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Introduction to Computer Music

Week 15

Instructor: Prof. Roger B. Dannenberg

Topics Discussed: Resources and Literature on Computer
Music

Chapter 15

Where Next?

This book has introduced fundamental technologies of digital audio, sound synthesis, and music creation by computer. We have touched on some related fields including musical acoustics, music perception, music theory, music information retrieval, and music understanding.

Our goal has been to focus on music synthesis and composition, particularly through the programming language Nyquist, as this offers tremendous flexibility and a chance to build a wide range of computational models and abstractions around music. While Nyquist is quite general for signal processing and automation, extending even to music composition, this is not to say Nyquist is the best approach to every task. Clearly, there are *less general* systems that are *more powerful* in the sense that they make it easier to do the limited set of things they are intended to do. If you want to edit recorded audio, by all means use an editor like Audacity or your favorite digital audio workstation. If you want to synthesize a rock drum track, by all means use a commercial drum machine. Hopefully, this book has enabled you to better understand and apply these more specialized systems and to go far beyond them when the need arises.

In addition, this book is just an introduction to a rapidly growing field. Our goal has been to remain compact and only cover essential and important information, providing a readable basis for exploring further. To learn more, it is good to have some idea of what is out there and where to look for it. This final chapter by no means comprehensive, but it offers some directions for study and some references to consider.

15.1 NIME and Physical Computing

In 2001, a workshop called “New Interfaces for Musical Expression” or NIME was organized to discuss physical controls and interfaces that sit between performers and computer music systems. The annual NIME conference continues to draw researchers who study sensors, control strategies, haptics, robots, and many other topics, often with an emphasis on user studies, adopting methodologies from psychology and human factors. NIME proceedings are all online and free (www.nime.org).

In the early days, it was an accomplishment simply to combine a sensor, a microcontroller, and perhaps a MIDI interface to send controls to a synthesizer, and many projects explored variations of this configuration. Today, parts are available “off-the-shelf” to quickly put together the electronics needed for a computer music instrument controller. See offerings from www.adafruit.com and

www.sparkfun.com for example. Still, if you have no electronics skills, it could be quite liberating to master some basic skills. Many universities offer courses in “physical computing” or “Internet of Things” where you can learn to assemble small self-contained computing devices with sensors and outputs of various kinds. If not, look for Electrical Engineering courses in digital electronics or microcomputers/microcontrollers with lab sections where you actually build things.

15.2 Music Information Retrieval, AI and Machine Learning

Almost coincident with the beginnings of NIME, a new field emerged combining library science, data retrieval, computer music, and machine learning called Music Information Retrieval (MIR). Like NIME, the International Society for Music Information Retrieval (ISMIR) conference draws hundreds of researchers every year who present work which has steadily drifted from retrieval problems and library science to more general research on music understanding and music composition by computer. This field is strongly weighted toward popular music and commercial music. Proceedings tend to be very technical and are available online at ismir.net.

ISMIR has become a favorite venue for applications of machine learning to music. Although research on machine learning in music is increasingly published in major machine learning conferences, ISMIR has by far the greatest variety and concentration of this work.

Some textbooks, mainly for graduate students, have appeared, including *Fundamentals of Music Processing* [?], which has a large collection of online support material. George Tzanetakis created an online course on MIR for Kadenze. (www.kadenze.com/programs/music-information-retrieval)

15.3 Signal Processing

Our introduction to music signal processing is an attempt to convey “what every computer scientist should know” about signal processing. A more rigorous approach is certainly possible, and to design new algorithms or really master the application of signal processing to music, there is much more to learn. Julius Smith has a wonderful resource consisting of multiple online books (ccrma.stanford.edu/jos). A formal Electrical Engineering course in Signals and Systems or Advanced Digital Signal Processing is a good way to learn more. The book *Audio Content Analysis* introduces many signal processing techniques for music analysis [?] with more formal and complete descriptions. There are online materials for this book as well. Another conference series, DAFX, has many papers on various synthesis and analysis techniques for music (www.dafx.de) and there is a book: *DAFX - Digital Audio Effects* [?].

15.4 Real-Time Systems

It is surprising given the importance of time in music that there is not more literature on building real-time systems for music. There are some important techniques, but few good sources to learn from. One recommendation is Ross Bencina’s blog (www.rossbencina.com/code/real-time-audio-programming-

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[101-time-waits-for-nothing](#)). Ross and I gave a workshop and wrote a short document with some good references. This might be a good starting point for further reading (www.cs.cmu.edu/rbd/doc/icmc2005workshop/real-time-systems-concepts-design-patterns.pdf).

15.5 General Computer Music

Beyond these more specialized areas, there are many musicians, scientists and engineers who simply create and explore music with computers. There are too many ideas to classify or label them. Literally thousands of papers on computer music are reported in *Proceedings of the International Computer Music Conference* (ICMC), available free online from the International Computer Music Association (computermusic.org). Two main publications on Computer Music are the *Computer Music Journal* (www.computermusicjournal.org) and *Journal of New Music Research*. Unfortunately, neither of these journals is open, but your library may have access to online content. *Computer Music Journal* has a wide readership and tends to be less technical and less academic, while *Journal of New Music Research* has more in-depth articles and work related to contemporary art music. There is a good deal of overlap in topics, and both are important resources.

There are many more conferences we have not mentioned. Most of these conferences publish proceedings online. Searching the Internet for scholarly articles in journals and conferences is a good way to learn, and you will get to know which journal and conferences are most relevant to your personal interests.