ON-LINE LABORATORIES FOR IMAGE AND TWO-DIMENSIONAL SIGNAL PROCESSING

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Abstract *- This paper presents innovative on-line java-based educational DSP software modules that were developed to render possible on-line laboratories for two-dimensional digital signal processing. The developed software modules provide on-line 2-D DSP capabilities, including 2D signal generation, 2D FIR filter design & implementation, and 2D transforms. On-line image processing capabilities are also provided, including image restoration and enhancement. In order to illustrate 2D concepts graphically, contour (2D) and perspective (3D) plots have also been implemented and incorporated as part of the developed software tools. On-line laboratory exercises have been developed in the aforementioned areas for use in the graduate-level Multidimensional Signal Processing and Image Processing courses at ASU. Statistical and qualitative evaluations are presented to assess the effectiveness of the developed on-line 2D DSP software and laboratories in improving the learning experiences of the students.*

Index Terms – Java, On-line Laboratories, Two-dimensional Signal Processing, Web.

INTRODUCTION

Distance learning is very active at Arizona State University (ASU) with high enrollment of students from local companies. Although many existing educational software tools [1]-[5] were developed to enhance the students' learning experience, most of these existing tools are platform- and location-dependent, or delivered through CD-ROMs. With the advancement of the Internet and the World Wide Web (WWW), flexible, location- and platform-independent web-based educational tools [6] can be developed to provide fast and convenient anywhere and anytime access.

This paper is organized as follows. First, an overview of the developed lab environment is presented. The developed 2D DSP java tools and on-line laboratories are described next. Finally, the conducted learning assessments are summarized and discussed.

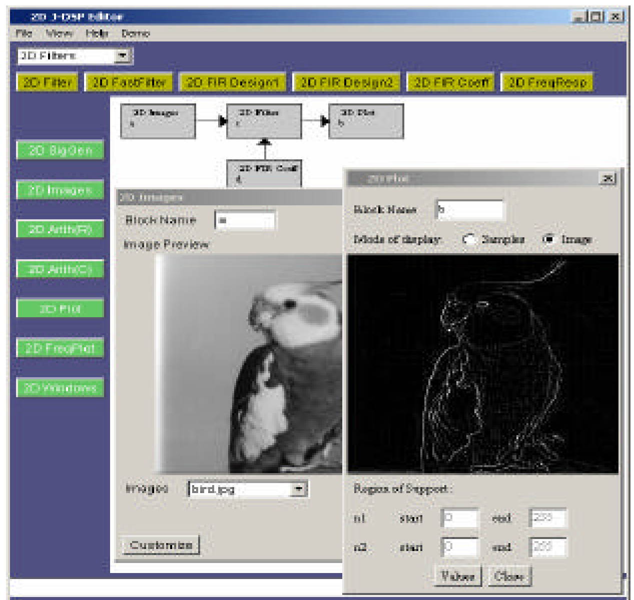

FIGURE 1
2D J-DSP LAB ENVIRONMENT.

OVERVIEW OF THE ON-LINE LAB ENVIRONMENT

The developed laboratory environment is a platform-independent, java-based, object-oriented, visual dataflow simulation environment, also called two-dimensional java digital signal processing (2D J-DSP). The objective of the developed visual simulation tools is to help students, and especially distance learners, understand and visualize 2D signal processing concepts without the need to spend time and efforts on programming details. The user-friendly, visual simulation, platform-independent 2D J-DSP environment does not only help students improve their understanding of advanced 2-D DSP concepts, but also the developed tools are accessible from anywhere in the world by means of the Internet and the World Wide Web.

Simulations are established by placing the required blocks in the workspace and linking them together. Each block opens up with a double click of the mouse button, which brings up a dialog window where the user can set up the desired parameters in the available fields. All the blocks come with a Help feature that illustrates their capabilities and limitations. Fig. 1 shows a simulation diagram for high-pass filtering of a natural image.

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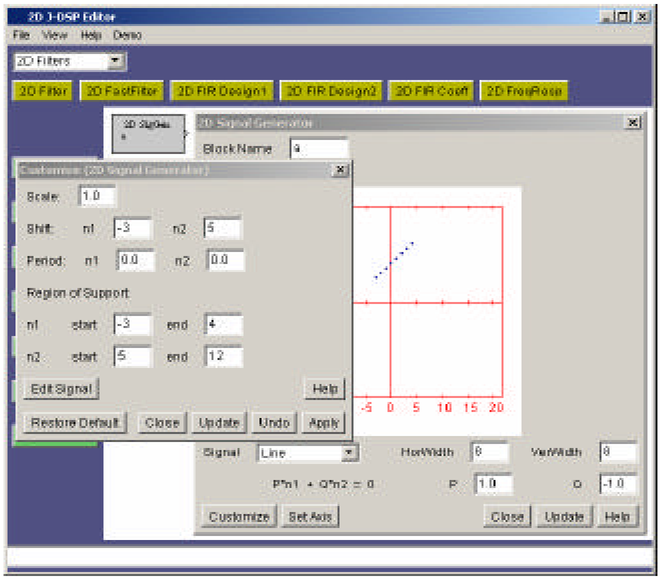

FIGURE 2
2D SIGGEN BLOCK.

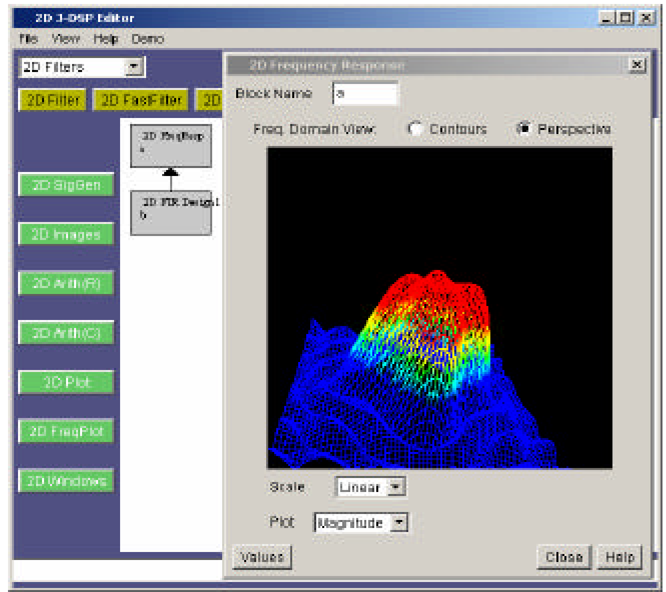

FIGURE 3
PERSPECTIVE PLOT FOR 2D FIR FILTER.

DESCRIPTION OF DEVELOPED 2D DSP JAVA TOOLS

The developed 2-D DSP java tools include generation of 2D signals, design and implementation of 2D linear and shift invariant (LSI) systems and 2D transforms. The developed 2D DSP java tools can be accessed at http://jdsp.asu.edu/multid. The description of some of the developed 2-D DSP java tools is given below.

2D Sig Gen Block

This block generates 2D time/space-domain signals with a maximum length of 125 samples in each of the horizontal (n1) or vertical (n2) direction. Horizontal and vertical widths can be specified explicitly and can be used to zero-pad or truncate the defined time/space 2D digital signals. Defined signals can be scaled up or down by any integer or floating-point factor. Positive and negative shifts in n1 and n2 directions can be performed with any integer value. Any defined signal can be made periodic in any or both directions by just specifying the period in the required fields. Furthermore, a sample value can be added in or deleted from the defined signal. Fig. 2 shows some of the features of the 2D SigGen block.

2D Arith(R) and 2D Arith(C) Blocks

Three types of arithmetic operations can be performed on real and complex 2D signals using these blocks, that is, addition, subtraction and multiplication. 2D Arith(R) is for real while 2D Arith(C) is for complex arithmetic operations.

2D Plot Block

Any 2D signal can be viewed at any point of the 2D system by connecting the output of the corresponding block to this 2D Plot block. Signals can be viewed in two forms, that is, sample view and image view.

2D Freq Resp Block

This block is used to view the frequency response of 2D LSI systems. The frequency response is calculated by taking a 64x64 point 2D DFT of the impulse response of the 2D LSI system. Magnitude and phase frequency responses can be viewed both in linear and in dB scale. A contour plot that shows the 2D view and perspective plot that shows the 3D mesh view of the frequency response are also provided. Fig. 3 shows the frequency response of a window-based designed 2D FIR low-pass filter with a cut-off frequency of 0.45p and which was designed with a separable rectangular window of order 9.

2D FIR Design1 Block

This block designs 2D FIR filters using the window-based method. Rectangular, Hamming, Hanning, Blackman, Bartlett and Kaiser separable or non-separable windows can be formed and used to design the desired 2D separable or non-separable FIR filter [7], [8]. In order to design the required 2D FIR filter, frequency specifications are entered in the required fields as shown in Fig. 4.

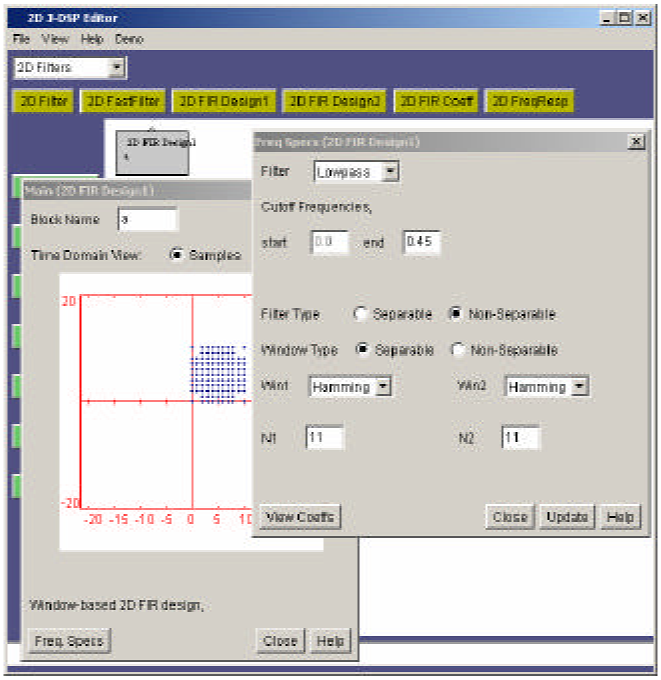

FIGURE 4
2D FIR FILTER DESIGN.

2D FIR Design2 Block

This block implements the design of 2D FIR filter using a 2D frequency-sampling method. The desired 2D FIR filter is designed by specifying the filter type, filter order, and cut-off frequency.

2D Filter Block

This block performs the 2D filtering operation using the 2D convolution sum.

Row-Filter and Col-Filter Blocks

These blocks perform, respectively, row and column filtering operations on the 2D input time/space-domain signal respectively and can be used for implementing filter bank analysis and synthesis sections.

Row_UpSampling and Row_DownSampling Blocks

These blocks are used to perform up- and down-sampling operations along the rows of the 2D input signals.

Col_UpSampling and Col_DownSampling Blocks

These blocks are used to perform up- and down- sampling operations along the columns of the 2D input signals.

2D FFT, 2D DCT and 2D Wavelet Blocks

A number of 2-D DSP java tools for computing 2D transforms have been developed. These include the 2D Discrete Fourier Transform (DFT), 2D Discrete Cosine Transform (DCT) and 2D Discrete Wavelet Transform (DWT). The 2D DFT and DCT transforms are implemented using the row-column decomposition method [with 1D DFT and DCT transforms, respectively. The numbers of 2D FFT and DCT points to be calculated are powers of 2 with a maximum limit of 256. Zero padding is performed on the 2D input signal if the region of support (ROS) of the 2D input signal is not a power of 2. The implemented 2D wavelet transform makes use of the Antonini 9/7 discrete wavelet transform (DWT) filters [9].

DEVELOPED ON-LINE LABORATORIES

To improve the learning capacity of students and help them understand advanced 2D DSP concepts that are hard to visualize in a traditional classroom environment, a number of lab exercises have been developed. These on-line laboratories mainly cover fundamentals of 2-D signals and image processing concepts, implementation of 2D linear systems, 2D FIR filter design and 2D transforms. These on-line laboratories can be accessed by clicking on the "Multidimensional Signal Processing" link on the web page http://jdsp.asu.edu. An overview of developed labs is given below.

"*Lab 1: Introduction to 2D J-DSP*" helps students getting familiarized with the 2-D DSP java environment with simple simulations. It is also a good starting point for the beginners who want to learn the basics of 2-D signals and systems.

"*Lab 2: Implementation of 2D LSI systems and applications*" deals with the implementation and application of 2-D linear and shift-invariant (LSI) systems. Basic image processing concepts, e.g., average intensity and low/high frequency image areas, have also been illustrated in this laboratory exercise. Furthermore, low-pass and high-pass filtering effects on images along with noise removal simulations have been added to further improve the concept of 2-D systems and their applications.

"*Lab 3: 2D FIR design*" covers the design of 2D FIR systems. In this laboratory exercise, the focus is mainly on window-based and frequency-sampling based design. To clarify the issues related to 2D FIR filter design, several simulation exercises have been added.

"*Lab 4: 2D transforms*" has been developed to illustrate some of the most commonly used 2D linear transforms including the 2D DFT, DCT and discrete wavelet transforms. The students can also implement 2D filter banks by using row/column filters and up/down sampling tools.

LEARNING ASSESSMENT

Statistical and qualitative evaluations that assess the learning experiences of the students that use the developed on-line tools have been carried out. General assessment includes providing feedback on the developed 2-D DSP java tools and lab environment, while specific assessment focuses on the developed laboratory exercises by posing questions to

TABLE-I

STATISTICS BASED ON USER EVALUATIONS – GENERAL ASSESSMENT.

Evaluation questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Establishing/connecting blocks are easy.	53%	39%	7%	1%	0%
The graphical user interface of 2D J-DSP is intuitive and user-friendly.	31%	63%	5%	1%	0%
Setting up the required lab simulations was easy.	40%	52%	8%	0%	0%
Blocks are elaborative and sufficient for visualizing 2D signals.	20%	70%	10%	0%	0%
Lab exercises improve 2D DSP concepts.	20%	70%	10%	0%	0%

TABLE-II

SPECIFIC ASSESSMENT FOR 2D FIR DESIGN ON-LINE LAB

Sample evaluation questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The simulations in this exercise are well oriented around the topic.	33%	50%	17%	0%	0%
Issues related to different types of windows in a window-based 2D FIR filter design are very well explained.	100%	0%	0%	0%	0%
This lab improved your understanding about various windows trade-offs.	17%	66%	17%	0%	0%

determine whether the students have effectively learned the intended concepts using these simulations.

Table I lists some of the general assessment statistics for the developed 2D J-DSP environment. Table II shows an example of specific assessment questions and statistics related to the 2D FIR Design on-line laboratory (Lab 3). Overall, the response is very promising. 95% of the users appreciated the idea of an internet-based simulation tool. The evaluation forms can be accessed through the following web site http://jdsp.asu.edu/.

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REFERENCES

[1] Schodorf, J., Yoder, M., McClellan, J., and Schafer, R., "Using multimedia to teach the theory of multimedia," in the *IEEE Trans. on Education*, Vol. 39, pp. 336-341, Aug. 1996.

[2] Donohoe, G. and Valdez, P., "Teaching digital image processing with Khoros", in the *IEEE Trans. on Education*, vol. 39, pp. 137-142, May 1996.

[3] Arnold, J. and Cavenor, M., "A practical course in digital video communications based on MATLAB", in the *IEEE Trans. on Education*, vol. 39, pp. 127-136, May 1996.

[4] Oakley, B., "A Virtual classroom approach to teaching circuits analysis", in the *IEEE Trans. on Education*, vol. 39, no. 3, pp. 287-296, Aug. 1996.

[5] Hollabaugh, C., and Allen, P., "PC-based interactive computational server for educational purposes", in *IEEE Conf. Frontiers in Education*, pp. 38-42, Jul. 1992.

[6] Spanias, A., et al, "Development and Evaluation of a Web-Based Signal and Speech Processing Laboratory for Distance Learning", in the *Proc. IEEE ICASSP-2000, Istanbul*, Vol. 6, pp. 3534-3537, June 2000.

[7] Dudgeon, D. E. and Mersereau, R. M., Multidimensional digital signal processing (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1984).

[8] Lim, J.S., Two-dimensional signal and image processing (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1990).

[9] Antonini, M., Barlaud, M., Mathieu, P., and Daubechies, I., "Image coding using wavelet transforms," in the *IEEE Trans. on Image Processing*, vol. 1, no. 2, pp. 205-220, Apr. 1992.