A MULTIMEDIA DIGITAL SIGNAL PROCESSING TUTORING SYSTEM

Sam Pointer, John Wawrzynek, and David Wessel
Center for New Music and Audio Technologies
Department of Music
University of California, Berkeley
1750 Arch Street
Berkeley, CA 94709

ABSTRACT: We have developed an interactive multimedia software system to act as a tutor of digital audio signal processing. The DISIPLE system (DIgital SIgnal Processing Learning Environment) is intended for use by people without specialized engineering training, such as composers and psychoacousticians. We have implemented a prototype of the system on the NeXT computer to: 1) explore the relationships among text, graphics, and sound in a interactive teaching environment, and 2) explore the tools available on that platform and the feasibility of developing the full system. In this paper we concentrate on our use of tools to implement the interactive multimedia system and our specific approach to teaching individual topics. Our system is organized as a Mathematica notebook with external support from NeXT's Sound and Music Kits through Objective-C code. With the DISIPLE system we have illustrated some possibilities for developing interactive multimedia systems on the NeXT machine, and for teaching topics in audio technology. The experience gained here will be useful in the development of related systems.

Introduction

We have developed an experimental interactive multimedia software system to act as a tutor of digital audio signal processing. The DISIPLE system (DIgital SIgnal Processing Learning Environment) is intended for use by people without specialized engineering training, such as composers and psychoacousticians. We have implemented sections of the system on the NeXT computer to: 1) explore the relationships among text, graphics, and sound in a interactive teaching environment, and 2) explore the tools available on that platform and the feasibility of developing the full system. In this paper we will concentrate on our use of tools to implement the interactive multimedia system and our specific approach to teaching individual topics.

This work is being carried out at the Center for New Music and Audio Technologies (CNMAT) at the University of California, Berkeley [1]. We are particularly interested in utilizing and developing technologies which will further the creative process for musicians and composers, and in bringing current technology within the grasp of users outside the fields of engineering and computer science. One measure of our success will be in the degree to which our work merges art and technology and can offer the advantages of one field to a specialist in another.

The New Media

"Multimedia" refers to any presentation format which does not confine itself to a single medium of expression such as text, sound, or animation, but instead utilizes two or more media. An "interactive" system is one in which the user can affect the behavior of the system, often by choosing among alternatives or choosing when he is ready to proceed to a later section. Researchers have explored the use of interactive multimedia in a number of topics [2].

Topics in audio technology are particularly suited to multimedia presentation because they inherently involve sound and are normally taught using a combination of text and graphics. In addition, because they involve many phenomena which are non-stationary and evolve over time, the ability to use animation (non-stationary graphics) is useful as well. Understanding these topics often means the ability to leap freely between the realms of mathematics and sound, and we hope to promote that understanding with an interactive presentation format allowing the user to change the representation in one realm and see the effect in another.

Teaching DSP to Non-Specialists

Computer technology has permeated every aspect of music synthesis, composition, and psychoacoustics, yet many users of the new technology lack the knowledge to exploit it . People without engineering and computer science backgrounds—composers wishing to explore new sounds, psychologists wishing to develop psychoacoustic experiments, and architects wishing to model the acoustic properties of a proposed building—can only harness the power of computers by understanding the basics of digital signal processing (DSP). However, DSP is a difficult subject. Many engineering students find digital signal processing one of the most difficult topics in their curriculum. The traditional way of teaching DSP provides little insight into practical applications, and is nearly useless to those without an engineering background. Although these topics may seem difficult when presented in textbook form, we believe that they will become clear and intuitive using examples with animated graphics and sound. To that end, we developed a syllabus for our interactive "course" in DSP and implemented several major sections.

DISIPLE Design Goals

Our design goals for DISIPLE are:

- To structure it as a textbook with a syllabus, so that later chapters depend on earlier ones, and so the user may revisit topics at any time.
- To use sound, graphics, and animation where appropriate to illustrate topics.
- To allow the user to vary aspects of the demonstrations which help illuminate the topics being addressed.
- To allow the user to explore the interrelationship among topics via the interactive demonstration environment.
- To ensure that interactions are easy and convenient.
- To use primarily graphic interfaces in the interactive demos.
- To develop an expanding demonstration environment, adding one topic at a time, ending with an environment where the user can choose non-trivial combinations of options.
- To use standard DSP terms and graphic conventions.
- To make it fun so that it holds the user's interest.

Implementation

Much of DISIPLE's functionality, as well as its presentation format, comes from the Mathematica system [3]. Mathematica can be used as a glorified calculator, an engine for graphics and animation, a programming language, and a document processor. DISIPLE uses Mathematica for all of these things. However, Mathematica input must be textual, and there is no way, therefore, to develop graphic user interfaces within Mathematica. For these, we turn to NeXT's application development environment, NextStep (which includes a window server, an Application Kit of pre-defined software objects, and the Interface Builder, an application to ease user-interface development) [4]. The following three figures are snapshots of a sample user session with DISIPLE.

Figure 1: The user has finished reading an introduction to sinusoids, presented through text and static graphics in the Mathematica notebook at left. S/he now highlights and sends a command to start an interactive demonstration. A graphic interface window appears at right. The user chooses parameters of the sinusoid using the sliders at the top of the interface window. S/he clicks on the "Play" button to hear the sinusoid through the speaker, or on the "Graph" button to see it graphed back in the Mathematica window. Two sample graphs are shown.

Figure 2: The user has been learning about quantization. The interface panel at top right allows him/her to bring up an existing sound file, or record his/her voice to create a new one, then play it by pressing the "Play" button. S/he uses the slider to choose the number of bits of quantization, in this case three, then clicks on the "Quantize" button to have the sound quantized. Now playing the sound will play a three-bit version. Both versions are displayed graphically in the windows at bottom.

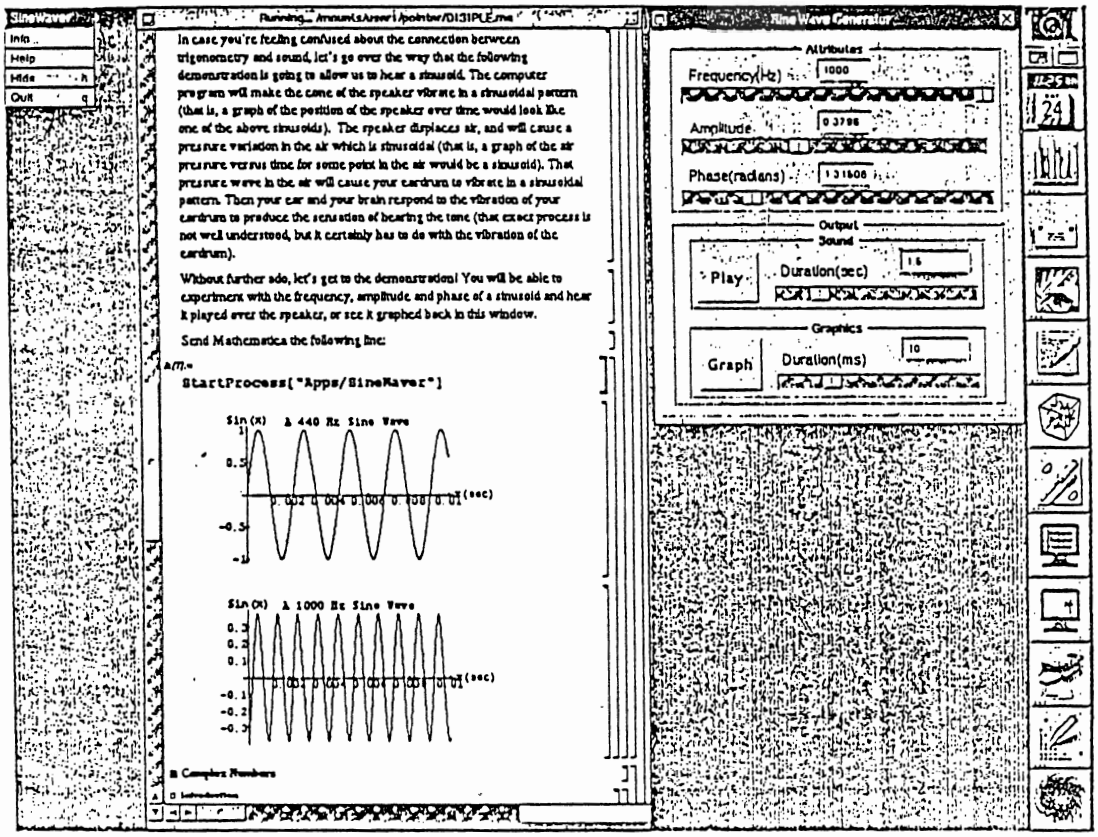

Figure 1

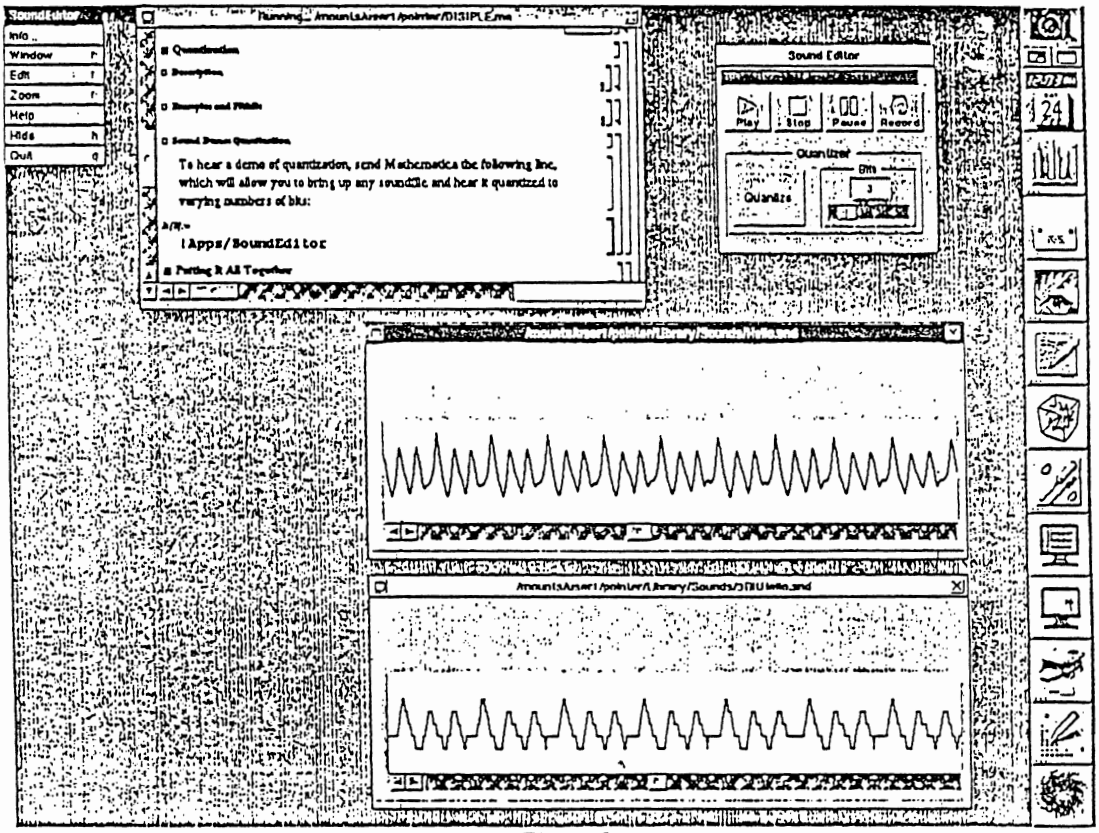

Figure 2

Figure 3: The user has been learning about the discrete Fourier transform. This example allows the user to choose the sampling and quantization of an input sinusoid, and see the digitized signal or its DFT graphed in Mathematica.

Conclusion

We believe that the DISIPLE system illustrates some possibilities for developing interactive multimedia systems on the NeXT machine, and for teaching topics in audio technology using interactive multimedia. The experience gained in its development will be useful in developing related systems. Although we have concentrated on the domain of digital signal processing, these techniques can be used in other domains in music and music technology. We envision interactive multimedia systems to teach music theory, psychoacoustics, arranging, and performance, to name just a few.

References

[1] Wessel, David, R. Felciano, A. Freed, and J. Wawrzynek, *The Center For New Music and Audio Technologies*, Proceedings of International Computer Music Conference 1989, Columbus, Ohio, 1989.

[2] Ambron, Suanne, and K. Hooper, eds., **Interactive Multimedia**, Microsoft Press, Redmond, Washington, 1988.

[3] Wolfram, Stephen, **Mathematica: A System For Doing Mathematics By Computer**, Addison-Wesley, Redwood City, California, 1988.

[4] NeXT, Inc., **The NeXT System Reference Manual**, Redwood City, California, 1989.

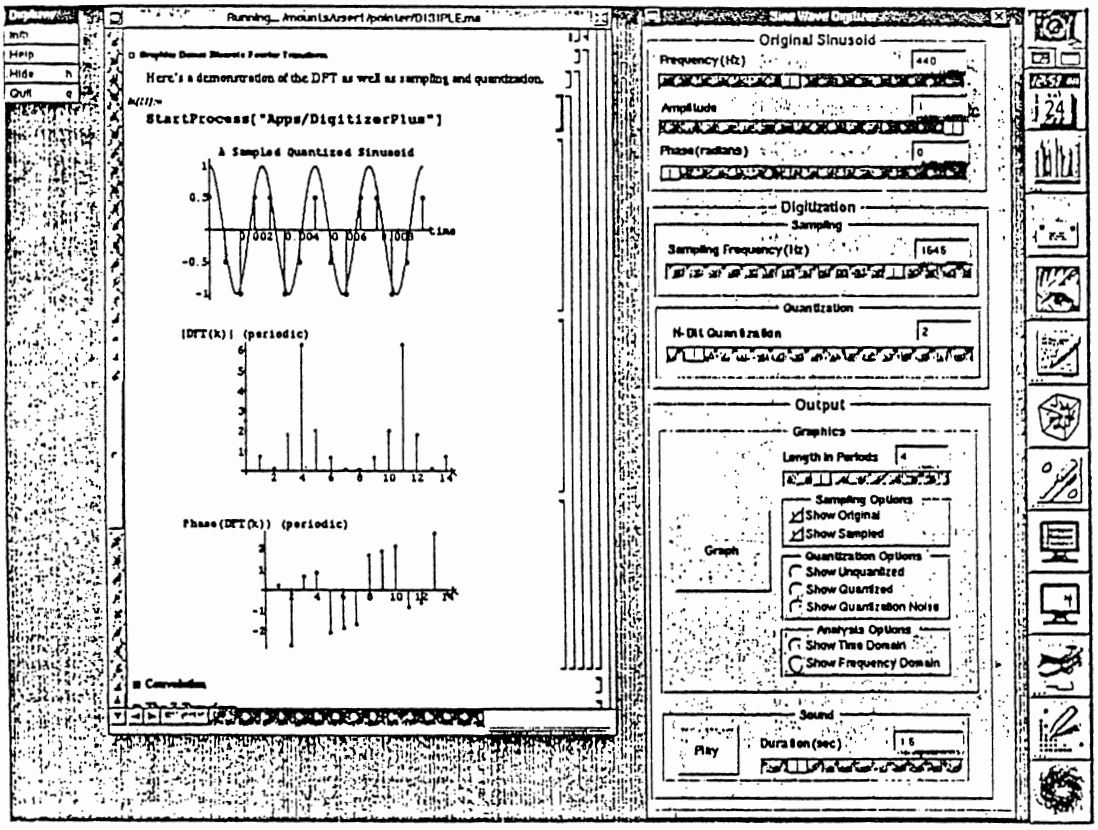

Figure 3