Multimedia and Cooperative Learning in Signal Processing Techniques in Communications

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***Abstract*—The letter describes how multimedia technology and cooperative learning were used to teach an online course, Signal Processing techniques in Communication Systems (SP/CS). Students study online presentations enhanced by multimedia animations and perception quizzes, discuss problems using an asynchronous conferencing system, and complete cooperative laboratory simulations based on MATLAB. A locally designed course management system provides access to the online features of the course. A survey that assesses the benefits of multimedia and cooperative support materials is also included.**

***Index Terms*—Asynchronous learning networks, distance education, distributed learning, multimedia online education.**

I. Introduction

ADVANCES in the multimedia technology provide an opportunity to enhance learning in the university education. Several university courses[1] in the electrical and computer engineering (ECE) curriculum have used multimedia to improve the quality of learning for their students. The letter presents an overview of the multimedia and cooperative instructional material developed for an online course, Signal Processing techniques in Communication Systems (SP/CS). We describe how SP/CS is organized and delivered online using a locally developed course management system (CMS).

A learning object is defined as an animation that uses a combination of text, graphics, sound, and video packaged together. The learning objects used in SP/CS include multimedia animations and online quizzes. The multimedia animations are designed using Macromedia Flash (MF) that allows us to illustrate the details of the implementation of important signal processing algorithms covered in the course. Questionmark Perception (QP) is used to develop the online quizzes. QP records the average scores achieved by the students on different questions included in the online quiz. The data are used to judge the students' weaknesses, which are then addressed in the face-to-face (F2F) sessions. In the delivery of SP/CS, we introduce a series of cooperative activities based on Mathworks MATLAB. To assess the benefits of multimedia support material, we complete a study comparing the overall scores of the students taking the online version of the course with those of an earlier section of students registered in an equivalent course taught using the standard lecturing mode. Our study shows an improvement of 10% points in the scores of the students with access to the multimedia instructional material.

The letter is organized as follows. Section II describes the course management system (CMS), which provides access to the online features of SP/CS. Section III presents the course outline, the delivery model used, and the list of cooperative activities designed for the course. Section IV includes a representative collection of the learning objects, while Section V presents the results of our comparative study and survey. Finally, Section VI concludes the letter. The learning objects and cooperative activities can be accessed by visiting the web document maintained at http://www.cs.yorku.ca/~asif/spc/LO.htm.

II. CMS

The support provided by the course management system is crucial to the successful delivery of the course. After reviewing several commercially available systems, we decided to build a web-based CMS with core functionality written in XML/RPC, Dynamic HTML, and JavaScript. Specialized functions are provided by using a variety of commercial products. For example, web-conferencing is based on FirstClass, while online quizzes are designed using Questionmark Perception. Other notable features of the CMS are as follows.

- An entry page designed to support community building by providing general announcements, a Java-based text chat serving as a virtual cafe, and links to the online conferences dealing with a variety of students' concerns.
- A personal page providing links to the student's calender, registered courses, emails, announcements, and personal file space on the server. Since the personal page is personalized for each student, it is also referred to as the *i*-space, in short for the "individualized space."
- Links to the syllabus pages (Fig. 1) of the registered courses. The syllabus page directs the student to the learning objectives, presentations, online conferences, assignments, and cooperative activities for that course.
- A teams' page listing the class members by teams. The teams' page provides access to the team conferences.
- A navigation bar is available throughout the CMS.

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[1]Such as the following web sites: http://aiki.ccaps.cs.cmu.edu/ [1], http://www.eas.asu.edu/~midle/jdsp/ [2], http://www.conted.gatech.edu/dsp/ [3], http://www.sfu.ca/surrey/ [4], Rice University's The Connexions Project (http://cnx.rice.edu/), and "Demonstrations in Signals, Systems, and Controls" (W. J. Rugh, John Hopkins University: http://www.jhu.edu/~signals/).

III. COURSE OVERVIEW

The objective of SP/CS is to develop a mathematical and conceptual understanding of digital communication systems from the information source through the transmitter, channel, receiver, and the information sink. Emphasis is on signal processing techniques used in source and channel coding, modulation, and demodulation; detection of signal in the presence of noise; and spread spectrum techniques. We developed a course specification document (see http://www.cs.yorku.ca/~asif/spc/LO.htm) that describes the course content of SP/CS in terms of its learning objectives, cooperative projects, and multimedia learning objects. The following course outline summarizes the specification document.

1) Review of Probability and Stochastic Processes.
2) Source Coding I: Lossless Codes (Huffman, Arithmetic, and Dictionary Codes).
3) Source Coding II: Lossy Codes (Vector Quantization, Predictive and Transform Coding).
4) Shannon Bounds, Sampling and Quantization (PCM).
5) Line Coding and Baseband Transmission: (PAM, PCM, PWM, PPM, DPCM).
6) Binary signal detection and matched filtering.
7) Digital bandpass modulation and demodulation schemes (PSK, FSK, ASK, and DPSK).
8) Error performance analysis of the M-ary schemes.
9) Channel Coding I: Linear Block and Cyclic Codes.
10) Channel Coding II: Convolutional Codes.
11) Decoders for Convolutional Codes: Viterbi Algorithm.
12) Application of Convolutional Codes: Compact Disc.
13) Synchronization Techniques.
14) Spread Spectrum (SS) Modulation: Direct Sequence and Frequency Hopping SS.

The prerequisites for SP/CS are Signals and Systems and a basic understanding of Probability and Random Variables. The course text is the Sklar text on Digital Communications [5].

A. Delivery Model

A course delivery model is a combination of logistical, technological, and pedagogical features. The delivery model has implications for the scheduling of classrooms and laboratories, division of roles among the teaching staff members, and the hardware and network infrastructure needed for the course. To enable scalability, the department developed a set of delivery models [4] consisting of appropriate combinations of the learning methods and technologies. SP/CS uses the Presentational Cooperative (PC) model, which supplements a lecture with web presentations designed to explain the material in the text using interactive multimedia elements, such as animations and streaming videos. Student review the relevant topics from the text, study the online material designed for that week, and attempt an online quiz before coming to an optional face-to-face (F2F) session. The F2F session is held on campus for a duration of 1.5 h per week.

B. Cooperative Learning

An important feature of the PC delivery model is the weekly cooperative activity that requires the students to code signal processing algorithms in MATLAB. Students complete the activities in teams of three to four members either in the university laboratory or in an off-campus environment. An asynchronous online conference is used by the offcampus students to interact with their team. The cooperative activities in SP/CS are based on the following projects.

1) *Introduction to MATLAB:* Included as a review to MATLAB with some elementary exercises.
2) *Computer generation of random variables:* Generate random variables (RV) with any given distribution by transforming independent, identically distributed (i.i.d.) random variables with an uniform distribution on (0,1).
3) *Quadrature amplitude modulation (QAM):* Review continuous time analog modulation and demodulation techniques with emphasis on QAM.
4) *Quantization:* Simulate uniform and nonuniform quantizers using the Lloyd–Max algorithm.
5) *Matched filtering:* Design optimum receivers for transmitting binary information through a channel corrupted with additive white Gaussian noise (AWGN).
6) *Phase shift keying (PSK):* Monte Carlo simulations of an M-ary PSK communication system. Error performance analysis is performed.

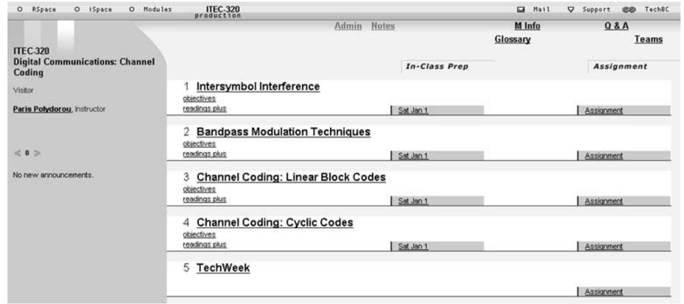

Fig. 1. Syllabus page for Module 2 of SP/CS. Each unit (1–4) is covered in a week and includes online presentations enhanced with learning objects, assignments, MATLAB projects, and quizzes.

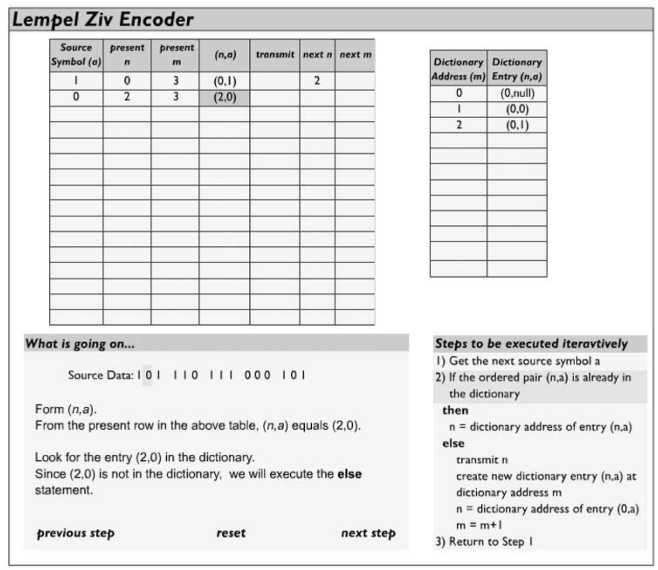

Fig. 2. Snapshot of an MF animation illustrating the LZ encoder.

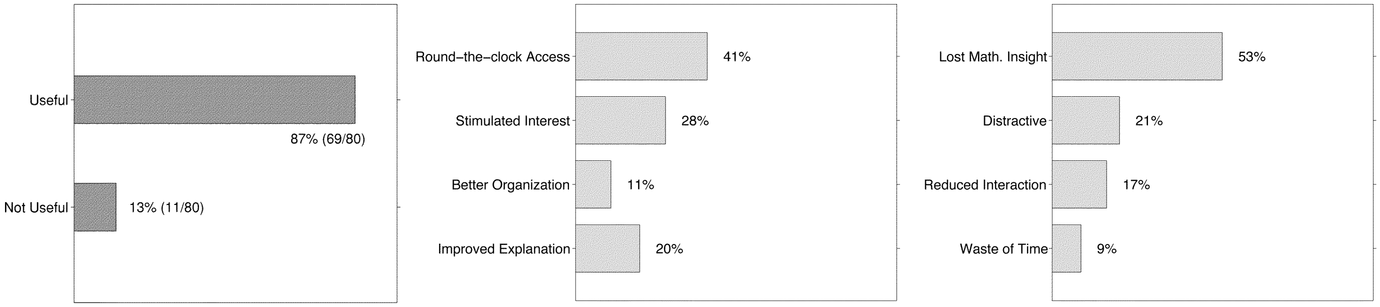

Fig. 3. Results from a survey demonstrating pedagogical improvements resulting from the use of the multimedia instructional material in SP/CS. Subplot (a) compares the distributions of students, who rated the material as "Useful" or "Not-Useful." The Useful category is classified into four subcategories or attributes, shown in (b). The Not-Useful category is classified into its four attributes shown in (c).

7) *Frequency shift keying (FSK):* Same as 6) but for an M-ary FSK communication system. Performance is measured for different values of M and compared with the corresponding M-ary PSK communication system.
8) *PSK modulation with convolutional codes (http://www.cs.yorku.ca/~asif/spc/LO.htm):* Monte Carlo simulations for a binary communication system using the convolutional coding scheme after the PSK modulation. Quantify improvements over 6) and 7).
9) *FSK modulation with convolutional codes:* Same as (8) but with the FSK modulation scheme. Performance is compared with 7) and 8).
10) *Direct-sequence spread spectrum communications (DSSS) (http://www.cs.yorku.ca/~asif/spc/LO.htm):* Demonstrate the effectiveness of DSSS in suppressing jamming interference.
11) *Frequency hopping spread spectrum (FHSS) Communications:* Repeat 10) for FHSS and compare the two systems 10) and 11) in terms of the symbol error-rates.

C. Feedback

To answer queries from the students, we use moderated question and answer (Q&A) boards. Each team working in a cooperative activity has access to a private Q&A board for internal discussions within the team and a public Q&A board for general discussions. The instructor monitors the Q&A boards and answers important concerns and questions. We also maintain a list of frequently asked questions (FAQs), which can be explored by the learners, when needed. We have also implemented an online facility that provides a summary of the overall score and the current standing of each student. The facility allows the students to review their performance.

IV. Learning Objects

A series of multimedia animations, referred to as the learning objects, were developed to explain the intrinsic details of complex signal processing algorithms. We found MF to be an excellent software that allows stepwise analysis of each algorithm. The student can go back and forth at their own pace while studying a MF animation. Sample MF animations included in the letter illustrate the algorithms for convolution sum, convolution integral, Lempel Ziv (LZ) encoder, Lempel Ziv (LZ) decoder, arithmetic encoder, arithmetic decoder,

Mode	mean	max	min	std
PC Delivery	73.1	93.2	50.2	10.7
Lecture	62.4	85.8	46.2	13.6

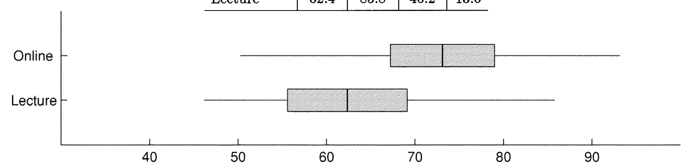

Fig. 4. Comparison of percentage marks of students taught with lecturing and online modes.

Huffman code, and Viterbi algorithm. A snapshot of the LZ animation is shown in Fig. 2.

Perception Quiz: To ensure that the learners are studying the material on time, we ask them to write a weekly online quiz based on Questionmark Perception. The facility records the performance of each learner and can be used to judge where the "sticky spots" exist for the learners. These weaknesses can then be addressed in the face-to-face sessions for the on-campus students, or in the Q&A boards for the off-campus students. An example of a perception quiz is available at http://www.cs.yorku.ca/~asif/spc/LO.htm.

V. Evaluation of the Online Experience

In this section, we present a study and a survey to demonstrate the improvement offered by the multimedia features of SP/CS. A brief comparison with three existing online resources developed for continuing education in signal processing is also included at the end of the section.

Survey Results: The online course in SP/CS was offered in the Fall semester of 2001. A total of 12 week-long modules were developed, each emphasizing a subset of topics chosen from the course outline included in Section III. To access the benefits offered by the multimedia support material, we use two methods of evaluation. The first method is based on a questionnaire administered at the end of the course. The information required for the assessment was collected by a set of carefully drafted questions in the questionnaire. Anonymity was maintained for the responses to prevent biased outcomes, and participation in the survey was kept voluntary. A total of 80 responses were collected during the survey. The second method of evaluation is based on a statistical comparison between the overall scores of two different sections of students with and without access to the multimedia material. Both studies were completed

TABLE I
COMPARISON OF THE AVERAGE WEEKLY WORKLOAD OF THE STUDENTS

	PC Delivery	Lecturing Mode
F2F sessions	1.5 hours	3 hours
Cooperative Projects	2.82 hours	Not Applicable
Assignments	2.64 hours	3.28 hours
Quizzes	0.5 hours	Included in F2F sessions
Text Reading	1.82 hours	3.89 hours
Multimedia Material	1.24 hours	Not Applicable
Office Hours	Not Applicable	0.17 hours
Total	10.52 hours	10.34 hours

with full-time third-year university students. The results from the survey are included in Fig. 3, where the students' responses are classified in two categories: "Useful" and "Not-Useful". Students were asked to select the "Useful" category if they felt that the interactive multimedia support material enhanced the quality of the delivery of the course and promoted better understanding of the course material. In case the multimedia content did not promote better understanding or failed to improve the quality of learning, the students selected the "Not-Useful" option. Under each category, the students' responses were further classified on the basis of four different attributes included in Fig. 3. The attributes in each category provide a more in-depth understanding of the students' perception of the multimedia instructional material. Based on the effective rating of 80%, the survey confirms that the use of multimedia-based support material is an effective information medium for reinforcing students' attention and understanding. In the students' view, the multimedia content especially the learning objects and perception quizzes enhanced the quality of the delivery. Placing material online provided round-the-clock accessibility and added flexibility to the schedule of the students.

Our quantitative analysis compares the grades of the students enrolled in SP/CS delivered using the PC model with an earlier batch of students that used the conventional lecturing approach. Both sections used the Sklar text [5] and were taught by the same instructor. Similar grading schemes were used to access the students' performance in the two sections. Table I provides a distribution of the average weekly course work-load, estimated from surveys completed with the two sections. Table I illustrates that the average course work-load is roughly 10–10.5 h every week and is almost the same across the two sections. It is interesting to note that the students with access to the online instructional material spend less time on reading the text. It seems that the multimedia animations helped the students understand the difficult concepts and signal processing algorithms. Students without multimedia access had to read the text more carefully. Fig. 4 illustrates the spread of the cumulative percentile scores achieved in the two sections using a box and wisker-like plot, where the shaded rectangles depict the spread of scores within one standard deviation of the mean. The vertical lines within the rectangles represent the mean scores. For convenience of reference, we also list the mean, maximum, minimum, and standard deviation of the scores on the top of the plot. In terms of the mean score, there is a 10% improvement in the performance of the section with access to the multimedia instructional material. The maximum and minimum values have also improved considerably. We attribute the improvement to collaborative learning supported by multimedia delivery.

Other Online Signal Processing Resources: We summarize the results of a brief survey of similar online signal processing resources at three leading universities: Rice University [6], Arizona State University (ASU) [2], and Georgia Institute of Technology [3]. The Connexions Project at Rice University uses a collaborative approach for the creation, organization, and dissemination of the course content. The course modules are stored in a central repository that is accessed by the students using the Roadmap navigational software. The Java digital signal processing (J-DSP) project at ASU provides an object-oriented Java tool to enable online laboratories in the system-related areas of communications, image processing, and controls. Georgia Tech's distance education program offers several short-term online courses directed toward industry professionals interested in continuing education. There are other resources at Georgia Tech that provide Java-based animations for signal processing algorithms. Each of the online program has its own niche nd advantages. Our approach is focused toward the delivery of a one semester course in Signal Processing techniques used in Communication Systems. Since the audience is full-time university students, we take advantage of both F2F and online pedagogies. Unlik the Arizona's State J-DSP project and Georgia Tech's Java tools, our learning objects are based on Macromedia Flash (MF). While Java-related tools are useful in modeling a complete system, we found it difficult to illustrate the internal working of an algorithm using Java. On the other hand, MF allows stepwise illustration of the algorithms and is therefore a valuable tool in understanding such algorithms. In future, we anticipate close collaboration between such online educational endeavors.

VI. SUMMARY

The letter describes how cooperative learning and multimedia technology were integrated with the face-to-face delivery of a junior-level course covering Signal Processing techniques used in Communication Systems (SP/CS). In our study, the delivery of SP/CS was improved significantly with the cooperative projects and multimedia animations. The pedagogical multimedia content of SP/CS was particularly liked by the students. The lessons learned in SP/CS have been applied toward the development of a four years partially online Bachelors degree in Information Technology at the Surrey campus [4] of the Simon Fraser University (SFU) in British Columbia, Canada.

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