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An Interactive and Team Approach to Multimedia Design Curriculum

Over the past decade, increasingly powerful technologies have made it easier to compress, distribute, and store multimedia content. Many international multimedia standards have been established to enable new technologies—HDTV, DVD, digital audio, and real-time Internet games, just to name a few—to be enjoyed by millions of people around the globe. Simultaneously, advances in wireless and networking technologies, along with a significant decrease in cost for storage media, have led to the proliferation of multimedia data. This convergence of networking, computing, and multimedia technologies has collapsed the distance between the ability to create content and the ability to consume content.

The merger of computing and communications has created a ubiquitous infrastructure that brings digital multimedia closer to users, opening up tremendous educational and commercial opportunities in multimedia content creation, delivery, rendering, and archiving for millions of users worldwide. As such, multimedia has become a basic skill demanded by an increasing number of potential jobs for electrical engineering/computer science (EE/CS) graduates. Yet multimedia has been widely regarded by educators as a very difficult subject to teach at the undergraduate level because it involves a wide spectrum of issues, including coding, compression, enhancement, communication, data mining, and rendering of speech, audio, image, video, and their combinations; it also involves interaction with databases, networking, and artificial intelligence. At the graduate level, often we find each medium (e.g., image and speech) is a subject taught separately, focusing on specialized techniques and advanced theories. Given the limited theoretical foundations of undergraduate students, one can imagine that it is even harder to teach them multimedia technologies in an interesting, yet nonsuperficial way.

Multimedia has many practical aspects, with a variety of applications attractive to undergraduate students, especially members of the new digital generation who are introduced to all sorts of digital media as children. A student must have some hands-on experience in developing algorithms and performing simulations before he/she can have a level of true understanding and appreciation of the theoretical aspects in advanced studies.

How much can an undergraduate student learn and practice during one semester? And what is the best way for them to learn multimedia? During the fall semester of 2001, the University of Maryland, College Park, embarked on the development of a multimedia Capstone Design course targeting senior-level students. The course has been offered to seniors and first-year graduate students every semester since. It serves as our first step toward a new way of teaching undergraduate multimedia. The central idea is to teach students the principal concepts through lectures, then to reinforce their understanding through hands-on lab exercises and team projects.

In this article, we intend to share our experience and new ways of thinking about curriculum development. We hope it will be beneficial for colleagues in multimedia signal processing areas for use in developing or revising curriculum to fit the needs and resources of their own programs. We would like to cordially invite interested colleagues to join us in building an international partnership on multimedia research and education for a broader impact.

VISION AND CONCEPTS OF INNOVATIVE MULTIMEDIA EDUCATION

The multimedia curriculum at the senior level has high potential impact in terms of the number of prospective students. This makes it very important to think carefully about the vision and concepts on which we want to base our unique approach. As it is unrealistic to expect an undergraduate student to master the extensive theoretical background in a matter of months and finish with a perfect project, our vision is to

- offer strong intuitive components revealing a solid scientific perspective such that students with limited background can participate and contribute
- provide room for creative thinking through open-ended problem formulations
- match students with various backgrounds to the corresponding hands-on, open-ended projects that will capitalize on their existing skills and special talents
- utilize visualization, interactive tools, or computer-aided design facilities to shorten lengthy learning and implementation time so that the focus can be on the appropriate engineering context.

In addition to understanding the fundamental aspects of engineering disciplines, students need skills beyond their technical fields. The technology development paradigm in the IT era is being revolutionized; now someone with an idea and know-how can pull together enough resources—capital, talent, facilities, and market—to be able to realize his or her

 1053-5888/05/$20.00©2005IEEE

dream. This paradigm of students' futures is quite different from the traditional path of finding engineering jobs in large corporate and research laboratories and *fitting in*. The entrepreneurial spirit can be essential to the success of engineers of the digital generation. We try to incorporate elements of entrepreneurship in the proposed curriculum through a term project.

A FUN WAY OF LEARNING MULTIMEDIA

Based on the vision and concepts described above, we developed and first offered the multimedia Capstone course (ENEE408G) in spring 2002. The experiment has been quite encouraging, as evidenced from a report in an interview in the summer 2003 issue of the UMD ECE *Connections* newsletter. Our course development has employed a number of methodologies that have made ENEE408G a unique and attractive course.

WELL-DEVELOPED, HANDS-ON LAB ASSIGNMENTS

As shown in Table 1, one of the two parallel tracks of the course covers the fundamentals of four basic media types (speech, audio, image, and video) through eight-week lectures and lab assignments. We use PowerPoint presentations and Flash demos to illustrate fundamental concepts and multimedia examples that cannot be vividly conveyed using traditional blackboard teaching.

The lecture learning is complemented by four lab assignments on audio, speech, image, and video. Each lab consists of tasks of increasing difficulty and creativity levels. For example, in the "Image Processing and Digital Photography" assignment, we first provide students with conceptual understanding through playing with a powerful image editing tool (e.g., Paint Shop Pro or Adobe Photoshop) to accomplish several image processing and enhancement tasks. We then give students a few MATLAB building blocks and ask them to integrate and build a simple JPEG-like image coder. Next, students are asked to study a sample program in the Pocket PC multimedia programming manual that we have developed for them and extend it to design a small PocketPC image processing program using Microsoft's embedded Visual C++/Basic. Finally, each student team is provided a high-end digital camera to learn digital photography first hand and create an art piece using the image processing techniques that they have learned.

INNOVATIVE TERM PROJECT WITH ENTREPRENEURIAL SPIRIT

The second track shown in Table 1 is an innovative term project in which students work in teams to develop a creative product on a desktop platform or a mobile platform such as PocketPC. Such a learning process is described in the course syllabus as follows:

> Term Design Project: This is a team-based final project on design and implementation of multimedia signal processing systems using handheld devices or desktop computers. Each student team will emulate a high-tech company that will:
>
> 1) develop a product idea and decide on system specifications of a multimedia product,
>
> 2) partition and coordinate the design tasks,
>
> 3) implement, test, and document the design, and
>
> 4) demonstrate and market the product.

BUILDING A TEAM CULTURE WITH SOUND ORGANIZATIONAL SKILLS

We recognize that it is unrealistic to expect every student to master an extensive technical background and finish with a perfect project in a matter of months. Therefore, teamwork and sound team spirit are key to success. We encourage students to use their imagination and creativity to find an interesting idea that they are excited to develop; then we guide them to complete a proof-of-concept prototype within four to six weeks through well-organized teamwork.

We experimented with various ways of forming student teams. For example, students are assigned at random to form teams for the first design project, and they are assigned to work with different partners on the second project. From the third project on, the students are asked to team up voluntarily and stay with one team for the remainder of the semester. This way "forces" all students to learn to work with people they are unfamiliar with, yet allows for some stability and enough time to develop expertise and team culture for the final big project. Students have incentives to behave well and contribute to the team work from the first project; otherwise, they may be embarrassed if no group wants them as a member.

A peer evaluation form is collected after each project to give us an idea

[TABLE 1] ENEE408G COURSE SCHEDULE CHART.

WEEK	LECTURE	LAB ASSIGNMENT	TEAM PROJECT
1	INTRODUCTION	WARM UP ON MATLAB AND POCKETPC	
2	IMAGE PROCESSING	IMAGE	TEAM UP
3			
4	VIDEO CODING	VIDEO	
5			IDEA DEVELOPMENT
6	SPEECH PROCESSING AND RECOGNITION	SPEECH	
7			DEFINE SYSTEM SPEC
8	AUDIO PROCESSING AND RIGHTS MANAGEMENT	AUDIO	SCHEDULING
9			INSTRUCTOR'S APPROVAL OF DEVELOPMENT PLAN
10			PROJECT DEVELOPMENT: 1) JOB PARTITION, 2) PROGRESS REVIEW, 3) VERIFICATION, 4) INTEGRATION AND TESTING, AND 5) DOCUMENTATION
11			
12			
13			
14			PROJECT PRESENTATION AND DEMO
15			FINAL REPORT DUE

about team dynamics and help resolve any problems. The evaluation form also asks each student to briefly summarize how the job is divided, processed, and integrated by the team. One intent of this question is to ensure that a student understands both his or her own role and other teammates' roles in the project, regardless of whether the student was in a leader position or was being led.

INCORPORATE UP-TO-DATE DEVELOPMENT TOOLS AND DEVICES

To prepare students to meet the demands of the IT workforce of the 21st century, it is important to equip them with behind-the-scenes knowledge as well as algorithm development and implementation skills. We incorporate the most up-to-date, state-of-the-art tools and devices into the course, such as PocketPC, digital photo and video cameras, multimedia editors, and speech processing software. Recognizing that many employers expect that students have already mastered cutting-edge software tools and platforms, we have adopted in our course the latest platforms on desktop PC and PocketPC, as well as major prototyping and development tools such as MATLAB, Visual Studio, and Embedded Visual Studio. Given today's rapidly advancing pace in the technology field, the ability to learn to use references and examples to quickly master new concepts and tools has become an important skill for EE/CS students. This is why we have provided students with examples and reference material to help them learn new tools for new platforms (such as programming on PocketPC), which is mostly conducted on their own. Through lab assignments and projects, students master the tools with first-hand experience and extensive practice.

SYSTEMATIC ASSESSMENT OF STUDENTS' LEARNING

We have constructed a systematic assessment mechanism for student projects and teamwork. For each lab and project, we have developed a grading sheet that outlines major tasks, requirements, and grading criteria. At the beginning of the project, we clearly convey to the students the expectations and rationale behind the grading in terms of developing key skills useful for their future careers. Along with our department undergraduate office, we have developed assessment rubric on oral communications, written report, and engineering designs, to quantitatively assess students' performance and provide timely feedback that helps students improve.

For team-oriented projects, we have developed the teamwork evaluation questionnaire to solicit students' peer assessment. Handed out before the start of the project, the questionnaire is intended to provide constructive guidelines and incentives for students to develop effective mechanisms for working together. For example, the importance of timely communication for effective teamwork is emphasized on the questionnaire through a multiple-choice question about how

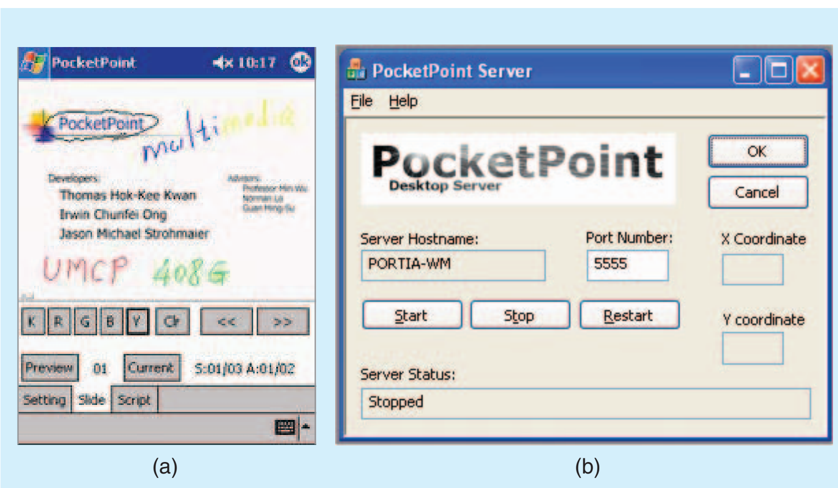
[FIG1] Screen shots of the student project "Kanji Tutor."

soon students communicate and respond to teammates, whether it is promptly (within a day), moderately (within two to three days), or rarely. We complement the peer evaluation with close observation and interaction with the student team during the lifespan of the project. This allows us to provide timely feedback and guidance for students to resolve issues in team coordination and improve the effectiveness of teamwork.

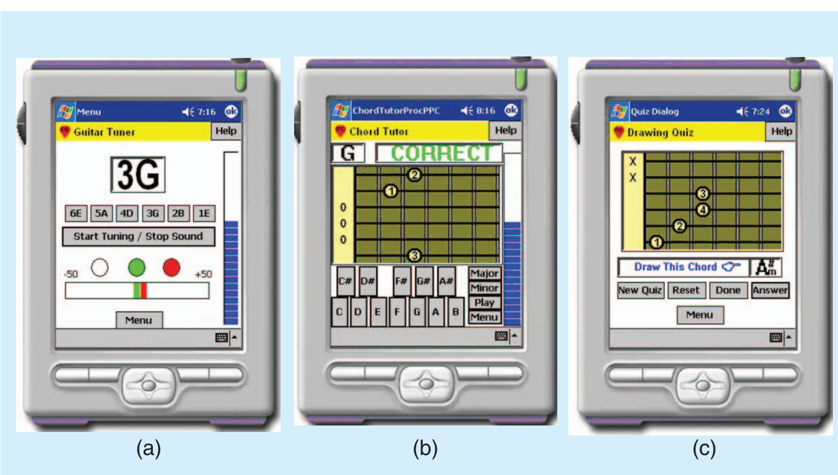
EXAMPLES OF TERM PROJECTS

"Kanji Tutor" is one example of capitalizing on students' special talents and creativity. As a beginner learning Japanese, one student led her team to develop a novel PocketPC tool to facilitate learning to read and write sophisticated Japanese/Chinese characters ("Kanji"). As illustrated in Figure 1, the student team developed an algorithm to verify the correctness of Kanji writing in different strictness levels. The team designed a friendly user interface and created unique animations and quizzes to help users memorize Kanjis.

Inspired by a TV remote controller software coming with PocketPC, another student team took just six weeks to complete the creation of "PocketPoint" shown in Figure 2. This prototype demonstrates the concept of using PocketPC to wirelessly control the flow of a desktop PowerPoint presentation; it provides a mobile visual aid such as thumbnails or a preview of slides. With this unique course, the creativity and proof-of-concept capability achieved by the undergraduate students are often far above expectation. For example, an idea similar to PocketPoint was independently investigated as a multiyear research project at another institution.



[FIG2] Screen shots of the student project "PocketPoint."



[FIG3] Screen shots of the student project "Pocket Interactive Chords."

A student team led by an amateur guitar player developed "Pocket Interactive Chords," a PocketPC application that allows users to tune a guitar and learn to play basic guitar chords. Capturing guitar sound from the built-in microphone of PocketPC, the students used their signal processing knowledge to develop estimators for tuning guitar strings and identifying notes and chords being played. They designed other fun modules and integrated them into a complete program with a rich set of features, including tuning, tutoring, and interactive quiz, as shown in Figure 3.

We have also exposed students to topics from the latest research and have encouraged them to develop projects keyed to emerging technologies. Secure multimedia multicast, content-based audio fingerprinting, and digital watermarking are just a few examples. For these research-oriented projects, we invited graduate students to serve as mentors for the undergraduate teams. These efforts have provided an effective vehicle for fostering interaction between undergraduate and graduate students and integrating research and undergraduate education.

SHARING AND COLLABORATION OF MULTIMEDIA RESEARCH AND EDUCATION

Multimedia has become a vital component of the digital era, and it has fundamentally changed the way we work and live. Research related to multimedia has grown to encompass a number of areas, such as multimedia coding, communications, synthesis, indexing, search, retrieval, recognition, understanding, security, and forensics. The global nature of information technology has nurtured a number of strong research groups with unique strengths worldwide. Multimedia research has evolved to a stage where a single institution often specializes in a subset of active areas or particular methodologies. Collaboration among multiple institutions across the globe will provide a breeding ground for cooperative research and education for multimedia technologies with much broader impact. This will, in turn, allow people all over the world to overcome physical distances and access a huge amount of text, image, audio, and video information through networks.

To respond to the global demand and the technical skills required by the new generation of the workforce, we are sharing our development experience and material. We intend to build an international partnership for a combined research and education program on multimedia. The program will offer multimedia education at the undergraduate level with a hands-on, team-oriented approach, and it will aid in cooperatively developing and transferring the latest results from multimedia-related research to education in a timely fashion. Close collaboration in developing and sharing research results and resources can expedite the transfer of new research into curriculum for the global, high-tech multimedia workforce. A set of course modules, including presentation material, lab assignments, and sample codes, will form a repository to enable multimedia educators worldwide to assemble suitable material for building a multimedia course tailored to their specific needs and facilities. If any reader is interested in teaming up and participating in this program, please feel free to contact the authors.

FINAL REMARKS

A number of students have found the multimedia course added much to their personal and professional interests. Student comments include:

> "This course was my first full-fledged exposure to multimedia signal processing. Now, I hope to investigate multimedia signal processing in work or in graduate school at least on some level. This has become one of my favorite interdisciplinary topics."
>
> "I had a lot of fun in your course. I learned a lot, which I hope to use very shortly. I have a product idea that I am going to start designing . . ."
>
> "The reason I applied for jobs instead of graduate schools last fall is that I had not yet found a problem that I was passionate about. . . . However, last semester, I finally found what I was looking for. I want to devote myself to signal processing challenges . . . Taking 408G opened my eyes to all sorts of signal processing problems I would love to tackle."

Dr. Teddy Kumar, technical director of Media Vision Laboratory of Sarnoff Corporation, came to the University of Maryland in early March to recruit students. A number of former and current ENEE408G students were invited for interviews. In an e-mail to the instructors, Dr. Kumar wrote, "Almost all students said that the best course they had taken at the University of Maryland was the multimedia signal processing course. They were all excited about their work in it and the hands-on project experience."

For more information, please visit the online showcase at www.multimedia.umd.edu or contact the authors at kjrliu@umd.edu and minwu@umd.edu.

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