



E-Book on DSP Theory with Interactive iOS, Java, and Android Simulations

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Abstract

Internet and multimedia technologies have had a profound impact in STEM education in the past decade. The increase in the use of mobile devices among students adds another novel dimension to course design and delivery. Furthermore, the traditional textbooks are being replaced and supplemented by inexpensive and mobile e-books, and hence there is an opportunity to integrate the multimedia and mobile technologies in an e-learning environment. As a part of the NSF TUES phase 3 project for development and dissemination of the J-DSP software (Award no. 0817596), we are developing an e-book, with associated software and multimedia tools, for teaching signal processing to undergraduate students. The e-book covers DSP theory, problems and examples demonstrated using J-DSP, a freely available online DSP simulation environment. Each simulation in the e-book is hyperlinked to an interactive web page that uses Java software, videos and MATLAB scripts to deliver the technical content. Video demonstrations of simulations in performed in a computer as well as iOS and Android mobile devices are also provided. The proposed e-learning environment will be employed in Signals and Systems, and Digital Signal Processing courses at Arizona State University during the spring 2013. The proposed learning methodology will be assessed continuously throughout the semester with specially tailored assessment instruments. We believe that such an integrated, anytime-anywhere e-learning framework with rich multimedia content will be a convenient mobile platform that will lead to effective student learning.

Introduction

The widespread increase in internet and mobile technologies has the potential for a profound impact in STEM education. In the past decade, computers have been the major part of electronically supported learning and teaching, which is shortly referred to as e-learning. Currently, they are being rapidly supplemented by handheld mobile devices. The utility of computers in aiding formal instruction was recognized several decades ago and there was a

growing understanding that they can augment the role of learner, teacher, monitor, and learning materials¹. In the late 1990's Internet evolved as a major force in online and distance education, and web-based learning tools started to make an impact². Around the same time, we developed a Java applet, the J-DSP, which is an interactive web-based simulation tool for use in DSP and other related electrical engineering courses³. The software uses a block-based simulation environment that enables students to visualize web-based interactive demonstrations, perform simulations and computer laboratories from remote locations.

Recently, with the advancement of the Internet-II tools and the availability of mobile devices, there has been a renewed interest in using these technologies for formal as well as informal education. One of such efforts is propounded by the *Khan Academy*⁴, which has created a self-paced learning tool with a website containing videos and instruction materials catering to a wide audience and a variety of subjects. Another example, which corresponds to a more formal course delivery framework is *Coursera*⁵, where instructors from several institutions around the world conduct online courses where students can enroll, attend online classes, do homework assignments and take exams. Both of these provide education free of cost to the user and have been well-received. In addition, with the emergence of powerful video hosting and sharing sites such as You TubeTM, and social networking websites such as Facebook and Twitter, there is a possibility of enhancing technical content delivery and promoting discussions among the learning group. From the DSP education perspective, previously we created an integrated learning environment centered on the J-DSP software, which provided a way for the instructors to integrate J-DSP simulations, video lectures, quizzes, homework assignments, and tests⁶. One of the authors of this paper has also developed a textbook that combines J-DSP simulations with the traditional learning materials such as theory and problems⁷. Furthermore, we have recently developed two versions of the J-DSP software that can be used with iOS (iJDSP) and Android (AJDSP) mobile devices^{8,9}.

Given the large set of DSP education tools that we have made available, and the potential to introduce new tools in e-learning, we are currently developing an e-book that can be readily used with computers and mobile devices, along with a companion website¹⁰. The e-book contains chapters that are developed based on the DSP textbook written by one of the authors. It contains

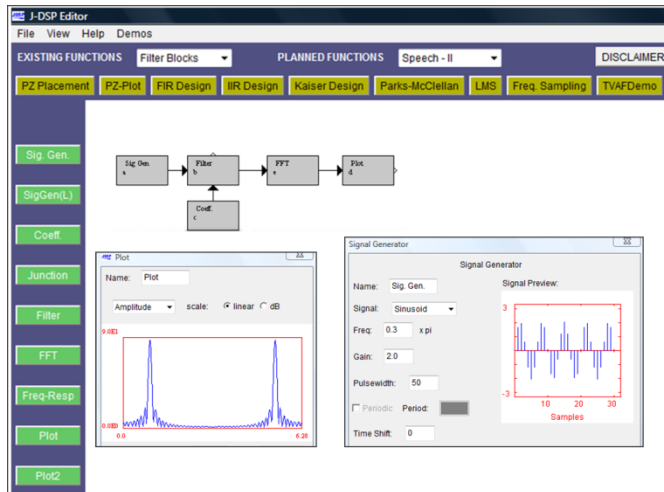


Figure 1: An example block diagram and plot in J-DSP.

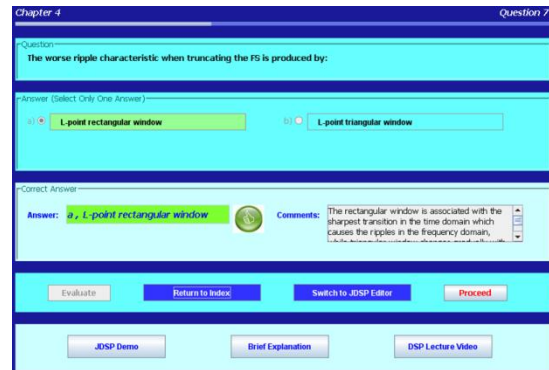


Figure 2: A Sample quiz question with links to J-DSP demos, explanation and lecture videos.

both theory and examples, along with simulations that can be performed using the Java-DSP software. Each Java-DSP simulation is hyperlinked to a corresponding page in the companion website. The website contains block diagrams, scripts that can be used to execute the example in Java-DSP and MATLAB, along with videos of simulations created in Java-DSP, the award winning iJDSP¹¹ and AJDSP. The e-book along with the website forms a comprehensive e-learning environment that includes online labs, animations, and video clips on various DSP concepts. Preliminary assessments for teaching DSP concepts using iJDSP show a significant improvement in student understanding. We plan to develop specialized assessment instruments to gauge the impact of the proposed e-learning platform and perform assessments during the spring and the fall 2013 semesters in the senior-level DSP class and the sophomore level Signals and Systems class at Arizona State University (ASU). In the future, we plan to integrate the developed assessments as a part of the e-learning interface and provide ways to encourage self-learning and self-evaluation among the students.

Existing DSP Education Resources

We will describe in detail the existing computer and mobile DSP education resources that will form a part of the e-book and the proposed learning environment.

The J-DSP Simulation Environment

J-DSP, a web-based DSP education software, is a block-based environment where simulations are established by choosing blocks through a *drag-n-drop* process and connecting them to establish signal flow. Any change in the simulation parameters are automatically reflected in the following blocks. An example simulation established in the J-DSP interface along with visualization of the output is shown in Figure 1. A set of DSP laboratories have been developed in J-DSP that cover several DSP concepts including the z -transform, digital filter design, spectral analysis, multirate signal processing, and statistical signal processing along with a rich set of visualization functions. In addition, there are multidisciplinary toolboxes available for image processing, control functions, time-frequency signal processing, communications and Earth systems signal processing. DSP has been perceived traditionally as a hard subject for an average Electrical engineering student because of its mathematical rigor. J-DSP has attempted to change this perception by giving the students a hands-on learning experience and allowing them to explore concepts on their own without having to do any text-based programming. J-DSP has its native script which can be used to import and export simulations. Furthermore these scripts can be embedded in HTML pages which can be used by instructors to build interactive demonstrations. Apart from this, J-DSP simulations can be exported as MATLAB code and LabVIEW mathscript code that can be used to extend the simulations in other programming environments. In order to further help in course delivery, an integrated learning interface has been built using J-DSP, which consists of a web-based quiz with links to simulations, lecture notes, and videos⁶. It also allows the instructors to customize the quiz questions, and include additional learning materials. A sample quiz question is shown Figure 2.

Mobile DSP Learning Environments

Mobile devices are pervasive and interactive and hence they can be used effectively by the instructors to stimulate student interest. Investigation of the advantages of using handheld devices over personal computers in K-12 education has been performed, and it has been concluded that they result in an increase in student interest because of their easy accessibility and

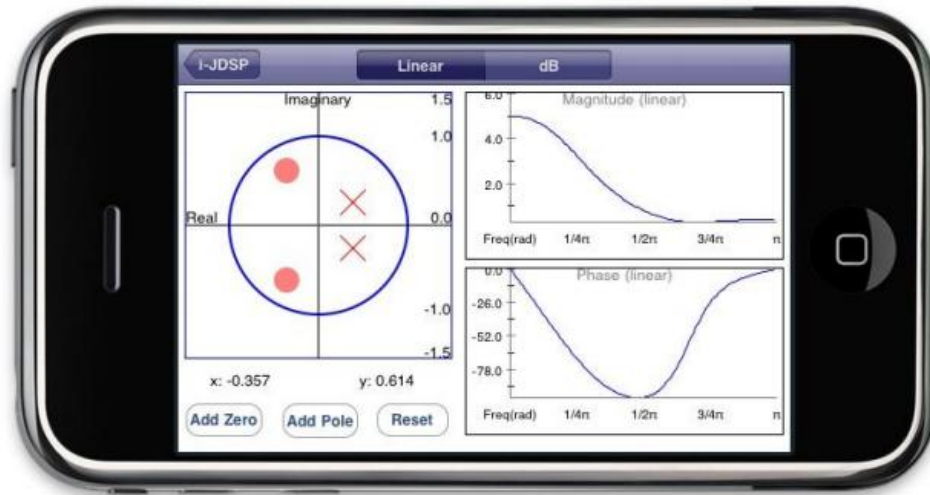


Figure 3: An example iJDSP plot demonstrating the relationship between pole-zero plots and frequency response.

maneuverability¹². In order to exploit the high potential of mobile devices in STEM education and create a compelling anywhere/anytime student learning environment, we have developed the iJDSP and the AJDSP which are the versions of J-DSP for iOS and Android devices. Both these versions have been inspired by the J-DSP, but the architecture and the functions have been re-programmed completely.

The core idea behind iJDSP and AJDSP is the idea of using smartphones as: a) calculators to solve signal analysis exercises, b) instruments to perform labs, and c) as dashboards to display/plot data and parameters. The i-JDSP has been developed using the Xcode IDE provided by Apple and the AJDSP has been programmed in the Android SDK, a Java based open source programming platform. Similar to J-DSP, the functions in iJDSP and AJDSP are available as graphical blocks that can be added to the main simulation view. They have been designed to provide maximum simulation space with minimum navigation. Both the versions support all basic signal processing functions in an intuitive touch-based programming environment. The iJDSP application is available on the iTunes store for free download¹³ and an example simulation view of the iJDSP is shown in Figure 3. Assessments conducted with the iJDSP showed that the students were able to understand complex DSP concepts well using iJDSP simulations and they became familiar with using the interface in a few minutes. The AJDSP is in the beta testing phase and extensive assessments have been planned. It will be made available soon in the Android marketplace.

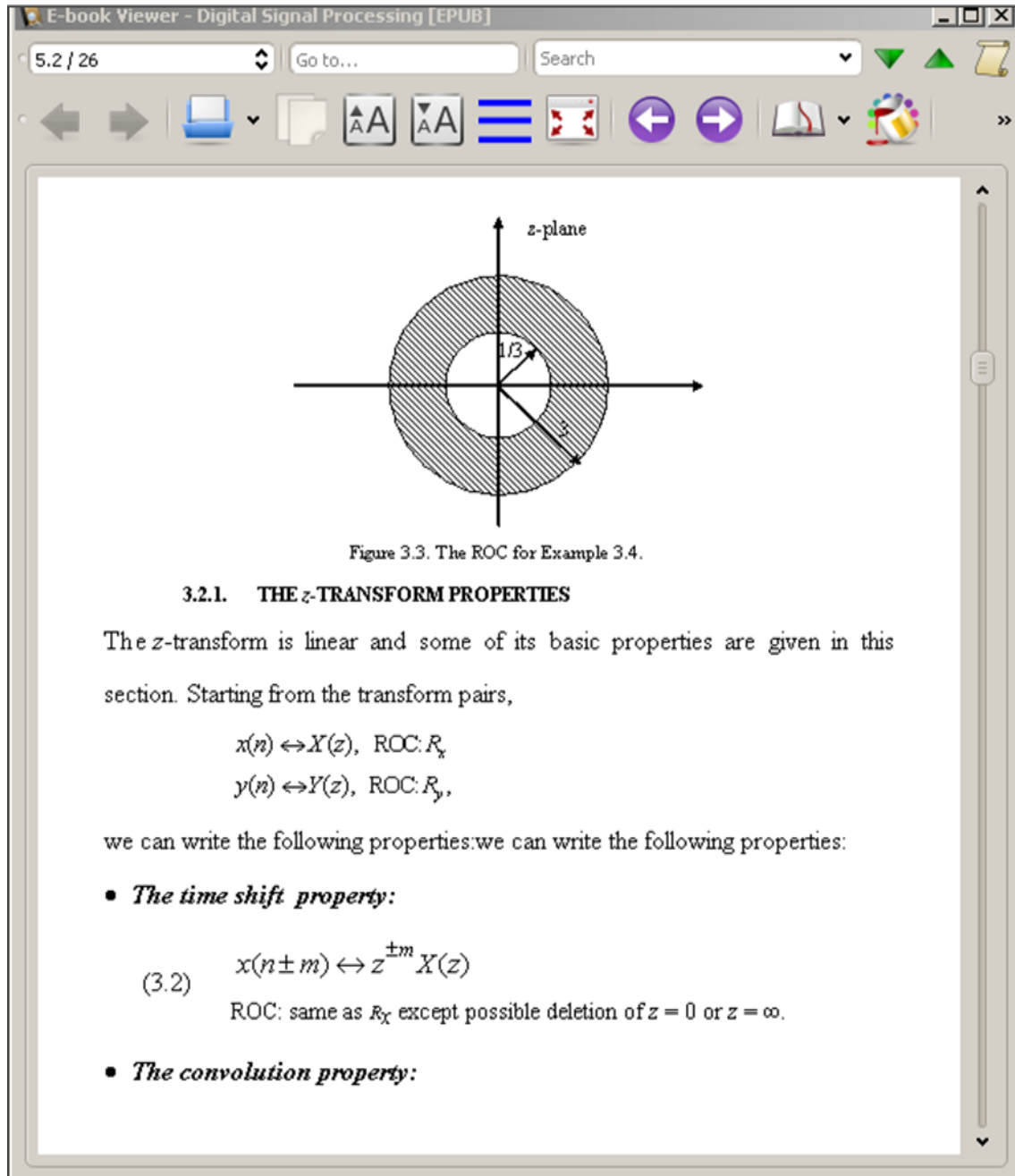


Figure 4: An example page from the e-book. The e-book page will have active visualization links to demonstrate the properties listed on the page.

E-Book and Internet Technologies for DSP Learning

The existing DSP education tools are integrated using an e-book that we have developed along with a companion website.

The e-Book

The e-book is based out of the J-DSP book written by the author. The broad topics covered in the first version of the e-book will include introduction to continuous and discrete-time signals, convolution, Fourier transforms, z-transforms, poles and zeros, windowing, fast Fourier transforms, and filter design. The e-book is created in the free and open EPUB format that can be used in a variety of mobile devices as well as in the personal computers¹⁴. In contrast to the PDF format which is a universal book format for computers, the EPUB format is easily adaptable to several types of mobile devices in terms of wrapping text and equations, being more closely related to the HTML format. The J-DSP e-book was created using the *Calibre ebook management* software¹⁵, which is compatible with Windows, Linux or MAC machines. An


JDSP SIMULATION EXAMPLES

Click on each Chapter to view the J-DSP examples

Learn about DSP algorithms and software

By using the interactive J-DSP software you can explore the concepts of digital signal processing in a more intuitive way. The software is designed to be user-friendly and easy to use. It includes a comprehensive set of examples and simulations that cover the most important topics in DSP. The software is available for free download and can be used on any computer with a web browser.

- Interactive simulation of the discrete-time Fourier transform (DTFT)
- Interactive simulation of the discrete-time Fourier series (DTFS)
- Interactive simulation of the discrete-time Fourier transform (DTFT) and the discrete-time Fourier series (DTFS)
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Chapter 1: Review of Continuous-Time Signals and Systems

Chapter 2: Basics of Discrete-Time Signals and Systems

Chapter 3: The z-Transform

Chapter 4: FIR Filter Design

Chapter 5: IIR Filter Design

Chapter 6: Multirate Signal Processing

Chapter 7: The Discrete and the Fast Fourier Transforms

Chapter 8: Discrete-Time Random Signals

Chapter 9: Adaptive Filtering

Chapter 10: Speech Processing Algorithms

Chapter 11: The MPEG-1 Layer III (MP3) Algorithm

Figure 5: Home page of the companion website¹⁰.

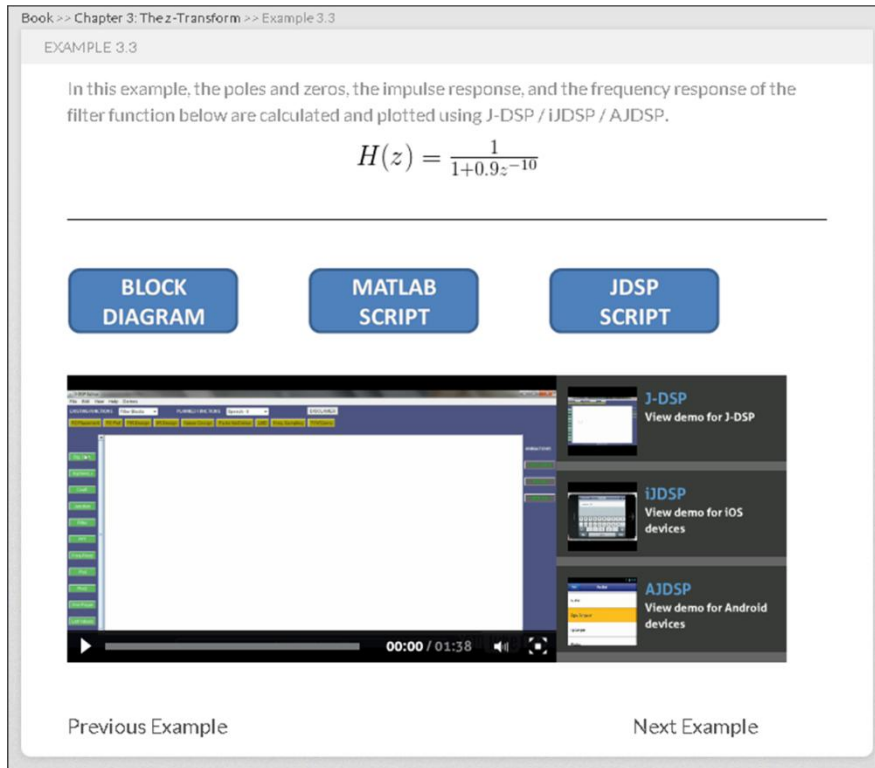


Figure 6: The webpage corresponding to a typical example.

example page of the e-book is shown in Figure 4. The J-DSP simulations in the e-book are linked to examples in the companion website, where block diagrams, videos, demonstrations, and MATLAB scripts are available. The e-book was created by first converting the content in Microsoft Word format to HTML and using the *Calibre* software to convert the HTML to EPUB format. The conversion is seamless for the most part except some tweaks that need to be made to make the headings and equations appear properly. Since the process is simple, any existing content in HTML or MS Word format can be readily converted into a flexible e-book format.

Website Accompanying the e-Book

An extensive website has been created corresponding to example in the e-book, and linked from it. The home page of the webpage which has links to simulations in each chapter is given in

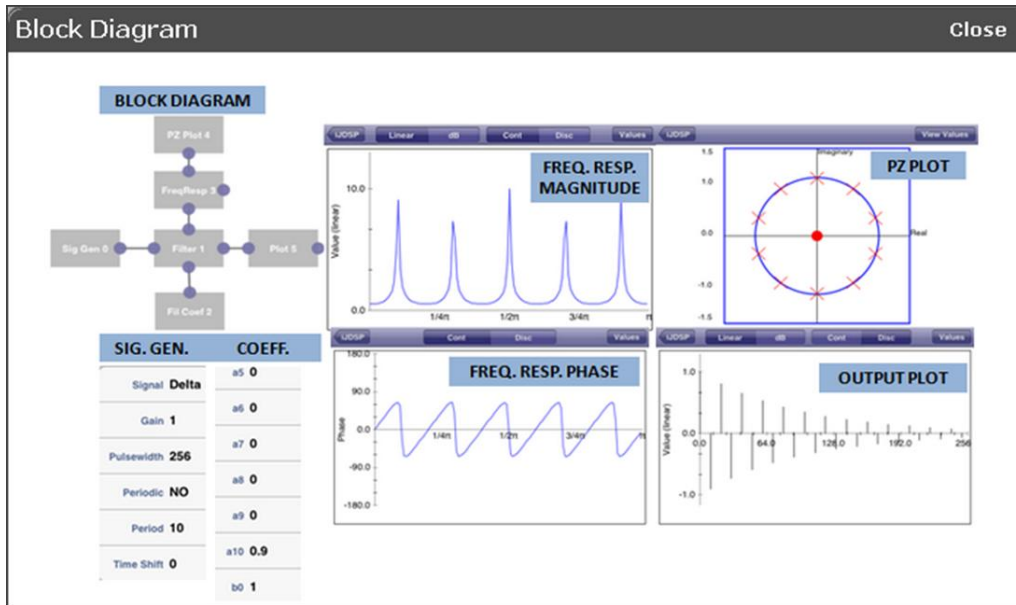
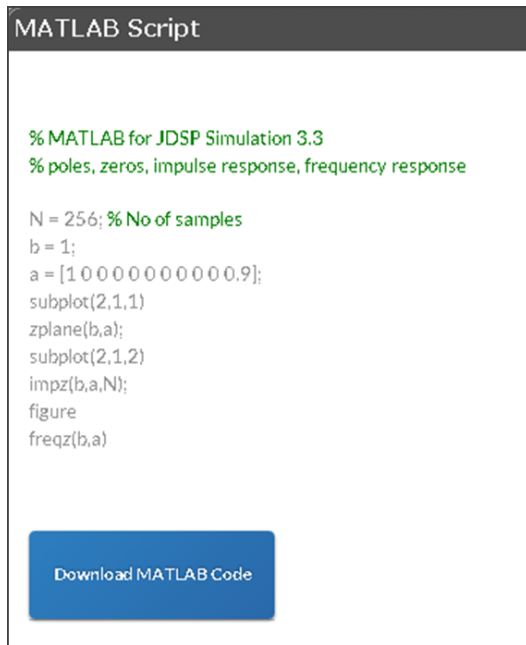


Figure 7: The block diagram displayed for the simulation.

Figure 5. The webpage corresponding to a typical example is shown in Figure 6. Each page follows a standard template as shown with the problem statement in the top, links for block diagram, MATLAB script and J-DSP script in the middle, and videos in the bottom. The topmost portion contains “breadcrumbs” – which is the navigation sequence that helps the user trace back to the website’s home page or to other chapters. Users can also quickly navigate to previous or next examples using links in the bottom. The *Block Diagram* button opens the complete iJDSP simulation diagram along with results as shown in Figure 7 that the users can replicate in their mobile device. The *MATLAB Script* button opens a popup window, similar to the one displayed in Figure 8 where the MATLAB script corresponding to the simulation is displayed and can also be downloaded. The J-DSP script can be downloaded and executed by clicking the *JDSP Script* button, which opens a popup as shown in Figure 9. When the *Execute J-DSP Example* Button is clicked, it opens a HTML page and the embedded J-DSP script is executed. The script functionality provides the user the capability to modify and extend the simulation in J-DSP or MATLAB. The videos embedded in the page correspond to the simulation examples as executed in J-DSP, iJDSP and AJDSP. When used in a mobile device, the J-DSP scripts cannot be executed since most mobile devices do not support Java applets, but still the users can get a good



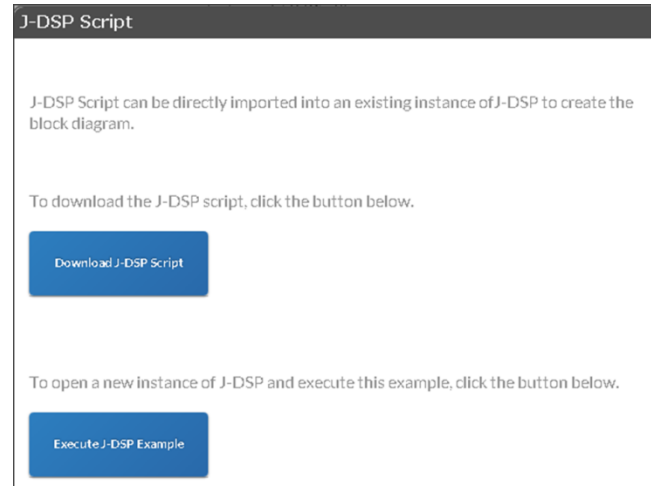
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MATLAB Script

% MATLAB for JDSP Simulation 3.3
% poles, zeros, impulse response, frequency response

N = 256; % No of samples
b = 1;
a = [1 0 0 0 0 0 0 0 0 0 0.9];
subplot(2,1,1)
zplane(b,a);
subplot(2,1,2)
impz(b,a,N);
figure
freqz(b,a)
```

Download MATLAB Code

Figure 8: MATLAB script displayed with a download link.



J-DSP Script

J-DSP Script can be directly imported into an existing instance of J-DSP to create the block diagram.

To download the J-DSP script, click the button below.

Download J-DSP Script

To open a new instance of J-DSP and execute this example, click the button below.

Execute J-DSP Example

Figure 9: J-DSP script that can be downloaded and executed as a demonstration.

learning experience by playing the videos which have recorded the demonstrations. The website has been designed such that it can render well in all mobile devices.

Assessments

Both the J-DSP and iJDSP software have been assessed extensively. As an example, we will present results from an assessment conducted using the iJDSP software in an undergraduate DSP course at ASU. The evaluation session consisted of administration of a pre-questionnaire followed by a lecture, and an iJDSP demonstration. The students then performed hands-on exercises and answered a post-questionnaire. In addition to the technical assessments, general assessments on the learning experience, and student comments were also collected. As it can be seen from Figure 10, in every exercise the student understanding improved on using iJDSP. Pictures of students using the iJDSP software in the DSP classroom are shown in Figure 11. We will create specialized assessments using the e-book and administer in the spring 2013 DSP class. The detailed assessments and results will be presented at the conference. In the future, we will integrate the automated assessment interface in the learning environment, so that this can be used for effective learning.

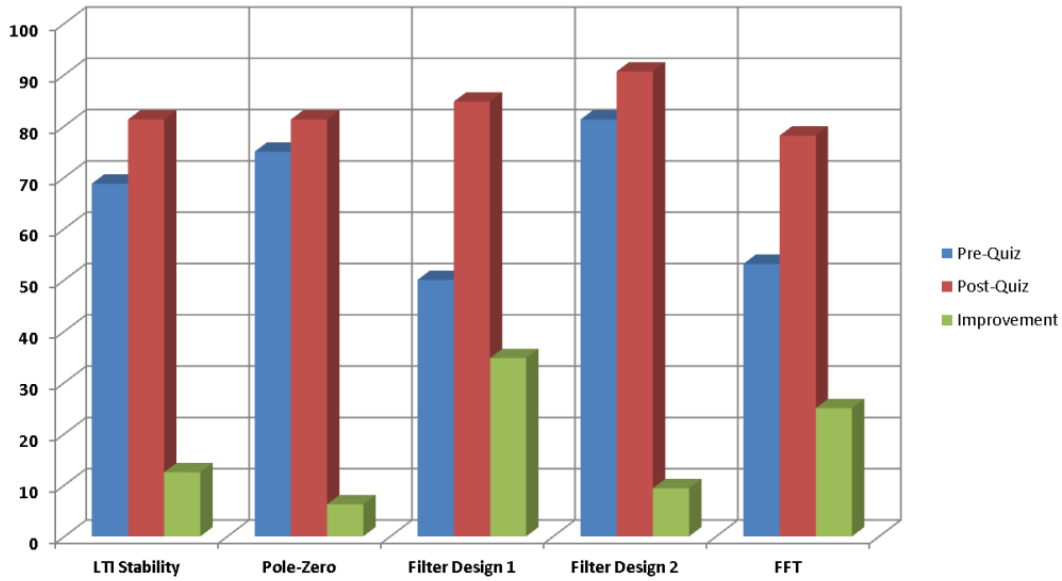


Figure 10: Technical assessment results with iJDSP software.



Figure 11: Students using the iJDSP software in the DSP classroom.

Summary

We presented details on the e-book that we are developing in order to facilitate teaching of signal processing concepts to undergraduate students. The e-book contains DSP theory as well as problems and examples that are demonstrated using J-DSP. The proposed e-book has an associated website which contains interactive technical content presented using Java software, videos and MATLAB scripts. We believe that the proposed e-learning environment will be an important step towards a fully virtual classroom setup, where the students will be guided by a remote instructor and they will be able to undertake a self-paced study.

Acknowledgment

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