Online DSP Education: DSP for Practicing Engineers

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Abstract

This paper discusses a new approach to DSP education for practicing engineers. At Georgia Tech we have embarked on a program to merge the comprehensive nature of traditional university courses with the accessibility of network-based training to make graduate and continuing education courses accessible to both traditional students and practicing engineers in remote locations. Many of the practical problems of Internet-based courses have been addressed by using a hybrid course organization and delivery mechanism that combines the flexibility and control of a course delivered from a central server with the high media quality of locally delivered high-bandwidth video and audio.

In addition to adapting the delivery method, we have worked with both academic faculty and industry representatives to modify existing course materials and develop special-purpose materials to fit the revised requirements of remote delivery to an audience of nontraditional students. Multiple faculty members participated in creating lecture materials to provide a unique perspective on DSP education. The course is comprised of three interconnected tracks: DSP system theory, real-time implementation principles, and laboratory exercises. The theory and real-time principles are presented in short lecture modules like the one shown below, while the laboratory exercises are performed using a DSP development board attached to the student's local computer. The use of a physical development board allows more realistic laboratory exercises to be performed than would a network-based simulation tool. Student interaction, instructor feedback, and course organization are provided through the web interface. The student interaction and hands-on aspects of the course more closely approximate a university experience rather than a typical asynchronous web-based training course.

1. Introduction

The rapid advancement of technology experienced over recent decades makes it difficult for engineers to keep themselves abreast of the current technology. This is especially true with digital signal processing (DSP). DSP is now pervasive as it is used in everything from disk drives and cell phones to automobiles and stereo equipment. The sale of special DSP microprocessors exceeds the sale of general-purpose microprocessors by almost 10:1. However, until recently DSP was only taught in the graduate curricula of most universities and many practicing engineers have never been exposed to DSP. Many of these engineers now find themselves working on products that use DSP microprocessors. Outside of the campus environment, the DSP semiconductor industry is doing a good job training engineers in the practical aspects of DSP use through workshops and seminars. The missing link is teaching engineers already in the workforce more DSP theory; especially, the implementation of this theory on real-time DSP processors.

The landscape of distance learning and continuing education has changed dramatically in the last few years, as the Internet has become a viable delivery mechanism. Traditional university involvement in corporate training or continuing education has been through short courses or video courses. Short courses are usually offered over several days at the university campus. They can be effective but may also disrupt an engineer's work schedule. Additionally, since the course is often offered in a remote location, there may be added inconveniences of travel and increased cost. Video courses, unless delivered real-time over dedicated satellite or network connections, provide very little interactivity. Internet-based education shows promise in many respects: materials may be delivered either synchronously or asynchronously; there are multiple modes of presentation available; many types of interactivity are possible; world-wide delivery may be possible, and delivery costs may be reduced. There are, of course, problems with Internet-based delivery and many of them will be discussed in the body of the paper.

The need for and difficulty in educating employees is not new and is evident in many engineering disciplines as well as in business, computer science, and a host of other specialties. This paper only discusses how the problem was addressed at Georgia Institute of Technology in the area of DSP through the development of an Internet-based course.

2. Overview of the Internet-Based DSP Course

Georgia Tech developed an internet-based course on the fundamentals of DSP and the implementation of DSP algorithms. The course was developed with the cooperation and support of Texas Instruments, Inc. and it features lecture modules by professors in the Georgia Tech Center for Signal and Image Processing; laboratory exercises using the TMS320c62x platform; and online feedback, testing, and exercises. The target audience consists of practicing engineers with disparate backgrounds. The goal of the course is to teach basic DSP theory as well as principles specific to the implementation of DSP algorithms on a fixed-point processor. The course length is designed to be roughly equivalent to a one-semester university course. It will be delivered asynchronously over the Internet as described below and it takes about 12 weeks to complete. Due to the breadth of the material covered, students will gain a firm foundation in basic DSP principles and learn skills needed to implement DSP algorithms but they will not be expected to become experts in the field. However, it is expected that the background will be sufficient that the students can effectively continue individual study in areas of concentration.

The material itself is divided into short modules, each consisting of a streaming media presentation, homework problems, and occasional supplemental material or on-line self-tests. Topics covered in the course are divided into three main areas addressing the following topics.

Linear, time-invariant (LTI) system theory,
quantization and finite word length effects,
basic Fourier analysis and frequency response,
z-transforms,
fixed-point filters,
sampling theory,
FIR filters and convolution,
IIR filters,
fixed-point arithmetic,
basic DSP microprocessor architecture,

TMS320c62x fixed point DSP architecture,
interrupts and I/O,
multi-string environments and re-entrant code,
buffering and direct memory access (DMA),
multi-tasking and scheduling,
and DSP development environments.

3. Pedagogical Considerations

3.1 Target audience

The first consideration in developing the course was the intended audience. The input of associates at TI was invaluable in assessing both the make-up and needs of the intended audience. This was done through questionnaires filled out by participants in TI training seminars. It was that the target audience consisted of people with engineering degrees who knew how to program and were often involved with the design of a DSP microprocessor based product. These engineers found that they needed DSP knowledge for their work but they did not usually have the luxury returning to school to obtain this expertise. They engineers in the target audience were likely to be implementing DSP algorithms but not designing them.

3.2 Topic selection

The course curriculum was then determined based on the target audience. In a typical university course, there is a great emphasis on the underlying theory, with applications being presented primarily to motivate the theory. This approach attempts to provide a broad base of understanding that the students can apply to solving new DSP problems. A single semester length course in DSP is insufficient to supply that level of understanding and an in-depth coverage of a few topics would leave many topics untouched. In addition, the students in this course wanted topics not usually covered in a university DSP theory course—fixed-point signal representation and quantization effects, fixed-point filter implementation, and real-time DSP microprocessor programming. Therefore, the guiding catch phrase in designing the course curriculum became, “walk them down the hall and show them the doors.” In other words, the course was designed to introduce basic theory, and implementation of basic algorithms in a fixed-point environment with enough practical applications to get the student started and enough theory so that they could understand whatever else they may need to learn through individual study. Advanced topics are mentioned but not covered in depth, hence the “show them the doors” phrase.

3.3 Curriculum organization

The target audience also influenced the presentation and organization of the course material. Since the amount of material to cover was great and since the students were located all over the United States and overseas, the course was developed as an internet-based course. Since the course was aimed at engineers with full-time employment, it was desirable to break the course into short modules that could be completed in a relatively short amount of time. Each module consists of a short (5-15 minute) streaming media presentation, homework problems, and online self-test problems.

The short modules have many additional benefits for both the students and those who maintain the course. Students can pick and choose to study only those topics with which they are not familiar. It is easier to produce or modify a short module than a long one and topics can be updated by simply replacing a short module rather than editing a long lecture. When viewing a streaming presentation over a slow or unreliable connection the likelihood of successfully viewing the entire presentation is greatly increased for short presentations. It may also be possible to download the entire presentation prior to viewing. Finally, the short modules keep the student's attention more easily than a longer lecture, with more frequent reinforcement of the concepts via the homework and self-test questions.

3.4 Laboratory exercises

Another important aspect of the curriculum was the need for "hands-on" experience. Learning is greatly accelerated by the application of the principles learned. This need was addressed by having weekly laboratory exercises that the students perform on a hardware DSP development kit. The laboratory exercises were designed to complement the material covered in the lecture modules.

4. Internet Course Delivery

The options available for Internet delivery of educational material are vast. Some of the possibilities considered for this course included HTML only; HTML synchronized with audio; HTML with audio and Flash animation; streaming video only; and streaming video synchronized with an HTML presentation, Flash animation, HTML slides, Java enhanced pages, etc.
For slow Internet connections the first three methods are preferred. Over a modem, the poor quality of a sustained video stream often makes it more distracting than useful. A straight HTML based presentation can be effective, but it is difficult to design pages that convey enough information in an engaging manner. Also, it is unlikely to meet students' expectations for taking a university course. HTML synchronized with audio is used by various online training establishments, but the authors of this paper found it to be somewhat less engaging than desired. Some online training web sites such as http://www.techonline.com use professional speakers to record scripts prepared by academics. This increases the quality of HTML with audio but it is was not a practical option at Georgia Tech. HTML with audio and animation results in presentations that can be streamed over low capacity connections and yet remain fairly engaging. The primary difficulty with this option is that the production time is very large to produce a quality presentation.

For faster Internet connections video becomes viable. However, for high-quality video even LAN connections can have problems when competing network traffic causes intermittent congestion. Because of the high resolution needed to convey written information, sending the entire presentation as one large video is impractical for general Internet delivery. Streaming video synchronized with an HTML presentation makes it possible to use smaller, lower-bandwidth video to show the presenter or supplemental information while using the HTML to convey all written information. Streaming video with HTML, Java, Flash, etc. is the most complex of the presentation types. When prepared with judgment this type of presentation may be the most effective at conveying information and providing interactivity. However, it must necessarily require the most effort during production. Estimated time for production of detailed presentations having the components of above can be as much as 100+ hours for every hour of presentation.

The list of 6 options above is not comprehensive but it does demonstrate the trade-off in designing a presentation that is high quality, easy to produce, and deliverable over the Internet. For the online DSP course Option 5 was used and tools were developed to decrease the production time by automatically putting the presentation together with synchronized slides. The presentations use a small video showing a headshot of the presenter designed to capture wandering eye and keep the student's attention on the presentation. Large slides are used to convey written information; and simple animations are achieved by timed slide transitions, as shown in Figure 1 below.

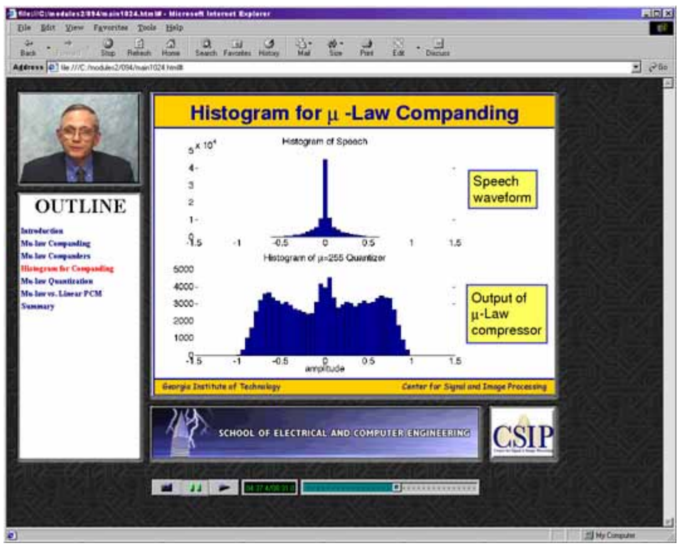

Figure 1

4.1 The bandwidth hurdle

Even with small video (about 150x100 pixels) at 10 frames per second, compressed, the required capacity is too large for slower Internet connections. To address this problem a hybrid delivery method was used. The hybrid method involves sending the students copies of a CD-ROM that contains the lecture presentations (the video, HTML and graphics). Then the course organization is provided via a web page that links to each student's CD-ROM drive on their computer. The web page is created using WebCT, a web course tool that permits each student to log in and keeps track of individual information, accesses, and statistics. WebCT also provides the tool to control access to the students' CD-ROM drives. This arrangement permits the viewing of high-bandwidth, high-quality presentations in a web browser while keeping control of the course from a central location using a low-bandwidth connection.

4.2 Web organization

In addition to the presentations, some other course characteristics were considered essential; these included interaction between students, a method for evaluating students' understanding, and student login. This functionality was also provided via the WebCT environment.

4.3 Student Interaction

Students need feedback in the learning process. They also need answers to their specific questions. For these reasons, delivering an Internet-based course must have a means of two-way communication. For the DSP course students used the WebCT bulleting board to post questions and/or comments to each other and to the instructor. The bulletin board was monitored by a professor as well as by graduate students in DSP, representatives of Texas Instruments, and continuing education department personnel. When questions on the bulletin board were not easily answerable in writing they were handled by telephone.

The amount of discussion on the bulletin board far exceeded that of a similar course offered on campus, using WebCT. It seems that when the students are not located near each other there is a greater need for individual attention. This seems to directly contradict the belief by some that Internet-based education is completely scalable.

5. Course Preparation

The professors involved in preparing the online DSP course found that the preparation time required far exceeded the preparation time required for a traditional course. To decrease the time required, we developed a presentation synchronization tool, inFusion, which significantly decreased the online lecture module construction time, making it possible for a professor to create lecture modules without other assistance, in little more time than required to present the material to a camera. However, filming and course preparation is very time consuming and, even with tools enabling quick construction of online presentations, it takes a relatively large amount of time and resources.

6. Conclusion

Many universities are under pressure from within and without to develop online courses. The belief by many is that this is a simple transcription from one medium to another. Our experience has shown us that Internet-based education is dramatically different from traditional courses or even from traditional distance education courses. In particular, the amount of work in preparing an effective online course exceeds all other continuing education and distance education courses that we have developed at Georgia Tech. In addition, the delivery of an online course must consist of more than simply giving out the address to a web site. If anything, online students require more individual attention than traditional classroom students, especially if they are involved in hands-on learning projects. We also feel that the benefits of online education, in many cases, justify the increased cost. Finally, we believe that Internet-based education will continue to grow, especially in the area of corporate training. As this field expands we must work closely with industry and individual engineers and professionals to ascertain their needs and prepare materials accordingly.

The short course "DSP for Practicing Engineers" was first offered beginning in February 2000, to 50 students. It has also been offered to 30 students in June 2000, to 65 students in September 2000, and will be offered again in February 2001. Information about this course can be found at www.ece.gatech.edu/streaming, along with further information about streaming media courses and software tool development at Georgia Tech.

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