DESIGN OF A GUIDED-ASYNCHRONOUS GRADUATE COURSE IN MULTI-MEDIA SIGNAL PROCESSING

V. Stonick, W. Kolodziej, and O. Gygax[*]

Modern Communications Center
Department of Electrical & Computer Engineering
Oregon State University
Corvallis, OR 97331-3211

ABSTRACT

This paper describes the design of a new guided-asynchronous graduate course in Multi-Media Signal Processing (MMSP). MMSP expertise is increasingly critical for many working engineers from diverse disciplines. Targeted students have some prior DSP-related experience, but need an introduction to MMSP fundamentals before participating in more specialized courses. A modular structure, asynchronous design and application focus are used to meet the educational and logistical needs of working engineers. Industry and University partners use MMSP technologies to provide remote access to pre-configured laboratory experiments and educational resources, and support for distributed collaboration and guided learning. Thus hands-on experience with MMSP technologies is integrated with learning about underlying MMSP concepts. A central element of the course design are on-line, multi-media topical learning modules which provide evaluation of student level of expertise, guidance in choosing course activities to effectively meet learning goals, student practice and projects, and feedback and evaluation of student performance

1. INTRODUCTION

Expertise in Multi-Media Signal Processing (MMSP) is becoming increasingly important for working engineers from diverse disciplines [1,11]. Traditionally expertise in individual media is developed in distinct courses of study aligned with the related industries. Individual media include, *e.g.*, audio and acoustics, speech processing and transmission, video and image processing and transmission, computer graphics, data management and document processing. However, these industries have merged as voice and audio, images and video, and data are all now increasingly stored, processed and transmitted using digital techniques. Thus, product design requires the integration of these different media streams on a single platform. Creating these technologies requires engineers that understand theory and technology issues related to both the individual media and their integration on a single platform.

Here MMSP refers to the combined processing of these audio, speech, image, video and data signals when viewed as multiple media streams. *Integrated* processing of these separate media streams is required as relevant information depends on content from multiple media streams. Processing may be accomplished in hardware, firmware or software. Processing goals include, *e.g.*, compression and robustness for transmission, distortion removal, synthesis of special effects, and extraction of information for sorting and searching [See, *e.g.*, 12]. While many engineers are trained in one aspect of this field (VLSI design, signal processing algorithms, telephony or computer graphics, for example), very few engineers have an integrated knowledge of underlying concepts, implementation issues, and current technologies for different media. There is a strong need for engineers with this integrated knowledge as evidenced by the growing number of short courses and specialized workshops in MMSP, *e.g.*, [3,4].

However, since MMSP is a new field, there are few engineering programs in the United States that have offered integrated, introductory courses on this subject. Hence many working engineers lack the basic knowledge of MMSP techniques and need to complete an introductory class before taking more advanced courses and participating in more specialized workshops. Traditional introductory DSP courses do not provide the needed hands-on experience with multiple media and technologies, both individually and integrated.

The hi-tech companies in the Portland, Oregon area, in particular, have significant investment in MMSP-related research and development. Thus the number of potential students is large and includes system designers, and applications and marketing engineers from industries in the greater Portland metropolitan area. We are targeting the audience of minimum 20 students for the first class in Spring 1999. This number is very conservative considering the size of engineering groups working on MMSP at Intel, Tektronix, NEC, Sharp, and Mentor Graphics. There are also numerous smaller companies focused on multi-media market where it is more likely that the engineers need to have an integrated knowledge of the field.

During the past few years, courses at the Oregon Center for Advanced Technology Education (OCATE) on digital signal, image and video processing have attracted a steady group of students, mostly with practical knowledge in these fields. At the same time a large number of students did not enroll due to the lack of prerequisites, although many had practical experience. Also observed was student attrition during the term, predominately because of non-anticipated work duties and travel.

The challenge and goal is to create an introductory course in MMSP, that both

1. Provides an integrated understanding of individual media processing and integration issues, and
2. Meets the logistical needs of working engineers.

[*] Supported in part by Oregon State Bill 504.

Distance learning and technologies provide a means by which relevant graduate education in MMSP can be achieved for working engineers.

Here we present the design of a course that uses MMSP technologies to provide relevant educational experiences in MMSP. Thus students are able to see MMSP underlying concepts in action while gaining hands-on experience with current MMSP technologies. Industry and University partners use MMSP technologies to provide remote access to pre-configured laboratory experiments and educational resources, and support for distributed collaboration and guided learning. A modular structure, asynchronous design and application focus are used to meet the educational and logistical needs of working engineers. A central element of the course design are on-line, multi-media topical learning modules which provide evaluation of student level of expertise, guidance in choosing course activities to effectively meet learning goals, student practice and projects, and feedback and evaluation of student performance. This paper provides an overview of the course goals, design and implementation issues.

2. COURSE DESIGN

2.1 Goal and Challenges

As indicated above, the goal is to provide an introductory course in MMSP that meets both the educational and logistical needs of working engineers. Existing course offerings typically do not meet this need. Specialized MMSP workshops and graduate courses generally are too advanced or narrowly focused, and thus are not amenable as introductory courses. Undergraduate DSP courses often are too low in level and expectations for students having professional experience, and generally do not address MMSP in an integrated fashion. In addition, existing graduate courses in related topics typically

1. Require a long pipeline of pre-requisites for entrance,
2. Have course structures that cannot fit working engineers schedules,
3. Cover topics that do not meet the educational needs of the working engineer and
4. Do not sufficiently integrate theory, tools, implementation and applications.

The proposed course is structured to try to minimize logistical problems 1-2 by using a modular structure and guided asynchronous delivery. Problems 3 and 4 are addressed by using a hands-on, application focus.

2.2 Modular Structure

During a given 10 week quarter, a 3-credit course is offered as three one-credit distinct modules. This modularity allows entering the course at different points (requiring different prerequisites) and times, and completing individual modules as is convenient. Individual module credits then can be combined into full course credits. This modularity allows for students to get, in essence, partial credit for a full course in the event of unplanned work-related duties.

The three modules include

- Module 1: 1-D DSP and Speech/Audio Applications
- Module 2: Image Representation and Processing
- Module 3: Video Representation and Compression Applications

The three modules are unified by using various multimedia standards as case studies to illustrate multimedia integration issues. Note that 2/3^{rds} of the modules focus on visual media which are critical for true multimedia and often are not included in depth in introductory courses [28]. Each course module is further divided into topical modules, as described later.

During the first offering, the start and finish time of each module will be fixed. Thus there are 3 distinct times during the year where students can enter the course or drop out and still get partial credit. For future offerings we will consider the feasibility of allowing more flexibility in module start and completion times, consistent with the guided asynchronous delivery described below.

2.3 Guided Asynchronous Delivery

To allow working engineers the flexibility work on modules at times more convenient to their schedules, the course is delivered in an asynchronous fashion which we call 'guided asynchronous'. The course is asynchronous in the sense that materials are available over the web. Students do not need to attend rigidly scheduled lectures and can learn, to a large degree, at their own pace during the quarter. However, it is well-documented that peer collaboration, timely guidance and feedback, and hands-on laboratory experiences are critical components in engineering education. Opportunities to participate in some specific educational activities of these types will be available during a limited set of pre-arranged time periods. Thus delivery is not purely asynchronous.

To understand guided asynchronous learning in the context of standard distance learning practice, consider the following: Most distance learning activities can be thought of as web-based – using the web to provide independent study or supplemental materials, or video-based – providing essentially standard lecture-based courses to students at distributed locations either by watching the lecture as it happens or later on a video tape. A number of courses have begun to make use of the WWW to provide flexibility in course structure: For example, students may cover topics in any order, using as a starting point topics which are closer to their own experience. Further, the on-line lessons and assignments can be completed at any time. This is commonly referred to as *asynchronous learning*.

While both the Web-based and video methods provide more reasonable structures for professional continuing education, neither to date has proven to be particularly conducive to engineering education where the group laboratory and project experience, with expert guidance, often is central. A number of new technologies are emerging which provide for collaborative and hands-on environments over networks. In the MMSP course, we use these to provide *guided* asynchronous learning, which allows for some flexibility in learning schedules, but provides the infrastructure for student collaboration in hands-on projects – sometimes with instructor guidance – from distributed locations.

2.4 Hands-On, Application Focus

Working engineers typically have a stronger immediate need for understanding implementation and application issues.

However, to provide long-term as well as short-term educational benefits, it is critical that the implementation and applications be framed using underlying theory, which enables generalization. Thus it is important to motivate theory and tools in the context of applications and implementation issues. Further, the course must provide instruction in and practice using major computational and hardware tools in applying the theory to the application.

To facilitate this integration of theory, tools, application and implementation, each course module is further divided into topical modules, each of which integrate all of these elements. Each topical module includes practice with basic theory and theory applied to different media, MATLAB exercises and demos, and hands-on experiments and demos.

Each course module includes hands-on practice with multimedia technologies. Hardware experiments are enabled by using remote, multimedia access to pre-configured laboratory experiments. Application-focused projects use MATLAB tools to see results of applying theory to the applications, where MATLAB is available from a central server for students who do not have local access.

For each course module, the experimental set-ups include

- Module 1: Remote and interactive programming of DSP boards for audio and speech coding, and matched filtering via the FFT for communications.
- Module 2: Image acquisition for computer vision and video-conferencing
- Module 3: Video compression and streaming for multimedia video-conferencing applications.

Each module also includes access to hands-on demos, including demos from Tektronix Video Labs and Sharps Labs.

3. COURSE FEATURES

In addition to the modularity and guided asynchronous delivery, this introductory MMSP educational offering will include

1. On-line 'Flashcards' allow for student self-quizzing. These provide a number of functions, including review of relevant background material, evaluation of student level of expertise, guidance in choosing course activities to effectively meet learning goals, student practice and projects, and timely feedback and evaluation of student performance. This aspect of the course will be totally asynchronous, and can help to assess where student difficulties lie. It also facilitates students taking the course without having to satisfy extraneous pre-requisite requirements.

2. MMSP Community. Prior 'graduates' of modules will be invited to continue to participate as tutors (via chat-rooms, email or video-conferencing, for example) for students working on the modules, thereby building a community with MMSP expertise. In addition, student projects will be integrated into future course exercises to facilitate evolution and enhancement of course materials over time.

3. Application Context. Each module will cover theory in an application context, with emphasis on implementation issues in existing standards and proposed multimedia technologies and products. Thus each module includes theory, simulation and implementation (hardware, software, DSP boards, as appropriate). The goal is to demonstrate how the theory and simulation tools can be used to facilitate the design process, including evaluation of implementation tradeoffs. Remote access to professional databases and tools provided by industry sponsors will be provided.

4. Distributed Project Collaboration. Provide a structure to facilitate different modes of learning. In particular, hands-on experiences and peer and instructor interactions are extremely valuable in engineering education and practice. Our goal is to use existing and emerging technologies (as well as our own expertise) to facilitate these experiences for working engineers who wish to participate in the educational offering from distributed locations and at various times.

4. FEATURE IMPLEMENTATION

To provide the features described above, the learning environment and technologies will need to provide, from distributed locations,

- Peer collaboration, both real-time (audio, video, white-boards, and chat functions) and asynchronous (email, electronic bulletin boards) interactions
- Hands-on practice in laboratory environments (DSP board programming, operation of audio/video/image acquisition equipment, etc.), both with and without peer collaboration, and with and without TA guidance.
- Guided Access to Course, Background and Extension Materials (on-line lectures, references, assignments, with a 'wizard' to help provide guidance regarding where to look)
- TA/instructor timely guidance and feedback, both real-time and off-line (e.g., answering frequently asked questions (FAQs), providing demos, responding to email).
- Opportunities for serendipitous meetings, a study space

We are building this environment using the experience of others [5-10, 13-22], and are structuring it for continuous improvement through participatory design, *i.e.*, the students who take the course will be contributing to the continual evolution of it.

5. ACTIVITY MODULE DESIGN

We use previously developed engineering education models for constructing the mix of activities and technologies needed to provide constructive learning experiences. Specifically,

1. Using a model for coaching team athletics, we build a menu of activity types in which students must participate to receive certification (credit) for a given module.
2. We use a model from feedback systems which identifies aspects needed for effective peer collaboration in designing the environment and in identifying critical technologies.
3. The engineering workspace identifies peer communication pathways that facilitate effective problem-solving and design. Specifically, the environment will provide opportunities for verbal and visual communication in small and larger groups, opportunities to work together in a laboratory environment and 'places' for serendipitous meetings.
4. A model for the engineering design process identifies steps that will need to be reinforced in activity design and facilitated by the technology.

These models are based on existing models from learning theory and were developed concurrent with the creation of new courses in the new curriculum at CMU [26,27], as well as used in updating communication and signal processing courses at OSU. Each course used participatory design: The signals and systems laboratories resulted in a book [23], co-authored with an MS student, and a number of undergraduate projects contributed to the individual laboratory assignment topics and design. Demonstrations and 'flash cards' were developed with graduate students, and the peer collaboration was developed concurrently with a colleague in Physics [24,25].

Using these models, we have structured each activity to include the following:

1. Purpose: Goals of assignment, stated in terms of application
2. Educational Objectives: Intellectual competencies and problem-solving (lab) skills to be developed through assignment
3. References: For review of concepts student should know before starting, for more in-depth exploration of topics addressed in the assignment, and for more understanding of the application addressed in the assignment
4. Preparation: Basic 'back-of-the-envelope type problems illustrating the concepts to be used, Computation of initial design and simulation parameters, Practice with tools (simulation commands, hardware tools, etc.)
5. Background: A brief discussion of the problem to be addressed, including application scenario and review of major concepts within the context of the application. Will include links to other information sources on relevant topics.
6. Activities: Simulations, experiments, directed questions and open-ended discovery questions, both time and transform domain questions.

6. CONCLUDING REMARKS

The presentation will describe specifics, with demos, as available.

7. REFERENCES

[1] America's New Deficit: The Shortage of Information Technology Workers, U. S. Dept. of Commerce, Office of Technology Policy, August 1997.

[2] Guided Discovery in a Community of Learners, in Classroom Lessons: integrating cognitive theory and classroom practice, Kate McGilly (Ed). The MIT Press, Cambridge, MA, 1994.

[3] NATO Advanced Study Institute, Signal Processing for Multimedia, http://www.cs.umb.edu/~asi/lectures.html

[4] 1998 Workshop on Multimedia Signal Processing, IEEE Signal Processing Society, http://imsc.usc.edu/Events/workshops/mmsp98.html

[5] A. Clausen, A. Spanias, A. Xavier, M. Tampi, "A Java Signal Analysis Tool for Signal Processing Experiements," ICASSSP98.

[6] M. Rahkila, M. Karjalainen, "An Experimental Architecture for Interactive Web-Based DSP Education," ICASSP98.

[7] J. Shaffer, J. Hamaker, J. Picone, "Visualization of Signal Processing Concepts," ICASSP98.

[8] L. Balmelli, S. Ayer, Y. Cheneval, M. Vetterli, "A Framework for Interactive Courses and Virtual Laboratories," IEEE SPS on Multimedia Signal Processing, 1998.

[9] G. Orsak, D. Etter, "Collaborative Signal Processing Education using the Internet and MATLAB," IEEE SP Magazine, 11/95

[10] D. Etter, G. Orsak, D. Johnson, " A Distance Learning Laboratory design Experiement in Undergraduate DSP," ICASSP 95.

[11] Proceedings of the IEEE, Special Issues on MultiMedia Signal Processing, Parts I and II, May and June 1998.

[12] S. Chang, A. Eleftheriandis, R. McClintock, "next-Generation Content Representation, Creation, and Searching for New-Media Applications in Education," Proc IEEE, 5/98.

[13] M. Kadiyala, B. Crynes, "Where's the Proof? A Review of Literature on Effectiveness of Information Technology in Education," Proc. FIE 98.

[14] Khader, M. and Barnes, Laboratory based courses in distance learning settings Proc. FIE '96.

[15] Jenq-Neng Hwang; Deshpande, S.G.; Ming-Ting Sun; Wang, Y.; Reibman, A.R.; Juang, B.H.; Chen, T.; Kung, S.-Y., Multimedia features for course-on-demand in distance learning IEEE 1st Wkshp on MMSP, 1997.

[16] Morreale, P.A.; Wang, Y.; Reibman, A.R.; Juang, B.H.; Chen, T.; Kung, S.-Y., Distributed multimedia education with real-time feedback, IEEE First Workshop on Multimedia Signal Processing, 1997.

[17] Patterson, E.K.; Wu, D.; Gowdy, J.N., Multi-Platform CBI Tools Using Linux And Java-based Solutions For Distance Learning ICASSP 98.

[18] R. Bamberger, A prototype distance learning laboratory for image processing education, Proc. FIE 1996.

[19] G. C. Orsak, Teaching signal processing on the Information Superhighway, 6^{th} IEEE DSP Workshop, 1994.

[20] Ng, J.M.; Chan, E.; Tsang, "Interactive group discussion system for distance education," Proc. IEEE 1st International Conference on Multi-Media Engineering Education , 1994.

[21] Taylor, K.D.; Honchell, J.W.; DeWitt, W.E., Distance learning in courses with a laboratory, Proc. FIE 1996.

[22] Pendergrass, N. and Sun, G., Using computer assisted collaborative learning to improve distance education, Proc. FIE 97.

[23] V. Stonick and K. Bradley, Labs for Signals and Systems Using MATLAB, PWS Publishing, 1996.

[24] M. Johnson, F. Reif, V. Stonick, "Using 'Supervised Practice' to Teach Thinking Skills in Introductory Physics and Engineering," Proc. ASEE Annual Conf., Anaheim, 6/95.

[25] M. Johnson, Creating a Common Visual Reference to Facilitate Peer Teaching, American Association of Physics Teachers Annual Meeting, Spokane, WA. August, 1995.

[26] V. Stonick, "Teaching Signals and Systems using the Virtual Laboratory at CMU," Proc. ICASSP 1994.

[27] V. Stonick, "An update on the Virtual Laboratory at CMU, Proc. ICASSP, 1995.

[28] V. Stonick, "Using Image Processing to Teach Introductory Signals and Systems," Proc. ICIP.