AC 2008-1693: APPLYING AN INTERACTIVE, MODULAR APPROACH TO EFFECTIVELY TEACH SIGNAL PROCESSING CONCEPTS

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Applying an Interactive, Modular Approach to Effectively Teach Signal Processing Concepts

Abstract

Working with computer-based tools such as LabVIEW[1] and Camtasia[2], educators can easily create interactive simulations, screencasts, and other types of multimedia that augment learning with content that is interactive, engaging, and readily available. Lectures, in-class demos, and laboratory projects for the Rose-Hulman ECE481 music synthesis and audio signal processing course, have been deployed as a set of learning modules hosted on Connexions (http://www.cnx.org), encouraging free distribution, customization, and localization of the content. The course materials include "screencasts" – narrated videos of computer screen activity. The screencasts embody the theoretical exposition with handwriting, diagrams, and animations drawn on a tablet device, and also demonstrate LabVIEW programming techniques to implement the concepts. In addition, downloadable LabVIEW simulations (VIs) offer students interactive tutorials that reinforce the discussed theory. The modular nature of the learning materials and its open availability on Connexions supports faculty who wish to augment an existing DSP course with selected topics and projects, as well as faculty who wish to create a new course similar to ECE481.

Introduction

This paper relates our application of screencasts, interactive LabVIEW Virtual Instruments (VIs), and Connexions-based deployment for these learning modules. As we define these elements and examine how they can augment the learning experience, we also discuss some guidelines / "best practices" related to optimizing production, development and deployment. Considerations range from module style, content organization, and method of delivery to how to effectively develop screencasts and interactive VIs. A companion paper[3], examines the course content, focusing on the subject material.

Content of a Typical Module

This project involved creating over 50 learning modules as part of an online course, "Musical Signal Processing with LabVIEW."[4] The modules address topics and projects from Rose Hulman ECE481, an elective music synthesis and audio signal processing course.

Modules consist of several different types of content. Some components are analogous to what you might find in a textbook or a lab manual. Such material includes text, equations, figures, example problems / solutions, and step-by-step project instructions. Other module components, including screencast videos and downloadable LabVIEW VIs, are more dynamic, intended to engage the student with video presentations and interactive exploration of concepts. Figure 1 shows a typical module from this course, "Additive Synthesis Techniques."[5]

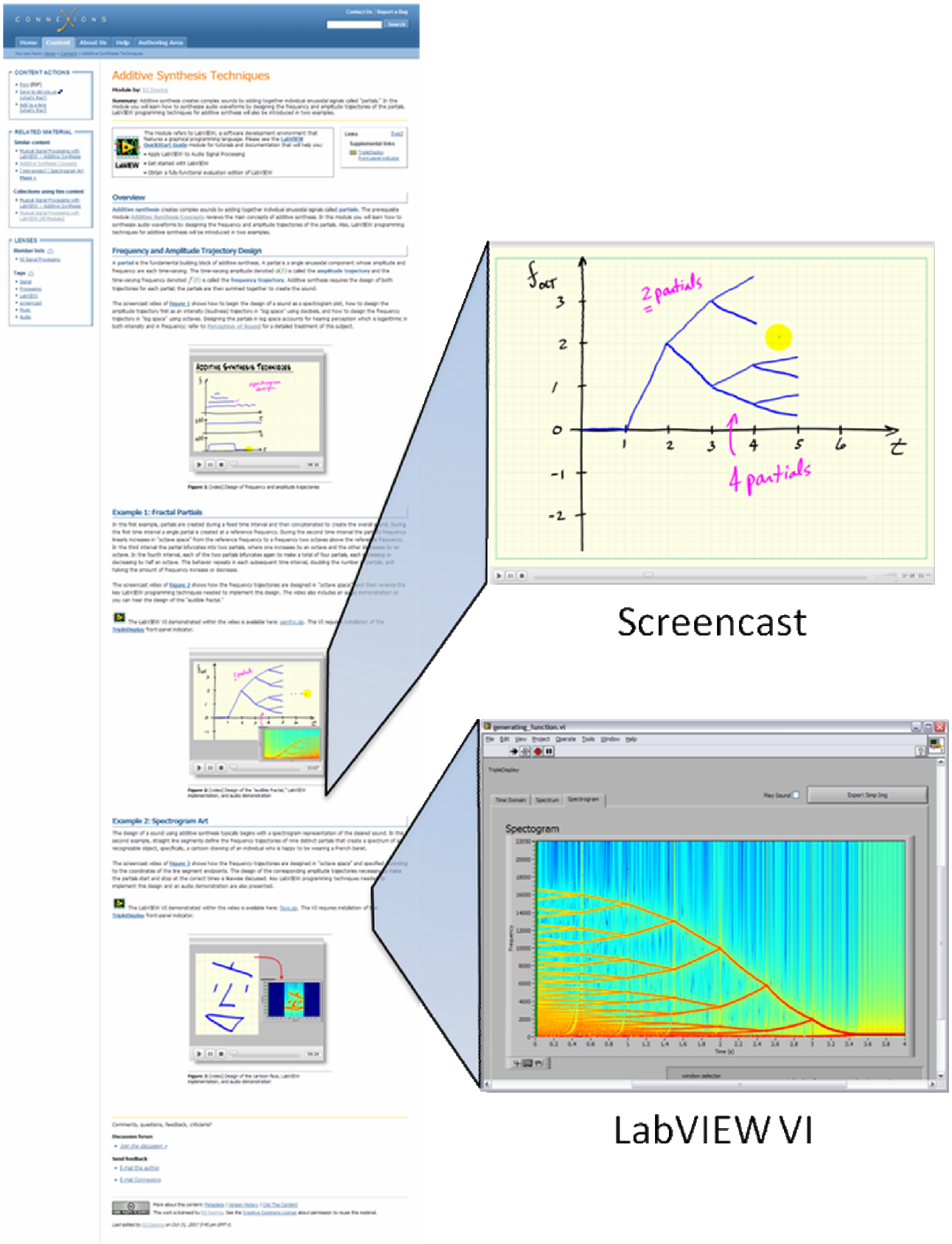

Figure 1, Screencasts and downloadable VIs are key elements of the "Additive Synthesis Techniques" learning module (left) and others that comprise the "Musical Signal Processing with LabVIEW" course.

Engaging Students with Screencasting

Screencast videos ("Screencasts") play a central role the modules created for this project. Screencasts are narrated video presentations that can be thought of as a multi-frame screen capture of on-screen computer activity and audio. A screencast can consist of multiple segments that can include animation, mouse interaction with software, annotation, and static slides. What's more, screencasts can record handwriting, diagrams, equations and other familiar elements to produce a whiteboard-like lecture experience.

There are a variety of applications for screencasts. In addition to training and educational applications, screencasts find use in software demonstrations, software usability testing, business presentations, and others.[6]

For students, the screencast format offers an engaging and accessible presentation that can dynamically present information. Completed screencasts can be added to web pages and streamed over the Internet for independent presentation through a standard browser. The ability to pause, rewind and play back allows students to watch the content at their own pace in a familiar browser hosted, YouTube-style interface. You essentially supply an infinitely patient instructor willing to explain a topic as often as necessary.

Screencasts offer educators a flexible multimedia format that doesn't require a lot of production overhead. Screencasting software such as Techsmith Camtasia Studio empowers the individual to record and produce screencasts on a standard desktop or laptop PC. This enables low-overhead development without the burden of a studio or elaborate camera setup—you can create your own "mobile recording studio" with only a quiet room, a microphone and a laptop computer.

Applying Screencasts

For the Musical Signal Processing with LabVIEW course, over 100 screencasts were created. These screencasts are distributed throughout the learning modules, embedded within them in a style that resembles a figure from a textbook. We chose to link to screencasts through figures that show a media-player style border displaying video duration surrounding a choice screen shot from within the video (Figure 2). This allows students to intuitively navigate the module differentiating between figures and screencasts.

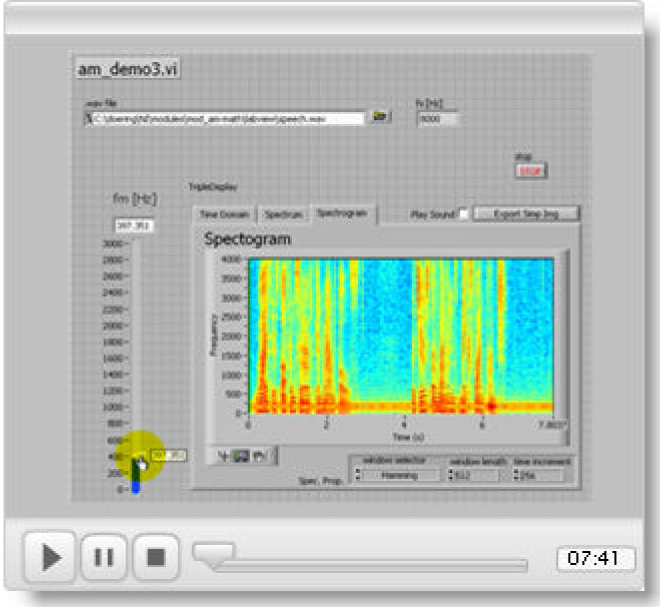

Figure 2, Screencasts are displayed in Connexions as figures with a media-player style border and an indication of duration.

The course employs screencasts to present theory and concepts related to music synthesis, signal processing fundamentals, and other topic-specific information. Additional screencasts show "Getting started with LabVIEW" content focused on introducing what's necessary to complete the course mini projects.

The basis for much of the content came from experience in teaching the class, including lesson plans, classroom notes, and lab projects. This type of material and experience is useful when planning the content for a screencast or a learning module.

Teaching experience and an understanding of the expected audience also help. For instance, the expected attention span of your audience is a consideration related to deciding the appropriate length of the modules and screencasts. For this project, the screencasts have an average duration of about 10 to 12 minutes. Preliminary analysis shows an average view time of 4-5 minutes per module.

Production time is a concern related to how to divide up the content within a screencast. As mentioned above, a single screencast might include multiple segments such as handwriting, software interaction and slides. Preparing a screencast with such segments requires recording the segments separately and later splicing them together to create the final screencast. Extra production time is required to perform the post-recording work of splicing the segments together, adding transitions, etc.

Audio narration is a key element of a screencast. In developing this material, we realized that the lack of the give-and-take interaction of a classroom plays a role, imparting the need for especially clear explanations. To this end, we found that it is useful to record the screen capture / visual portion of the screencast separately from and prior to recording the audio. Doing so allows you to focus first on the visual portion / interactions with the PC and later come back as an audio commentator for the visual portion of the project.

The Virtual Instrument approach to Demonstrations, Simulations, and Student Projects

Included LabVIEW-based simulations and student projects also seek to engage learners, this time through interactivity and intuitive graphical programming. Originally introduced in 1986, LabVIEW is a cross-platform software development environment used by scientists and engineers for instrument control, data acquisition, signal processing, control design / simulation, automation, and a variety of other technical computing applications. Some of the primary reasons that LabVIEW is well suited to signal processing education include built-in signal processing functionality, the intuitive syntax and flexibility of the LabVIEW graphical language, and the ability to rapidly create interactive user interfaces.

For functionality, the latest release of LabVIEW includes over 700 functions dedicated to signal processing, analysis and mathematics. Although LabVIEW is well known for its graphical dataflow programming language G, it has evolved to a software platform in which multiple programming approaches can be selected from and applied side-by-side. To this end, LabVIEW includes a textual programming component for signal processing, analysis, and math. This component, MathScript, can be integrated with graphical programming or through a command-line interface.

Another component that makes LabVIEW useful for signal processing education is the ability to rapidly create interactive user interfaces. User interface implementation is a straightforward, integral part of the LabVIEW graphical programming approach. This capability allows educators and students to “instrument their algorithms” with user interface elements for input and display of algorithm parameters, data, signals. Students can gain intuitive understanding of signal processing concepts and algorithm by changing settings and seeing the output signals and additional results through graphs, numerical displays, and other types of display indicators.

The learning modules for this project deploy LabVIEW in several ways. Many modules include downloadable VIs that students can execute locally on a desktop PC or Laptop running the LabVIEW environment. In this context, VIs enable interactive exploration of signal processing concepts discussed in the associated module.

As an example, the Additive Synthesis Techniques module includes a VI that synthesizes a signal by summing partials (sinusoidal waveforms with varying amplitude and frequency) created for a series of time intervals. The VI generates the complete waveform by iterating to create multiple intervals, with successive intervals containing partials with frequencies that are bifurcations in octave space of the partials in the previous interval. Students can modify input parameters on the VI front panel such as the interval duration, number of intervals, and reference frequency. As they do so, they benefit from both audio and visual feedback as the VI synthesizes the signal, outputting it through the PC sound card and presenting it graphically on time-domain, frequency-domain and time-frequency domain plots.

A second application of LabVIEW as part of this learning module set is for development of mini-projects. Mini-project modules guide students through the steps to implement signal processing algorithms using LabVIEW-based graphical and textual programming. For example, the Risset

Bell Synthesis mini-project guides a student through building a VI to implement a waveform synthesis algorithm that generates the sound of a bell ring.

A final application of LabVIEW in this learning module set is related to providing students the background necessary to complete the mini projects. To prepare students for these projects, the course includes modules that teach LabVIEW programming fundamentals.

Course Delivery through Connexions

The Internet gives us the mechanism to disseminate our work to an incredibly broad audience. However, simply posting content does not guarantee that an audience will even find it, let alone learn from it. In order to successfully reach an audience, the content needs to be organized for easy searching, browsing and reuse internationally.

To meet these needs and other requirements, we deployed our work on Connexions, a non-profit, web-based collaborative environment for developing, publishing, and sharing scholarly content. The Connexions Content Commons (http://cnx.org/content/) contains educational materials for all ages and disciplines. Content published on Connexions is available free to any user with a web browser and has copyright protection under the Creative Commons "attribution" license.[7] What's more, Connexions has both academic and industrial credibility through affiliation with Rice University, IEEE [8], National Instruments[9], and others.

Student Navigation

Connexions offers on a organizational framework for hosted content that consists of modules that can be linked together to form course collections. Students can access the modules in a linear approach, navigating from module-to-module following an order specified by the content creator. For the Musical Signal Processing with LabVIEW course, a student can begin at the beginning of the course collection found at http://cnx.org/content/col10507.

Students can also access content in a less linear way through Google and other search engines. As such, we considered how to improve the content ranking in search results. The inter-linked nature of the organization and inclusion of specific key terms in the text are elements that we expect contribute to good search result ranking. For instance, a Google search for 'Virtual Music Instrument' or 'Ring Modulation' will typically find Musical Signal Processing with LabVIEW modules in Connexions on the first page of search results.

Tracking Usage

To gauge the popularity and usage of the course content, we relied on web analytics tools available through Connexions and Google Analytics. Currently, Connexions can report basic web traffic information on a per-module basis. Information includes a count of the views over the previous week and from the module posting date. Google Analytics provides additional information including site traffic, view time, and location of the user (Figure 3). As an example, for the week of 1/7/08 to 1/14/08, these tools reported 1745 module views, 155 screencast views and an average screencast viewing time of about 4.5 minutes.

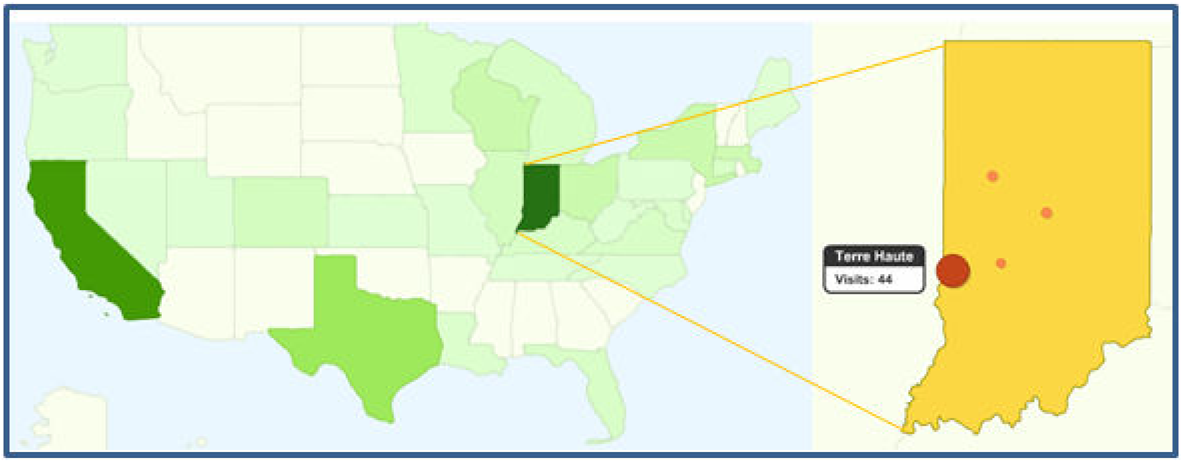

Figure 3, Google analytics location results for the week of 1/7/08 to 1/14/08

Conclusions

Modern computer-based tools give educators the ability to easily create dynamic, engaging educational content that can augment the student learning experience. To develop and deploy online content to teach signal processing fundamentals, we engaged screencasts, virtual instrumentation, and a modular, online delivery approach.

The course content exists as a set of interlinked modules that are freely available online through Connexions. Connexions allows content to be generated, compiled, and shared in an open source manner to foster reuse and to reach a worldwide audience.

Virtual instruments and screencasts and are embedded throughout the course modules. Virtual instruments engage students by allowing them to interact with theoretical concepts. Screencasts engage students with a whiteboard-like presentation experience. The format allows educators to create high-quality multimedia content without the burden of expensive equipment and other production overhead.

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