Flash-Based Interactive Learning of Fundamental Fourier Analysis

Trasapong Thaiupathump[*], Wanasanan Thongsongkrit[*], Rungchat Chompu-inwai[**]

[*]Department of Computer Engineering, Faculty of Engineering
Chiang Mai University, Chiang Mai, 50200, THAILAND
Phone: +66 53 942024
E-mail: trasapong@eng.cmu.ac.th

[**]Department of Industrial and Manufacturing Engineering
Oregon State University, Corvallis, Oregon, 97331-2407

Introduction

Fourier analysis is an important fundamental concept for many engineering disciplines, such as digital signal processing, communications, and digital image processing[1,2,3]. The analysis involves transforming signals between time-domain and frequency-domain. Many learners have difficulties in understanding or visualizing the relationships between these two domains and some basic Fourier concepts and operations as well. In traditional approaches, teaching the basic concepts of Fourier analysis with the use of only still images and descriptions is not an easy task and not very effective either. For example, the convolution operation of two time-domain signals can be better demonstrated with animation. Moreover, since most signals are generally controllable by some adjustable parameters, such as time period, frequency, or sampling rate, the learning will be more effective if learners can adjust these parameters and readily observe the results of the changes. Obviously, the interactive learning approach will provide learners with a better understanding of fundamental Fourier concepts.

This paper explores the interactive approach to teaching basic Fourier concepts and operations, which include basic properties of sinusoidal signals, Fourier series, sampling, aliasing, convolution, and modulation. Macromedia Flash MX[4], which currently is a standard for the interactive animation for the Web, is used to implement the interactive teaching approach. The developed tutoring system will utilize animation contents and maximize the interaction with students for distance education as well.

Methods

This paper selects some of the Fourier basic concepts and operations that will be most beneficial by the use of interactive/animation tutoring approach. These selected basic concepts and operations are: fundamental properties of signals, Fourier series, sampling, convolution, and modulation.

Visualizations for the operations were implemented by using Macromedia Flash MX and the programming for interactive user interface and animation were implemented by using

ActionScript. The developed tutoring contents were tested on the Web with the Microsoft Internet Explorer 6.0.

Results

Figures 1-5 illustrate some captured screens of the interactive/animation tutoring system on the following topics: signal fundamentals, Fourier series, sampling, convolution, and modulation.

Signal Fundamentals

Figure 1 shows the pages for the signal fundamentals topic. The tutoring system allows users to change basic parameters of a sinusoidal signal, such as frequency, amplitude, and phase, which will help students understand important properties of sinusoidal signal better.

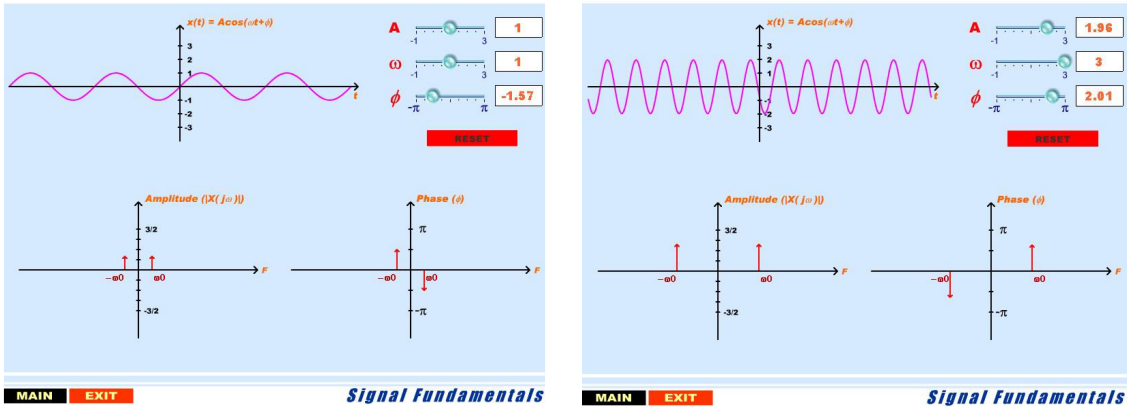

Figure 1. Signal fundamentals pages

Fourier Series

In the study of Fourier series of periodic signals, such as square or triangle signals, it is important to understand that such signals can be synthesized as a linear combination of several sinusoidal signals at frequency multiples of fundamental frequency. In figure 2, the tutoring system allows students to specify the number of terms in synthesis equations and see the synthesized time-domain signal waveform and its spectrum.

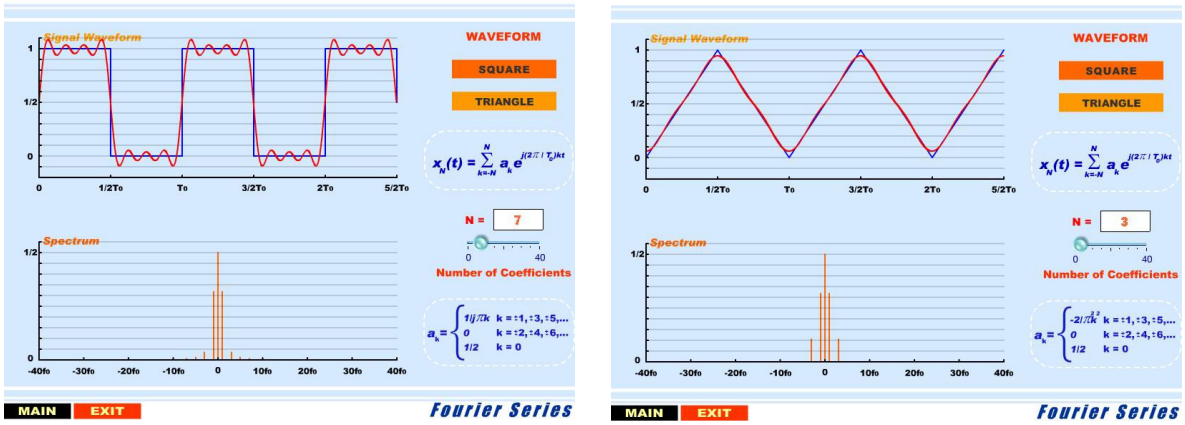

Figure 2. Fourier series pages

Sampling

Figure 3 illustrates the pages on sampling theorem topic. The tutoring system allows students to change the sampling frequency (via sampling period) and to learn about sampling theorem in order to see if the sampling frequency is less than twice the highest frequency of the band-limited signal, which is known as Nyquist rate[3]. In this case, the reconstructed output is related to the original input through a distortion referred to as aliasing[3]. Figure 3 presents the concept of sampling theorem in time-domain waveform and frequency-domain amplitudes.

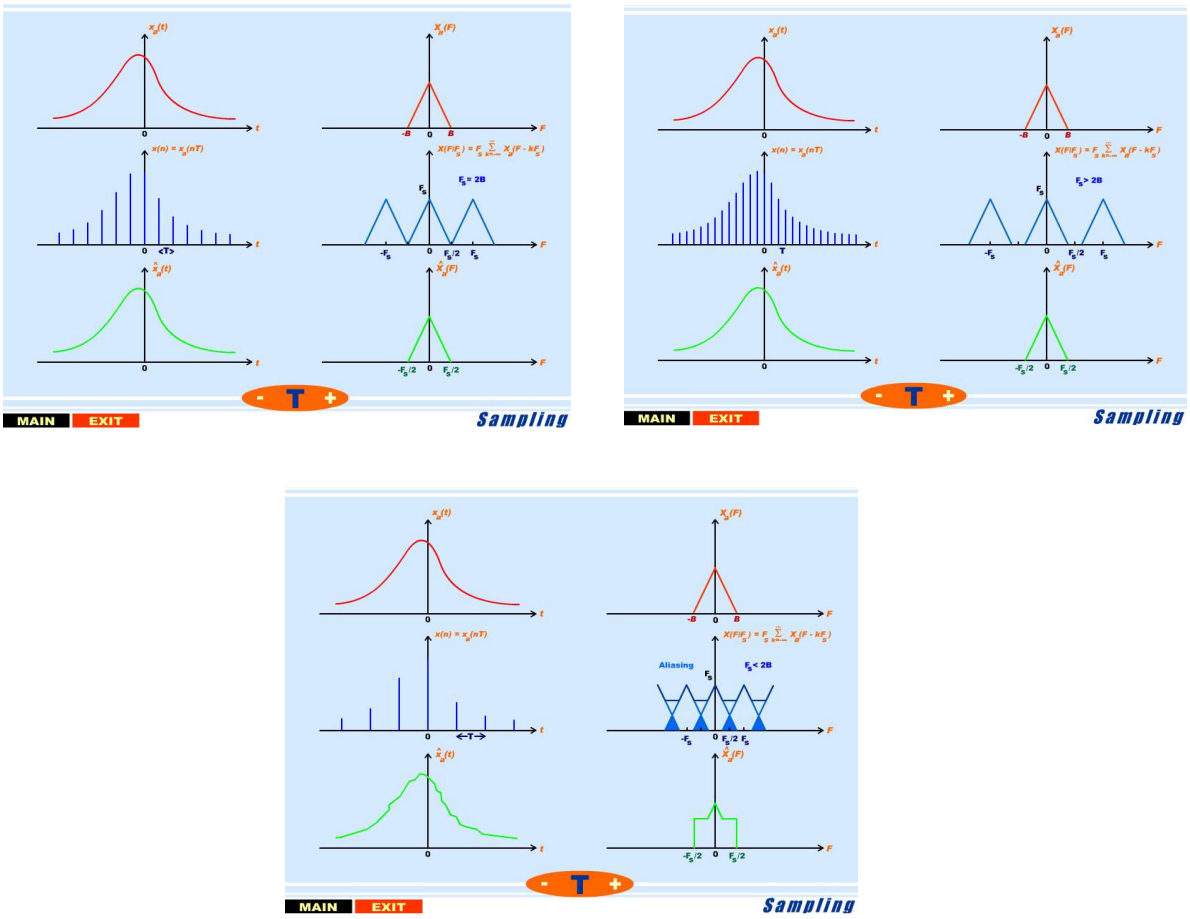

Figure 3. Sampling pages

Convolution

Convolution is one of the operations that are difficult to visualize and understand, especially when illustrated with only still images and descriptions. Figure 4 shows animation of the convolution operation. The tutoring system allows students to select two discrete-time signals and to be able to observe the step-by-step operation via animation.

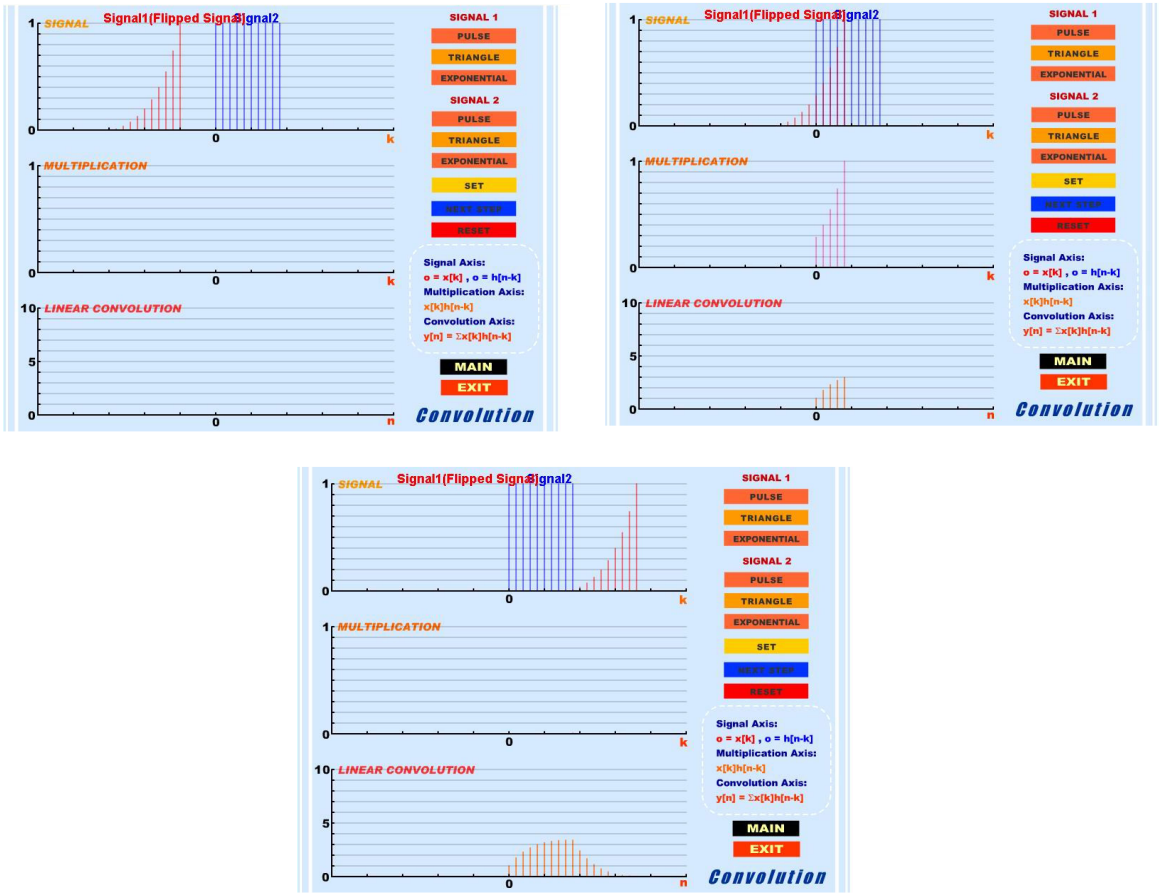

Figure 4. Convolution pages

Modulation

Figure 5 shows the modulation operation of a low-frequency base-band signal and a high-frequency carrier signal. Students can adjust the frequency of the carrier sinusoidal signal and observe the changes in both time-domain and frequency-domain.

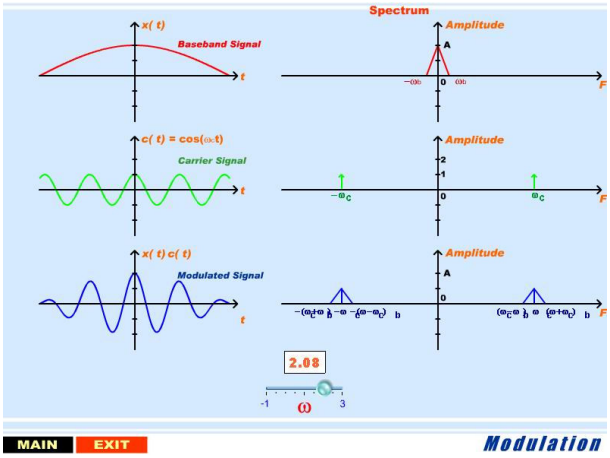

Figure 5. Modulation page

Evaluation

A junior level Digital Signal Processing course at Chiang Mai University was identified to be used as a test vehicle to gain a better understanding of the impact of incorporating the Flash-based tutoring system in lab sessions on basic Fourier theory. Main topics of the course are signal fundamental concepts, basic Fourier concept, and basic filter design. The course consists of two 50-minute lectures and one two-hour lab each week. Lectures are held in a traditional classroom. Lab sessions take place in computer lab. The course enrollment at the time of this study was 41 students. After the topics were covered in lecture classes, the flash-based tutoring system was used in computer labs. Students can access the tutoring system from the course webpage.

A moderator facilitated a 1-2 hour discussion with a group of 3-4 volunteer students. These focus groups were conducted at the end of the lab sessions. Students attending the focus groups were asked a series of questions. These focus groups were used to assess student attitudes on the usage and the role of the flash-based tutoring system, as well as the student learning.

In general, the results from this initial study suggest that students in Digital Signal Processing course had fairly positive attitudes towards the usage and the role of the flash-based tutoring system when utilized in lab sessions. Students found that the system helps them understand somewhat better the basic concepts of Fourier theory. However, even though there are many parameters that the students can alter and observe the results, they found the system is not flexible and not extensive to cover more advanced concepts. The system is not very user-friendly for most of the first-time learners.

These findings do point to the need to further study this system in order to provide a deeper and broader understanding of the potential for relationships between the introduction of the Flash-based tutoring system in the classroom and student attitudes, as well as student learning.

Discussion

The Flash-based tutoring system allows users to adjust important parameters interactively to gain a better understanding of Fourier operations. One of the most significant benefits of the Flash-based tutoring system is its small size, which allows students to deploy the interactive tutoring contents on the Web easily. Students can conveniently access the tutoring contents anytime, from anywhere, with only an Internet connection and a standard Flash player. The system is considered to be a more learner-centered teaching system than a traditional teaching approach.

In this tutoring system, only the Fourier operations which significantly enhanced the understanding via the interactive animation approach were used. Nevertheless, the Flash-based tutoring approach can be used as effective teaching aids in other hard-to-visualize concepts as well.

Conclusion

The developed Flash-based tutoring system can be used interactively by allowing learners to adjust Fourier operations' key parameters. The system can be considered to be an auxiliary teaching and learning aid. The ability to readily observe the results of operations after changing parameters provides learners with a better understanding of fundamental Fourier concepts. The

developed tutoring system utilized interactive/animation contents and also maximized the interaction with students for distance education via the portability of Flash documents.

Bibliography

1 McClellan, J.H., Schafer, R.W., Yoder, M.A. (2003), *Signal Processing First*, Pearson Education, New Jersey, 2003.
2 Gonzalez, R.C., Woods, R. E. (1995) *Digital Image Processing*, 2nd Ed., Prentice Hall, New Jersey.
3 Proakis, J.G. (1995), *Digital Communication*, 3rd Ed., McGraw-Hill, New York.
4 Kaye, J., Castillo, D.(2002) *Flash MX for Interactive Simulation*, Onword Press.

Biography

TRASAPONG THAIUPATHUMP is a lecturer in the Computer Engineering Department at Chiang Mai University, Thailand. He received his B.Eng. in computer engineering from the King Mongkut's Institute of Technology, Ladkrabang (KMITL), Thailand in 1993. He received his M.S. in computer engineering from the University of Southern California in 1996. He received his M.S. and Ph.D. in electrical engineering from the University of Pennsylvania in 1998 and 2002, respectively. His research interests are signal processing and computer communications.

WANASANAN THONGSONGKRIT is a lecturer in the Computer Engineering Department at Chiang Mai University, Thailand. She received her bachelor degree in Computer Engineering from Chiang Mai University in 1996. She received an M.Eng. in Computer Science from Tokyo Institute of Technology, Japan in 1999. Her research interests are in the fields of Digital Image Processing and Pattern Recognition.

RUNGCHAT CHOMPU-INWAI is a doctoral student in the Industrial and Manufacturing Engineering Department at Oregon State University. Chompu-inwai received her B.S. in Industrial Engineering from Chiang Mai University, Thailand in 1997. She received an M.Eng.Sc. in Manufacturing Engineering majoring in Industrial Management from The University of New South Wales, Australia in 2000. Her research is focused on mobile technology use in education.