

ASSESSMENT OF THE JAVA-DSP (J-DSP) ON-LINE LABORATORY SOFTWARE

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Abstract - This paper presents assessment results of the Java-DSP (J-DSP) on-line laboratory. J-DSP software has been developed from the ground up at Arizona State University (ASU) to support the computer lab portion of the senior-level DSP course EEE407. The software enables on-line interactive DSP laboratories. Along with the software, we have developed several J-DSP laboratory exercises that have been posted on the internet. Assessment of the EEE 407 labs was carried both on the web and as part of the instructor and class evaluation. The web-based assessments have been organized into: general software assessments, general laboratory assessments, concept-specific lab-by-lab assessments, and differential pre/post assessment for each lab. Statistical and qualitative evaluations have been compiled for all the J-DSP laboratories and are described in the rest of the paper.

Index Terms – Assessment of J-DSP, On-line labs, filter design, ASU EEE407 DSP Course

INTRODUCTION

Java-DSP (J-DSP) is an NSF funded on-line software environment that was developed to provide on-line laboratory experiences to distance learning and on-campus students. J-DSP consists of object-oriented Java software that resides on the internet and enables students to build simple and complex simulations of DSP algorithms. The core software environment was initially developed in the late 1990s [1]. Since then the J-DSP concept has been continuously developed and updated with a series of new functions and on-line laboratories [2] as well as other modular web content. The software resides on several servers and is used by students taking the DSP class at ASU and in other universities where beta sites have been established. Through the years, the software has been thoroughly verified and formal dissemination occurred at the 2002 FIE Conference and at the 2002 IEEE DSP Education workshop in Atlanta. The software has been disseminated to more than 50 instructors throughout the world.

Although initially, J-DSP assessment was carried within the course evaluation forms, in the last year we assessed separately the degree of learning attributed specifically to J-DSP. We focused in particular on assessing whether J-DSP accelerated the learning curve in the DSP class. Both on-line and off-line materials have been developed. Two types of on-line forms have been developed i.e., general and concept-specific. In the general forms, the students are asked to

provide general qualitative and quantitative evaluation of the J-DSP concept including logistics, accessibility, convenience, demographics, academic standing, etc. In concept-specific forms, students evaluated each laboratory task with regard to its impact on learning specific DSP concepts. Our newest assessment instruments assess learning attributed specifically to J-DSP by testing DSP concepts before (pre-assessment) the J-DSP lab and after (post-assessment) the J-DSP lab. In this paper, we present detailed qualitative and statistical results of this comprehensive assessment effort and describe how J-DSP contributes to the learning of several key DSP concepts.

DSP LAB ASSIGNMENTS

The laboratory assignments of the EEE407 DSP course are designed to enhance student learning in the DSP class. Several hands-on J-DSP computer exercises have been carefully developed not only to reinforce the DSP concepts covered in class but also expose students to complimentary material that is not covered in detail neither in class nor in text books. The computational nature of these laboratories and the inclusion of real-life signals made J-DSP particularly useful in providing engineering intuition and valuable hands-on experiences. On the other hand, simulations of quantization effects and manipulations of truncated signals made students aware of the limitations associated with processing real-life signals with DSP algorithms.

Currently EEE407 includes six computer lab assignments that are assigned on a weekly basis. 1) Difference equations and the Z-Transform, 2) Pole-Zero Plots and Frequency Responses, 3) FIR and IIR Filter Design, 4) The Fast Fourier Transform (FFT), 5) Multi-rate Signal Processing and QMF banks, 6) Introduction to Random Signal Processing.

All these labs require on-line access to the J-DSP editor. Each laboratory contains several problems and exercises. The students have to complete an on-line quiz and submit graphs and comments in the form of an electronic report

DESCRIPTION OF THE LABS

Lab 1: Difference Equations and the Z-Transform

The objective of this lab is to introduce the students to the concepts of linear-time-invariant (LTI) systems, z-transforms, and the impulse response of the LTI systems. Moreover, the students observe the filtering effects, and get

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familiarized with the source-filter configuration. Six problems have been developed for this lab. In problem 1, students are asked to simulate a digital filter using a given transfer function. Figure 1 shows an example simulation performed using J-DSP. In problem 2, the students are asked to design a digital oscillator. In problem 3, a finite impulse response (FIR) filter is provided and the students are asked to observe the behavior of the system for different inputs. In problem 4, the students study symmetric impulse responses. In problem 5, the students compute the transfer function for various pole-zero (PZ) representations. In problem 6, they simulate cascade- and parallel-configurations.

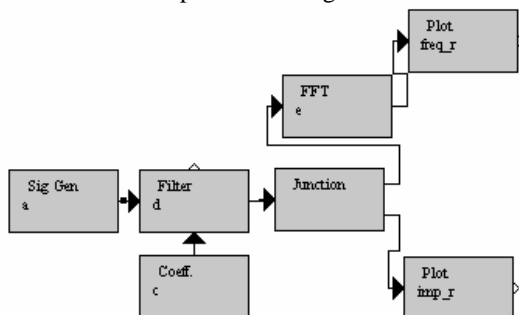


FIGURE 1

J-DSP BLOCKS USED IN SIMULATION OF DIGITAL FILTER IN LAB1, PROB 1

Lab2: Pole-Zero Plots and Frequency Responses

This lab deals with the effect of pole and zero locations on the magnitude frequency response. First, the relationship between the pole-zero plot and the magnitude response of a system is covered. Four problems are assigned in this lab. In Problem 1, the students are asked to find the poles and zeros and observe the frequency response of a given filter. In Problem 2, the students observe the variations in the frequency response by graphically moving the poles and zeros in the z-domain or, by manually entering their values. In Problem 3, low-pass and high-pass filters are designed based on the pole-zero (PZ) placement method. Figure 2 shows the design of a low-pass filter using PZ placement. In Problem 4, the pole-zero locations and the frequency response for an all-pass filter is examined.

Lab 3: FIR and IIR Filter Design

This exercise examines the four types of symmetric impulse responses that result in linear-phase. In addition, the constraints on the zeros of linear-phase filters are studied. FIR filter design using the Fourier series and tapered windows are covered. Seven problems are assigned in this lab. Problem 1 involves the design of FIR filters, i.e., the students are asked to observe the frequency response, Z domain symmetry, and the group delay for these filters. Problem 2 deals with the design of low-pass filters by truncating the ideal impulse response using windows. The following window types are supported in J-DSP: rectangular, Bartlett, Hamming, Hanning, and Kaiser.

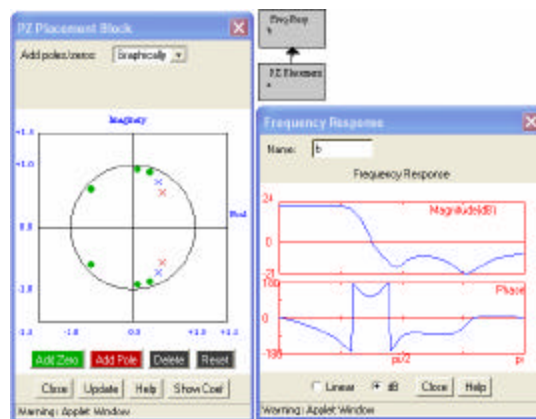


FIGURE 2

DESIGN OF LOW PASS FILTER USING PZ PLACEMENT BLOCK IN LAB 2, PROB 3

In problem 3, the students are asked to design high-pass filters using the Kaiser window. Problem 4 deals with FIR filter design using frequency-sampling method. In problem 5, the students are asked to design optimal FIR filters using the Parks-McClellan algorithm. In problem 6, students are asked to compare the sidelobe levels obtained for the filters designed using the Parks-McClellan method, the Kaiser design, and the frequency-sampling method. Problem 7 deals with the design of IIR filters using bi-linear analog filter approximations. In particular, students are asked to design and compare Butterworth, Chebychev I, Chebychev II, and Elliptic digital filters.

Lab 4: The Fast Fourier Transform (FFT)

In this lab, students learn various concepts related to the use of the DFT and the FFT. In particular, in this lab, students gain familiarity with the estimation of DFT spectra, DFT spectral leakage, DFT resolution, the Parseval's theorem for the DFT, FFT properties and symmetries, and signal estimation and reconstruction using the FFT. In Problem 1, students examine symmetries of the FFT. In Problem 2, students observe the effect of zero-padding and windowing on the FFT spectra. The blocks used in J-DSP for Problem 2 are shown in Figure 3. In Problem 3, the students are asked to examine and compare the FFT spectra of various signals. In Problem 4, students are provided with two sinusoids that are closely spaced in the frequency, and are asked to examine the FFT spectra with several windows

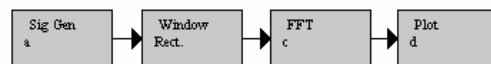


FIGURE 3

BLOCKS USED IN FIR FILTER DESIGN BY WINDOWING IN LAB4, PROB 2

Lab 5: Multi-rate Signal Processing and QMF banks

The goal of this exercise is to examine the effects and the use of the sampling rate conversion and simulate a two-band quadrature mirror filter (QMF) bank. The students get

familiar with the up-sampling and down-sampling rules. They also study the effects of aliasing and imperfect reconstruction in decimation and interpolation of digital signals. Four problems are assigned in this lab. In Problem 1, students examine the effect of down-sampling and up-sampling on FFT spectra. In Problem 2, students design a fractional sampler. In Problems 3 and 4, students implement and evaluate a two-band QMF bank and a tree structured QMF using J-DSP.

Lab 6: Introduction to Random Signal Processing

This lab is optional and covers elements of spectral analysis of random signals. The goal of this exercise is to provide students with the basics of classical and parametric spectral estimation. J-DSP has functions for estimating periodograms and correlograms. It can also estimate parametric autoregressive (AR) spectra by using the linear predictive coding (LPC) functions. Correlograms are established by connecting the output of the long signal generator to the autocorrelation block. This is followed by a connection to a lag window and then to SymCorr and subsequently to the correlogram block. The graph panel will then show the correlogram. The length of data, the window, and the length of correlation are selectable and enables students to experiment with trade-offs of spectral resolution and statistical variance. A task to estimate the spectrum of stationary data using a periodogram and a correlogram is assigned. The performance characteristics of the two estimators are evaluated in terms of variance and resolution capability. This process is repeated for the AR spectral estimator.

LAB SUBMISSION PROCEDURE

All the Lab assignments are accessed on-line and students submit their work on the internet. Each of the students in the EEE407 DSP class is given a user name and password for a lab account. Using lab account, students complete an on-line, media-rich report that includes a quiz that covers the laboratory material. The submitted electronic report contains responses to multiple choice questions, dialog boxes for writing qualitative comments, and facilities to upload the graph files and equations in 'gif' format. Upon submitting the report, all of the student's answers, comments and graphs are placed together in a static HTML that corresponds to each student's ID. Part of the grading is done automatically while part of it requires instructor intervention. The automatic part is processed by a UNIX shell script on the server computer that grades the answers of the multiple choice and true/false questions.

PRE/POST LAB ASSESSMENTS

In addition to the general assessment of JDSP and the pertinent exercises carried in EEE407 in the Fall of 2002, in the spring of 2003 we started running specific pre- and post-lab assessments for each lab. The purpose of the

assessments is to survey and evaluate the level of student's understanding of the key DSP concepts before and after performing a particular J-DSP lab assignment. Thus the statistics obtained from these assessments give us feedback on how the JDSP lab assignments helped the students in learning the key concepts on a particular topic. The pre/post quiz and the lab are assigned after the relevant theory has been introduced in class. We did this in order to ensure that all the students have had some, or ideally the same exposure to the topics covered in the lab, so that we can isolate specifically the effect of J-DSP labs in their learning. The students are asked to complete the pre-lab assessment before working on that lab. After they complete and submit the lab assignments, they complete the post-lab assessment. The questions on the post-lab assessments are same as the pre-lab assessments but given in a different order.

Results of Pre/post Lab Assessments

Pre/post assessment results are shown graphically in Figures 4 and 5 for Labs 1 through 5. Lab 6 was optional and by the time this paper was submitted we did not have the data available. The assessment results of each of these labs are discussed below.

Lab 1 assessment results

From Figure 6, we see that a total of 6 questions are assigned in Lab 1 assessment. Lab 1 is related to the Z-Transform and the frequency response. In Question 1, the students are asked to determine the impulse response for a given transfer function. We observe that 92% students answer correctly before performing the lab and 92.3% students answer correctly after they have finished the lab. Percentage improvement is negligible as the question was evidently very simple. In Question 2, students were asked to find the poles and zeros of a given transfer function. 88% students answered correctly before they started working on the lab and 92.3% students answered correctly after completing the lab. In Question 3, we asked students to find the impulse response for a given transfer function that is sum of two first-order all-pole filters, i.e., the composite system consists of two parallel systems. 76% students answered correctly before they attempted the JDSP Lab 2 assignment and 94.9% students answered correctly in the post-lab assignment. The percentage improvement is 18.9% and is noticeable. In Question 4, a sinusoidal impulse response of a system (i.e. a digital oscillator) is given and the students are asked to choose the true characteristics of the filter out of four choices. 17.5% more students answered correctly after using J-DSP. In Question 5, students are asked if it is possible to suppress completely a sinusoid of a certain frequency using an FIR or an IIR filter. We observed an 8.7% improvement in the post-lab assessment. In Question 6, students are asked about the structure of poles given the coefficients. For this question, only 1.8% improvement was observed. In summary, we observed a 10% average improvement in lab 1 after J-DSP was used.

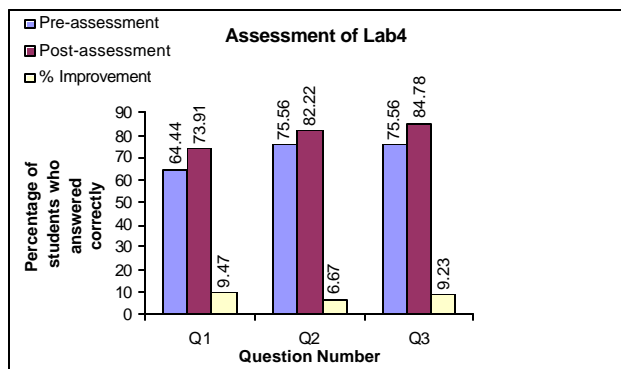
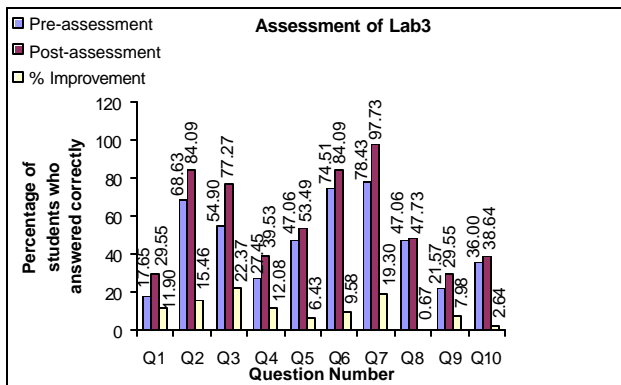
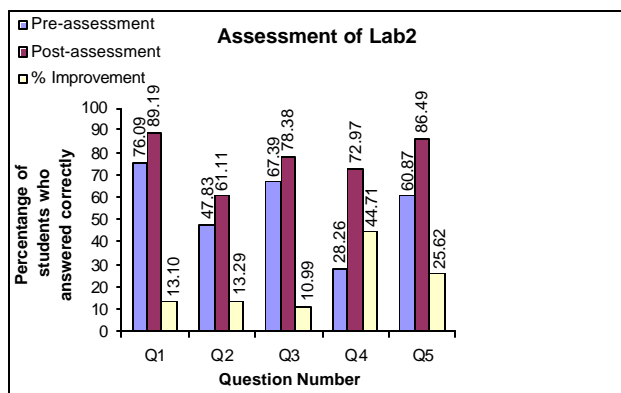
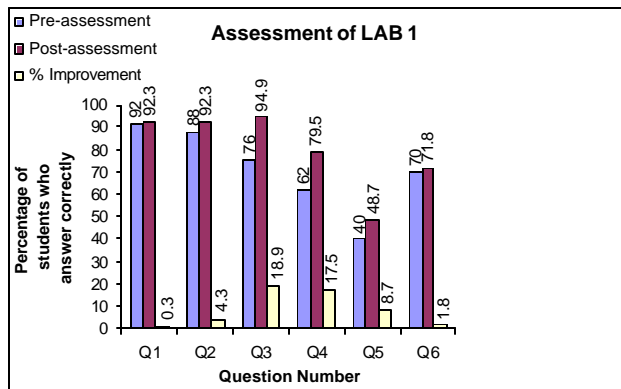


FIGURE 4
THE RESULTS OF LAB 1, 2, 3 AND4 ASSESSMENT

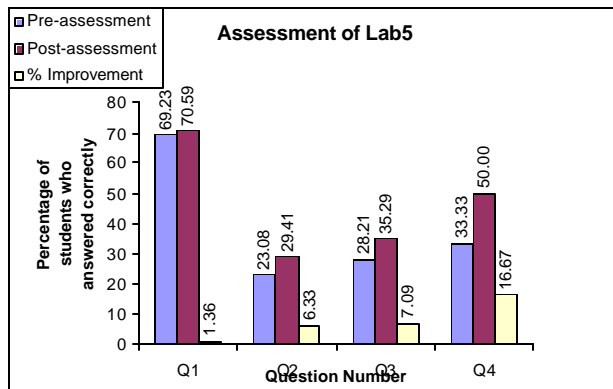


FIGURE 5
THE RESULTS OF LAB5 ASSESSMENT

Lab 2 assessment results

Again we observe in all the questions, students have performed better in the assessment after they have completed their J-DSP labs. Questions 1 and 2 assessed whether students can relate the pole and zero positions to the resulting magnitude frequency response. A 13.1% improvement was realized in question 1 and a 13.29% was realized in question 2 in the post lab assessment. In Question 3, two polynomial functions are given and students are asked if their magnitude responses are equal. A 10.99% improvement is noticed here. In Question 4, students are asked about the filter type (i.e. low-pass/high-pass etc.) of a given transfer function. We see that only 28.26% of students answered correctly in pre-lab assessment and it is indeed poor but the percentage has increased by 44.71% in the post-lab assessment. This is significant. In Question 5, students are given four choices regarding the change of magnitude response with displacement of the zeros with respect to the unit circle. A noticeable improvement of 25.62% in post-lab is evident.

Lab 3 assessment results

On the average around 11% improvement is evident in each question in the results of pre/post assessment of the lab 3 assignment regarding the design of FIR and IIR filters. In Question 1, the frequency response of an ideal low-pass filter is given and the students are asked to specify whether the filter is FIR or IIR and whether it is causal or non-causal. A 11.9% improvement of the student's performance is evident. Questions 2 and 3 are related to the characteristics of linear-phase FIR filters and 15.46% and 22.37% improvements are observed respectively. These improvements reveal that the lab clarified further the student understanding of linear phase filters. In Question 4, the students are asked to choose an optimal filter design method from four choices, namely, frequency sampling, Parks-McClellan, Kaiser window and Fourier series method. A 12.08% improvement is observed. Question 5 addressed the

reasons for which one may choose an FIR filter. Question 6 is set to assess the student's awareness on the constraints posed on the magnitude frequency response by certain linear-phase designs. In Question 7, four impulse responses are given to the students and are asked to choose those that have linear phase. A 19.30% improvement is observed here. Questions 8 and 9 are related to finding the group delay from the phase and impulse responses of FIR filters. Question 10 is set to assess whether students are aware of the fact that FIR design by frequency sampling of ideal frequency responses does not yield an ideal filter.

Lab 4 assessment results

Lab 4 is about the FFT. Question 1 is related to the symmetry properties of the DFT. The improvement observed is 9.47%. Question 2 is regarding the resolution of the DFT. Question 3 was about the mainlobe and sidelobe characteristics of the rectangular window. A 9.23% improvement is observed here. This was a relatively long laboratory exercise and our general impression was that the students were able to understand several concepts on the DFT that are not immediately evident from the lecture and the text book. The students gained valuable experience on spectral resolution and spectral leakage by viewing and interpreting spectra of several bench-mark signals.

Lab 5 assessment results

Lab 5 is on multi-rate signal processing and QMF banks. Figure 5 shows the assessment results of Lab 5. In Question 1, the students are asked to describe how spectral domain signatures are affected by down-sampling and up-sampling. Question 2 is about the use of a reconstruction filter for interpolation. Question 3 is related with the placement of a quantizer in a QMF bank. An average improvement of 8% is observed in this lab. This laboratory was also one that the students benefited from in that they gained hands-on experience on filter banks which are now common in MP3 players and MPEG video compressors.

GENERAL ASSESSMENT

In this assessment, students gave their general subjective opinions on JDSP and provided us with an idea as to whether the pertinent labs have been useful and helpful to them. In pre/post-lab assessment the questions posed were technical and are set to test the student's level of knowledge before and after performing the J-DSP lab. In the general assessment, the questions are less technical and are posed to get feedback from the students regarding the usefulness of the J-DSP software and associated exercises.

Overall, the responses were very promising. From Table 1 and Figure 6, we see that 95% of the users appreciated the various features of JDSP as an internet-based simulation tool. From Figure 6, it is clear that it took most (70%) of the users less than half an hour to learn using the software. In fact, 85.5% of the users agreed that they would consider

using J-DSP for DSP simulations. Lab specific general assessment was done on Labs 1 through 4 in the Fall 02 semester (the current semester is spring 2003).

From Table 2, we see that most of the students (above 90%) agreed that the J-DSP labs helped them understand the DSP related concepts. Also from Table 3, it is evident that more than 90% students are comfortable with the DSP related topics after completing the J-DSP labs. In the evaluation they were also asked if they received additional knowledge by performing the lab assignments in addition to the lectures. A few comments are presented to give a picture of student's impression. In Lab 1, some of them stated that the lab helped understand better the concept of cascaded and parallel configurations.

TABLE I
STATISTICS BASED ON USER EVALUATIONS OF J-DSP TOOL

Evaluation questions	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
Establishing and connecting blocks is easy.	53	39	7	1	0
The graphical interface of 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

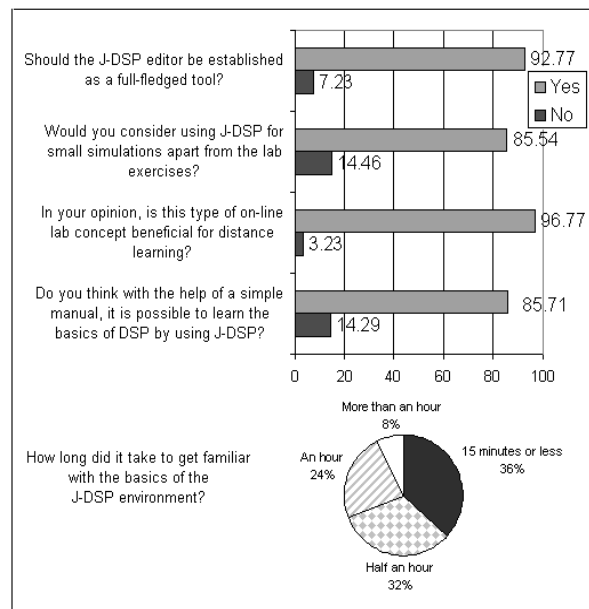


FIGURE 6
USER FEEDBACK REGARDING J-DSP EDITOR USED IN DSP LAB

Other comments included confirmations from students that J-DSP helped them understand better the issues related to filter design and the fact that pole and zero locations relate to the frequency response.

TABLE II
STATISTICS BASED ON USER EVALUATION OF LABS 1-4

Evaluation questions	Lab No.	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
Improvement of your understanding of the concepts of the Z-transform	1	50	46	3	1	0
Improvement of your understanding of the concepts of pole-zero plots and frequency response	2	47	44	7	1	1
Improvement of your understanding of the concepts of FIR and IIR filter design	3	42	47	8	3	0
Improvement of your understanding of the general concepts of using FFT in signal analysis.	4	24	61	13	2	0
You have learned how to generate a sinusoid with a digital filter	1	29	55	11	3	2
You have Learned which window to use for sharp transition in a filter from lab 4.	3	42	47	8	3	0
The exercise helped you to clearly visualize signal symmetries on the FFT spectra	4	18	65	9	6	2

TABLE III

STATISTICS BASED ON USER EVALUATION (YES/NO) OF LAB 1, 2, 3, AND 4

Evaluation questions	Lab No.	Yes (%)	No (%)
Understand more clearly the relationship of the impulse response with the transfer function	1	95	5
Understand more clearly that spectral resolution of the FFT is limited by frame size, window type and window size	4	99	1
Enough information in the help screen*	1	56	17
	2	53	17
	3	40	23
	4	47	13
Performing the exercises, you are now more comfortable with the topics related with each lab assignment	1	93	7
	2	94	6
	3	92	8
	4	90	10

* rest 27%, 30%, 37%, and 40% did not use help screen in Lab 1,2,3 and 4 respectively.

Students also recommended some of the changes in J-DSP on-line tools used in the lab simulations. One common suggestion is to accommodate the facility to save a workspace in J-DSP editor for the future use. This problem is now solved as in the new version of J-DSP there is a facility to import/export the work space as a script file. Also students reported several software bugs that have been fixed. We are especially appreciative of the ability to get immediate feedback from the students on the operation of the software.

CONCLUSIONS

Different types of assessment instruments have been prepared and disseminated to student users in the ASU EEE 407 class in the Fall 2002 and Spring 2003. Continuous feedback helped correct and improve the J-DSP software and exercises. The students in general found the J-DSP concept very convenient and easy to use. Concept specific assessments and pre/post assessment revealed that several J-DSP functions have been particularly useful in communicating key DSP concepts. J-DSP was proven to be particularly useful in learning issues related with filter design and interpretation of frequency spectra. The J-DSP visualizations involving pole-zero diagrams have shown prominent differences in pre- and post- assessments that lead us to believe that we need to integrate even more animation and develop demonstrations that are dynamic. In all, EEE 407 students asserted that they have benefited from J-DSP and they particularly appreciated the fact that the tool was available on the web from any location. Industry students taking the course from remote sites have been particularly impressed with the tools and exercises and some are using it for routine design and other compact DSP simulations. Here are few useful URLs that can be explored by the interested reader. For accessing all the lab assignments of DSP course use <http://www.eas.asu.edu/~eee407>. The J-DSP editor can be accessed at <http://jdsp.asu.edu>. The feedback from the users is also available by following the links on the J-DSP web site.

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