eDSP – A DSP-CENTRIC REUSALBE LEARNING OJBECT ENVIRONMENT

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ABSTRACT

The University of Florida (UF) offers a traditional curriculum having a strong signal processing presence. What is being observed is that the digital signal processing (DSP) students continue to study the same basic core material, but at different levels of the curriculum. What differentiates the treatment of material at one level from another is :

- *the order of presentation,*
- *level of mathematical challenge and rigor,*
- *amount of supplemental material added, and*
- *level of technology exposure.*

The University of Florida is exploring the use of reusable learning objects (RLO), objects that can be aggregated to build multiple lessons. Instead of designing complete courses, curriculum designers can use RLOs to configure content for general or course specific use over a range of curriculum levels. In this paper, the preliminary experience gained by using this new paradigm is reported. The outcome is called ***eDSP****, a concept that supportsa multi-level broad signal processing curriculum as well as define the next generation of academic ebooks*[1]*.*

1. INTRODUCTION

DSP is a relatively young academic discipline that is well established at the graduate level with a growing undergraduate presence. In fulfilling its mission to prepare young scholars for DSP leadership roles, one must be mindful of a caveat raised by the National Academy of Engineering (NEA). The NEA charged academia to change its emphasis from "knowing about" to "knowing how" [1]. This charge was made with the knowledge that most engineering academic programs are strongly influenced by existing graduate courses and faculty research interests. The result of extrapolating a DSP graduate model into undergraduate programs often led to pedagogical chaos. In addition, studies at the Universities of Colorado and Washington have found that engineering majors increasingly lack an *a-priori* understanding of what the engineer does or how they do what they do [2]. While today's students are eminently familiar with technology as end-users, they are less familiar with its inner workings than were previous generations. Today's student may have technology at their fingertips, but their predecessors had technology under their fingernails. These, and other problems, present a challenge to the DSP educators and content builders. One of the current barriers curriculum and content delivery innovation is found in the form of the traditional college engineering textbook. Overcoming this specific barrier is the mission og eDSP project.

UF's undergraduate DSP-track consists of a sophomore /junior discrete-time signals and systems (EEL3135) and a senior-level DSP technology driven (EEL 4750) course. At the graduate level there is an entry level (EEL5701) Foundations of DSP course as well as a host of specialized offerings in digital filter design, multirate systems, spectral analysis, adaptive filters, speech, image processing, and others. An assessment of the core courses would lead one to conclude that at the core, they are all topically similar (*e.g*., *z*-transform). This conjecture can be supported by comparing course curricula, and DSP textbook table of contents.

2. eBOOKs

The authors claim that today's textbooks and ebooks are two-dimensional entities (see Figure 1). The 1st dimension defines the *content domain* which is filled with material created for a specific grade level by the content author. Currently textbooks and ebooks classically aggregate this information into macro units (Chapters). The 2nd dimension defines the *referential domain* which, for books is the topical index and table of contents. To this mix, ebooks add pop-up help screens and hyperlinks. Though these are all valuable attributes, something very important has been overlooked. The material found in the content and referential domains are written for a fixed curriculum level chosen by the author. As such, the author's choices and text can often miss the mark because:

- Students have differing learner-centered needs and backgrounds that vary on a per course basis. Some require a remedial or entry entry-level exposure, some advanced, some theoretically motivated, others more technology oriented.

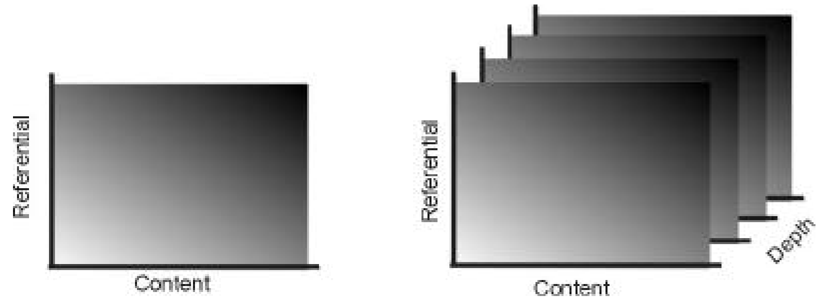

Figure 1: Traditional books/ebooks vs. eDSP

- Local curriculum and instructor needs dictate the depth and breadth of understanding that is expected for each course. Some curricula and instructor requirements are based on surveys, others focus only on mastering core material, and still others stress detailed mathematical and/or technological skill development, still others focus on case studies.
- Instructors use the textbooks and ebooks differently. Some view the content as the primary learning tool, to others it is supplementary or referential material.

A recent innovation in this area is emerging from the The Connexions Project from Rice University [3]. The project champions the use of Open Content Licensing which is claimed to lower the barrier to the re-use of academic intellectual property. While encouraging authoring and its use, the Project content remains 2-D, rather that 3-D as advocated by eDSP.

3. eDSP

The eDSP approach to content delivery is based on a RIO model. The eDSP pedagogical and logistical requirements are assumed to vary from student by student, class by class, institution by instruction, and instructor by instructor. Since textbooks and ebooks invariably present the material at curriculum one level, they are intrinsically 2-D entities. Adding a third dimension to academic content is the eDSP innovation. It is claimed that this is important because eDSP both enables and encourages:

- selected depth of coverage based on local needs, experiences, and academic objectives,
- continuity of studies across curriculum where similar courses share common core material, but at differing course-specific depths,
- robust use content in both on-campus and Internet delivered off-campus studies, and
- easy assimilation of eDSP content into other courses serving other allied disciplines.

This can be achieved, in part, by embedding by employing the eDSP paradigm based on a RLO environment.

4. REUSABLE LEARNING OBJECTS\

Learning objects refer to small stand-alone instructional units that can be tagged with descriptors (metadata) that are stored in repositories for reuse in various instructional contexts. Learning Objects contribute to the scalability and reuse of content and media assets. Reusable learning objects (RLO) can be aggregated to build multiple lessons. Instead of designing complete courses, and curriculum designers can use RLOs to configure content for general or course specific use. There are a number of RLO models in use today, such as the CISCO RLO/RIO, Autodesk, NETg, SmartForce, and the ADL SCORM Content Aggregation model. In the CISCO model, all information can be grouped as concepts, facts, principles, process or procedures. In an e-learning application, each RLO can be a Web page incorporating features such as Java code for SCORM compliance, and metadata XML documents. Standards committees, such as the Institute of Electrical and Electronics Engineers (IEEE) Learning Technology Standards Committee (LTSC), have also created a roadmap for defining RLO's. All these activities that are taking place within the serious learning community are also motivating the design and development of the eDSP 3-D learning environment. This process has informally begun in under the aegis of the NSF sponsored *InvestiGATOR*[1] project [4].

The *InvestiGATOR* is a studio-based delivery system. A studio format consists of a topical review, followed by in-class problem solving activities applying the reviewed material, concluding with a presentation of new material. This format has been shown to be effective in reinforcing technical studies, moving the emphasis from learning abstract concepts to one of applying knowledge in a collaborative setting. Due to repeated in-class exposures, studios are claimed to be particularly effective in a skill development role. An early assessment of the InvestiGATOR project was based on an interview of 25 seniors [4]. The results of the Q&A is as follows:

[1] The *InvestiGATOR* is a registered trademark of the University of Florida for educational products and technology.

Q: Compared to other engineering courses, evaluate the effectiveness of the Studio method in delivering content.
A: 12% superior, 46% better, 42 % same.

Q: Compared to other engineering courses, assess the Studio style of content delivery.
A: 29% superior, 38% better, 33 % same.

Q: Would you recommend continuing with the Studio-based experiment?
A: 33% yes, 66% yes with minor modifications.

Q: Access the value of the DSK workshop sessions.
A: 88% significant, 14% some.

Q: Compared to previous laboratory experiences, assess the InvestiGATOR laboratory activities.
A: 36% superior, 45% better, 14% same, 5% inferior.

5. eDSP DEVELOPMENT

Standard Container

The core material that provides the foundation for eDSP is a collection of topical lectures. Unlike a textbook whose organization is based on chapters, the lectures have a much finer grain. For example, a typical DSP textbook chapter is FIR filters. The lecture notes cover detailed material normally found integrated into the chapter. Examples include linear phase, equiripple, halfband and so forth. Because of the fine granularity of the notes, they necessarily are densely linked to topics, formula, figures, and tables found in other note sets. This provides a natural basis upon which a set of RLO's can be created.

Each eDSP RLO is limited to a single Web page and resides within a standardized container. The capacity of a Web page is assumed to be equivalent to that of a printed page. Based on reported K-12 experiences, a minimalist approach to Web page design is recommended. The standard eDSP page provides users with a consistent context-sensitive navigation and features, options, plus display content.

Content

Content is currently assembled from a set of computer-readable textbooks, namely:

- Hands-On Digital Signal Processing, Signal and Systems Engineering Series, Taylor and Mellott, McGraw Hill, 1998.
- Electronic Filter Design Handbook, 3rd Ed., Williams and Taylor, McGraw-Hill, 1995.
- Advanced Digital Signal Processing, Zelniker and Taylor, Marcel Dekker, 1994.
- Principles of Signals and Systems, Taylor, McGraw-Hill, 1994.
- Digital Filter Design for the IBM PC, Taylor and Stouratis, Marcel Dekker, 1987
- Digital Filter Handbook, F. Taylor, Marcel Dekker, NYC, 1984

The second source is the open literature and other references. Many of the articles are tutorial and technology application notes obtained from solution venders (e.g., Texas Instruments). This material is used to create the fine grain lecture notes. Access to the additional information sources are hyperlinked to prepared resources that range for pop-up factoids, tutorials, definitions, assessments, supporting Internet locations, and so forth. These transitions are made as student-centric as possible. That is, if the student is working at an intermediate level, then branching is made to complementary material.

Mechanics

In order to translate the fine grain lecture material into finer grain eDSP content, a metadata approach is required. A metadata (data about data) coding scheme is being developed to partition signal processing topics into logical units that define RLOs. There is a danger to partition information along classical lines. It was found that this will leads to the synthesis of the table of contents found in a general DSP textbook. The CISCO model is being used to code objects based on the following five object types:

- Concept: A group of objects, symbols, ideas, or events that are defined by a single word or term, share common features, and vary only in irrelevant features. For example, "What is the Shannon Sampling Theorem?"
- Fact: Unique, specific information in the form of a statement, audio or graphic data. For example, "The Shannon Sampling Theorem is also known as the Nyquist Sampling Theorem.
- Procedure: A procedure contains directions or procedural tasks and actions that are done the same way each time. "The statistical error associated with a quantized sample value is … ."
- Process A flow of events that describes how something works. For example, "The reconstruction of the original continuous time signal x(t) from its sample values x[k] is accomplished using convolution $x(t)=h(t)*x[kT_s]$, where h(t) is the ideal Shannon reconstruction filter and T_s is the sample frequency."

The granularity of the metadata scheme needs to be sufficiently fine so as to allow each RLO to be constrained to a single Web page. This level of granularity could not be tolerated with a traditional print book but is certainly realistic for electronically delivered applications. For example, the concept of state variables was a single lecture topic three versions ago. It now consists of eight mini-lectures. Each mini-lecture can be encapsulated on a single Web page. It should be remembered, however, that this by itself is simply a 2-D information presentation motif (see Figure 1). The eBOOK is a 3-D paradigm. Depending on the pedagogical need, a student can be presented an opportunity to explore a topic at a high level or in great depth depending on the student's experience and need, all within one consistent learning environment. Recognized levels could be:

- History, Background, Applications
- Entry or Neophyte Level (Basics)
- Intermediate Level – Theory
- Intermediate Level – Applications
- Intermediate Level – Technology
- Advanced Level – Theory
- Advanced Level - Applications
- Advanced Level - Technology

The opening Web page enables an RLO which includes principle direction links. Principle directions require students to use judgment and discretion when applying newly acquired knowledge. For example, "Argue why an ideal Shannon reconstruction filter physically unrealizable."

Each meta-tagged signal processing topic is integrated with referential domain material at multiple levels or depths which initially focus on 3rd year Signals and Systems, 4th year Introduction to DSP, and 5th year Principles of DSP studies. The material is supported with interactive (hands-on) audio and image processing demonstrations.

The eDSP referential domain is expanded over that normally found in textbooks or ebooks. The eDSP referential system being designed consists of indices, help/glossary features, hyperlinks, MATLAB/Simulink (Student Edition) simulations, TI DSK (6713) demonstrations, a context-sensitive pop-up calculator, audio/image examples, and guided Internet search help.

MATLAB/Simulink simulations require only the low-cost student version rather than requiring the expensive professional version along with assorted toolboxes. Furthermore, C-code for the low-cost TI TMS320C7613 DSK single board DSP system that will allow students to execute studied algorithms and test applications in hardware. Pop-up calculator that is calibrated to the topic of study, audio examples will use the native soundboard to reinforce signal processing objects, and recommend keywords and URLs for Internet searches are being prepared for eDSP insertion.

The eDSP system will be able to display information taken from any predefined depth. The default value will be taken from the configuration menu which includes information regarding the student's DSP level and previous academic DSP experiences. The system also allows students to move up or down in depth to meet their learning needs. At any particular level, depth-sensitive on-line assessments can be installed along with randomly seeded problems which will require the student to make choices and perform the required analysis. Requests for help will invoke the appropriate RLO that explains the specific task under study.

6. eDSP SUMMARY

The eDSP project is new and just beginning a life cycle at The University of Florida. At the time of paper submission, a formal learning assessment study has not been completed. When operational, the assessment protocol used to evaluate the NSF InvesitGATOR project will be employed to access the learning value of eDSP.

7. REFERENCES

[1] Science and Mathematics in the Schools: Report of a Convocation, National Academy of Sciences and National Academy of Engineering, May 1982, ISBN 0-309-03330-6.
[2] Sloan Foundation at www.sloan.org/programs/edu_careers.htm
[3]. R. Baraniuk, C.S. Burris, D. Johnson, and D. Jones, "Sharing Knowledge and Building Communities of Signal Processing," IEEE Signal Processing Magazine, Sept. 2004.
[4]. R. Frankel, N. Nezis, and F. Taylor, "The InvestiGATOR: A Studio Based Learning Paradigm," IEEE ICASSP Conference, Montreal, CA, May 2004.

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