have not been part of their mainstream occupations.

Information technology and digital systems are now widely used in the production of sound and in the composition of music for a wide range of end uses. Those working in these fields need to understand the principles of sound, musical acoustics, sound synthesis, digital audio, video and computer systems. This is a tall order, but people with this breadth of knowledge are increasingly sought after by employers. The series will explain the technology and techniques in a manner which is both readable and factually concise, avoiding the chattiness, informality and technical woolliness of many books on music technology. The authors are all experts in their fields and many come from teaching and research backgrounds.

Dr Francis Rumsey
Series Editor

Foreword

Composing music with computers is gradually taking its place alongside more traditional ways, such as pencil and paper or improvisation. Computer music is now finding its way into many musical genres, including pop, rock, techno, disco, jazz, and music for film. It is no longer confined to the aesthetics that emerged in the 1960s from the experimental works of *electronic music* (i.e., music composed using electronically synthesised sounds) and *musique concrète* (i.e., music composed using recorded acoustic sound, or sampling music). Gone are the days where computer-aided composition could only be carried out in select institutions using equipment far too expensive for any individual to own. The soundcard, now a standard component in most home computers, outperforms systems that were state-of-the-art a mere 10–15 years ago. Current processor speeds enable real-time synthesis and sound processing even on laptop computers. Consumer music software facilitates musical composition through relatively easy-to-use graphical user-interfaces that require no programming skills. What more could one want?

Electroacoustic music (music that combines *electronic* with *concrète* practices) in its first few decades inspired a somewhat romantic belief that the new technology, by enabling new sounds and compositional process, would in turn lead to a new music with new concepts, aesthetics, and musical experiences. It is not clear whether this has actually occurred, and if so, to what extent. It seems that the second half of the twentieth century, particularly with the move from using analogue devices to digital systems,

was occupied largely with problems of 'computation technology', i.e., how to compute music samples fast enough and with good audio quality. There is yet much to be learned about how the computer can help us to express and capture our musical ideas, to experiment with and develop them, and most importantly, to organise them and produce the finished work of art. This problem could be summarised in much simpler words: how to *compose* music with computers.

Consumer applications for musical composition still leave much to be desired. Sequencers, which are so popular for musical composition, model a multi-track recorder that is familiar from the recording studio. This familiarity makes them easy to use but provides little support for the varied musical concepts through which the composer may be conceiving his work. In addition this model emphasises the placing of musical content in time but doesn't directly support generation of musical materials.

Music is a complex and abstract domain and is inherently subjective. This subjectivity expresses itself in a multitude of different concepts and approaches. Traditional music theory, which developed through vocal and instrumental music over several centuries, has provided many concepts that form the building blocks of musical thought. Note and melody to phrase, motif, development, and structure; tension, and relaxation, to voice leading, counterpoint, harmony, and form are but a few. Newer musical forms introduced yet other ways of looking at music. The electroacoustic music of the 1960s and 1970s, made possible for the first time by analogue devices and digital computers, encouraged composers to think differently not only about music and the process of composition but also about the sensation of the musical experience. Electronic music built upon concepts derived from *music serialism* and produced musical complexity beyond the ability of human performance. On the other extreme, *musique concrète* led composers to explore timbre, textures, time flow, transitions, phase shifts, and sound morphs. In short, it is clear that different people think about their music using different concepts. Some of these concepts are more general and to some degree universal, but many are highly individualised and apply only to the musical world of a specific composition.

The important contribution of this book lies in its in-depth survey of the varied approaches and techniques that have been developed and utilised for generating music with computers in the academic community. Each technique represents a different way of thinking about music. With a little imagination the reader may find that a certain technique can map nicely to his unique

way of thinking about music. The tools described in this book can be used not only to express and generate new musical ideas but also to process previously composed musical materials. More importantly, the reader can experiment hands-on with each technique through a collection of music applications on the accompanying CD-ROM that have been developed by leading researchers in the field.

The reader will benefit if he keeps in mind several fundamental questions that Eduardo Reck Miranda raises. Is there a difference between instrumental and computer music? Is there a difference in the way one composes a work for instruments or for computer? Is there a different creative workflow when using pencil and paper, the computer, or improvisational techniques? These questions are especially relevant today where computers equally support the composition of traditional and experimental forms of music. The reader may not find a single decisive answer to these questions, but more aptly, many different answers depending on the person who is asking and the specific musical problem he is considering. This book is applicable whether the reader thinks about his music using traditional concepts or through individualised concepts that apply only in his own particular musical world. This book is also relevant whether the reader is concerned with manipulating the overall structure of his work or with refining minute details. It is highly likely that anyone interested in using computers to compose music will find herein a useful technique, regardless of his style or method of composition. In the tradition of computer music – experiment: try, listen, and refine.

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Preface

Composers, perhaps more than any other class of artists, have always been acutely aware of the scientific developments of their time. From the discovery, almost three thousand years ago, of the direct relationship between the pitch of a note and the length of a string or pipe, to the latest computer models of human musical cognition and intelligence, composers have always looked to science to provide new and challenging ways to study and compose music.

Music is generally associated with the artistic expression of emotions, but it is clear that reason plays an important role in music making. For example, the ability to recognise musical patterns and to make structural abstractions and associations requires sophisticated memory mechanisms, involving the conscious manipulation of concepts and subconscious access to millions of networked neurological bonds. One of the finest examples of early rational approaches to music composition appeared in the eleventh century in Europe, when Guido d'Arezzo proposed a lookup chart for assigning pitch to the syllables of religious hymns. He also invented the musical stave for systematic notation of music and established the medieval music scales known as the church modes.

Between d'Arezzo's charts and the first compositional computer programs that appeared in the early 1950s, countless systematisations of music for composition purposes were proposed. The use of the computer as a composition tool thus continues the

tradition of Western musical thought that was initiated approximately a thousand years ago. The computer is a powerful tool for the realisation of abstract design constructs, enabling composers to create musical systematisations and judge whether they have the potential to produce interesting music.

One of the first hints of machine composition came from Ada Lovelace around 1840 in England. The mathematician Charles Babbage had just conceived his analytical engine (Swade, 1991), a programmable calculating engine now considered to be the precursor of the modern-day computer, and Lovelace proposed the idea of using Babbage's invention to compose pieces of music; unfortunately her ideas were not put into practice at the time. All the same, at around that time steam powered machines controlled by stacks of punched cards were being engineered for the textile industry; musical instrument builders promptly recognised that punch-card stacks could be used to drive automatic pipe organs. This automatic organ revealed a glimpse of an unsettling idea about the nature of the music it produced: it emanated from a stream of information, or data, in a form that might also be used to weave a textile pattern. The idea soon evolved into mechanical pianos (popularly known as 'pianolas') and several companies began as early as the 1900s to manufacture the so-called *reproducing pianos*. Reproducing pianos could generate up to sixteen different shades of loudness and some could vary the volume on a continuous sliding scale. Such pianos enabled pianists to record their work with great fidelity: the recording apparatus could punch four thousands holes per minute on a piano roll, enough to store all the notes that a fast virtuoso could play. Because a piano roll stored a set of parameters that described the sound and not the sounds themselves, the performance remained malleable: the information could be manually edited, the holes re-cut, and so on. This sort of technology gained much sophistication during the course of the twentieth century, but the underlying principles remained the same. The medium has changed from punched cards and paper rolls to magnetic and optical storage, but perhaps the most substantial improvement is the invention of a processor that can perform operations on the stored data as well as create it: *the computer*.

The use of computers as composition generators was pioneered in the mid-1950s by such people as Lejaren Hiller and Leonard Isaacson in the United States of America, whose 1956 work, *The Illiac Suite for String Quartet*, is recognised as being the first computer-composed composition (Manning, 1985). Today, computers play key roles in several aspects of music making,

ranging from the synthesis of complex sounds which are impossible to produce with acoustic musical instruments, to the automatic generation of music. The role of the computer as a synthesiser is extensively discussed in my previous book in the Focal Press Music Technology Series, *Computer Sound Synthesis for the Electronic Musician*.

Composing Music with Computers focuses on the role of the computer as a tool for music composition with an emphasis on automatic generation. The first chapter introduces some fundamental concepts concerning compositional approaches and paradigms. Here we will touch upon issues such as music representation, modelling and compositional archetypes. Whilst astronomy, numerical proportions and esoteric numbers served to scaffold some musical pieces in the past, discrete mathematics, set theory, logic, formal grammars, probabilities and algorithms are the mathematical tools of the contemporary composer. In contrast to the discursive style of Chapter 1, Chapter 2 focuses on the mathematical background that musicians should master in order to fully explore the potential of the computer for composition; it is important to study this chapter to take full advantage of this book. Next, Chapter 3 presents the role that probabilities, formal grammars and automata can play in composition, followed by an introduction to the art of composing music with iterative processes, such as fractals, in Chapter 4.

Besides the fact that computers can process enormous amounts of data with precision and considerable speed, computers can also be programmed to mimic some aspects of human cognition and intelligence. One of the most exciting branches of computer science is *neural computation*, whereby scientists study the human brain by analysing its activities when we perform specific tasks, and building computer models that emulate its functioning. Very interesting technology for music making is emerging from this research, such as brain interfaces for music control, and systems that can autonomously learn to recognise and produce musical material. This technology is discussed in Chapter 5.

Compositional techniques involving mathematical models such as the ones introduced in Chapters 3 and 4 have contributed enormously to the radical changes that occurred in Western music after the second half of the twentieth century, leading to the countless tendencies and approaches to musical composition that are recognised today. An emerging new compositional trend that can be considered to be a natural progression in computer music research is presented in Chapter 6 'Evolutionary

music'. Here the tools for composition are drawn from research into the origins and evolution of biological organisms, ecology and cultural systems. Next, Chapter 7 presents three case studies on putting some of the techniques and concepts introduced in this book into practice. Finally, Chapter 8 presents the software on the accompanying CD-ROM. The CD-ROM contains examples, complementary tutorials and a number of composition systems mostly for PC and Macintosh platforms, ranging from experimental programs and demonstration versions, to fully working packages developed by research centres, individuals and companies worldwide.

I would like to express my gratitude to all the contributors who kindly provided the materials for the CD-ROM: Roger Dannenberg and Dominic Mazzoni (Carnegie Mellon University, USA); Gerard Assayag and Carlos Agon (Ircam, France); Steve Abrams, Robert Fuhrer, Daniel Oppenheim, Donald Pazel, and James Wright (IBM T. J. Watson Research Center, USA); Tim Cole and Pete Cole (SSEYO Ltd, UK); Bernard Bel (Université de Provence, France); Arnold Reinders (MuSoft Builders, The Netherlands); Kenny McAlpine and Michael McClarty (University of Abertay Dundee, UK); Jônatas Manzolli and Artemis Moroni (Unicamp, Brazil); Valerio Talarico, Eleonora Bilotta and Pietro Pantano (Università della Calabria, Italy); Drew DeVito (IBVA Systems, USA); Sylvia Pengilly (Loyola University, New Orleans, USA); Lars Kindermann (The Bavarian Research Centre for Knowledge-Based Systems, Germany); David Zicarelli (Cycling74, USA); Luis Rojas; Gustavo Diaz and Paul Whalley. I am indebted to Francis Rumsey (University of Surrey, UK), Stuart Hoggar (University of Glasgow, UK), Alan Smaill (University of Edinburgh, UK), Daniel Oppenheim and Peter Todd (Max Planck Institute for Human Development, Germany) who read the manuscript draft and made invaluable comments and suggestions; to James Correa for his help with the musical figures; to Larry Solomon (University of Arizona, USA) for the solution of the puzzle canon in Chapter 4; to Gerald Bennett (Swiss Center for Computer Music, Switzerland) for supplying the annotated score for Appendix 1; to Steve Goss (University of Surrey, UK) for testing the software on the CD-ROM; and to the Focal Press team for their support and professionalism.

Finally I would like to thank my wife, Alexandra, for her patience and for occasionally making me tea.

This book is dedicated to Felipe Brum Reck for his academic inspiration.

Eduardo Reck Miranda

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