

DSP FOR PRACTICING ENGINEERS: AN ONLINE COURSE FOR CONTINUING DSP EDUCATION

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ABSTRACT

The recent rapid increase in applications of DSP has generated a need for technical personnel with a DSP background. Until recently, most DSP education has been at the graduate level, so many practicing engineers are developing a need for additional DSP education. At Georgia Tech we are delivering an online continuing education course that is targeted at these engineers. The 12-week course is comprised of three interconnected tracks in DSP system theory, real-time implementation principles, and laboratory assignments with MATLAB and the latest fixed-point TI DSP chips. The course was designed after a needs analysis performed by Texas Instruments training specialists. It is intended specifically to provide a full semester's course in a way that is adapted to the schedules and circumstances of practicing engineers. In this paper we describe both the content of the course and the technology for delivering it online.

1. INTRODUCTION

Universities are developing very good curricula in DSP for undergraduate students with courses in DSP theory, implementation, and applications. 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 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 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. Recently, representatives at Texas Instruments, Inc., a leading producer of DSP microprocessors, presented to educators at the Georgia Institute of Technology this problem of how to train practicing engineers the basics of DSP and the implementation of DSP algorithms.

Corporate training is becoming a multi-billion dollar business and many universities are feeling pressure to become more involved through continuing education and/or distance learning

programs. Although a few schools have had such programs for years, educating practicing engineers is new for many universities. In addition, 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 and, since the course is often offered in a remote location, there may be the added inconvenience and increased cost of travel. 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;
- Worldwide 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 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. NEEDS ANALYSIS

2.1 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 makeup and needs of the intended audience. The target audience would be electrical engineers with bachelors or Masters degrees who are already working in the industry with little or no knowledge of DSP theory, but possibly some practical DSP programming experience, work experience with processors, and C-language programming. Thus, the target audience typically consists of people with engineering degrees who know how to program and are often involved with the design of a DSP microprocessor based product. These engineers may find that they need DSP knowledge for their work but they do not usually have the

luxury of returning to school to obtain this expertise. The engineers in the target audience are likely to be implementing DSP algorithms but not designing them.

2.2 Survey Results

Engineers at TI DSP seminars in the Southeastern US were asked to fill out a survey on continuing DSP education. The surveys were taken at the Atlanta, GA; Huntsville, AL; and Tampa, FL seminars. Of 64 participants, 34 engineers completed the surveys stating that they had interest in a continuing education course, 3 participants indicated no interest, and 27 did not complete the survey. Most of these engineers were people who wanted to know more about DSP but had very little real-world design experience with DSPs.

Some of the highlights of the survey results were:

- A slight majority of respondents (59%) were interested in Internet-based instruction.
- A large majority (85%) indicated that their preference would be DSP tools at home with assistance from a lab instructor via the Internet, phone, or email.
- The breakdown of respondents' interest in particular DSP topics is shown in Figure 1

Filters – FIR and IIR	85%
Implementing real-time operating systems	85%
Interfacing issues	76%
Discrete-time signal processing – sampling and aliasing	74%
Fixed-point processing techniques	68%
z-transforms	65%
Spectrum analysis	65%
Understanding current DSP hardware and design issues	65%
Code testing techniques	65%

Figure 1. Respondents' interest in individual topics within the DSP subject area.

3. STRUCTURE OF COURSE

3.1 Curriculum Design

The course curriculum was then determined based on the target audience and its needs. 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, such as fixed-point signal representations and quantization effects, fixed-point filter implementation, and real-time DSP microprocessor programming. Therefore, the guiding principle 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 the theory and implementation of basic algorithms in a fixed-point environment. It includes enough practical applications to get the students 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.

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 is 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 may 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 is sufficient so 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 supplementary material or online self-tests. Topics covered in the course are divided into three main areas:

Learning basic DSP concepts

- Sampling and quantization
- Linear, time-invariant (LTI) system theory
- Convolution and difference equations
- Filters and filter structures
- z-transforms
- Basic Fourier analysis and frequency response
- System response and characterization
- Fixed-point DSP issues

Gaining experience in implementing DSP algorithms

- Basic DSP microprocessor architecture
- An overview of the TMS320c62x fixed point DSP architecture
- Algorithm simulation and verification
- C-language algorithm implementation
- Buffering, threading, code organization
- Optimization

Becoming acquainted with the c^x DSP architecture and development tools

- C compiler and assembler
- Real-time kernel
- Debugging
- Profiling

- Libraries and intrinsics

The characteristics of this course are defined not just by its content, but by the material that had to be left out. A number of topics were intentionally *not* covered, including:

- Hardware design
- Different DSP platform comparisons
- Extensive optimization details
- Peripheral configuration and communication
- Most advanced DSP issues

3.2 Curriculum Organization

The target audience also influenced the presentation and organization of the course material. Since there was a large amount of material to cover 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 short streaming media presentation, nominally between 10 and 20 minutes long, with associated homework 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.

3.3 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 the 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. DELIVERY METHODOLOGY

There are a number of options available for Internet delivery of educational materials. For the construction of this course, a number of different possibilities were considered:

- HTML only
- HTML with synchronized audio
- HTML with audio and Flash animation
- Streaming video only
- Streaming video synchronized with an HTML presentation

- Streaming video, Flash animation, HTML slides with Java enhanced materials

The simplest method would be to create HTML-only materials. The primary advantage of this method is that construction of the course is very simple. Most presentation software can export HTML, and existing materials can be published using PDF or other formats. A significant drawback of HTML-only materials is that it is very difficult to engage students in the learning process, and the course is considered by the students to be little more than an electronic textbook, and does not meet student expectations of a university course. HTML with audio is used by a number of online training establishments, but initial tests at Georgia Tech showed that student engagement was still somewhat less than desired. HTML with audio and animation improves student engagement over HTML with audio only, and appeared to be a sufficient solution. However, in order to fully engage students, the number of animations must be relatively large, and production times became prohibitive.

For faster Internet connections video becomes viable. The primary advantage of video delivery is that it allows the projection of the instructor's teaching style, and results in a much more engaging process. However, for high-quality video even local LAN connections can be insufficient under congested network conditions. Sending an entire finished lecture over the network as a single large video becomes impractical if the resolution of the video is kept high enough to allow textual material to be conveyed. However, most of the advantages of video presentation can be achieved by transmitting video of the instructor, and using still images and animations to convey the course material.

A major difficulty with constructing course modules containing video, text, still imagery and animations is the time required to synchronize and connect all the materials into a coherent whole. To overcome this problem, a number of commercially available software tools were tested, but the difficulty of constructing the desired course layout was not decreased appreciably. Since multiple faculty members were involved in the development of the course, a simpler method of constructing the course modules was required. The solution used for this course was an internally developed tool, inFusion, that decreases the production time significantly. inFusion takes images and animations, and records the events that occur as the instructor presents the slides, as well as recording video of the instructor, and automatically creates a synchronized output presentation. The input images can be Powerpoint or LaTeX slides or any other web-displayable graphics. The use of inFusion enables the instructor to construct streaming rich media presentations in approximately the same amount of time as it takes to simply present the material.

4.1 Overcoming Bandwidth Issues

Even with small, compressed video (about 150x100 pixels) at 10 frames per second, 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 the local computer. The web page is created with 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 student's CD-ROM drive. 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 access control. 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, the primary means of communication is the WebCT bulletin board. The use of the bulletin board allowed two levels of interaction: student-student interaction and student-instructor interaction. All students in the course are encouraged to check the bulletin board every day, and the bulletin board is monitored by a team of five graduate teaching assistants. The board is also checked by the professors involved in the course and continuing education personnel. Observers at Texas Instruments also monitor the bulletin board occasionally. The volume of discussion on the bulletin board far exceeded that of a similar course offered on campus using WebCT.

Bulletin board communication was sometimes found to be insufficient. When real-time communication was needed, two methods were used: telephone and real-time chat. Immediate questions were handled via phone, and general interactivity was provided by scheduled chat sessions.

Perception of a student "community" by the students was found to be very important. When students are separated geographically, it appears that a greater demand for individual attention and community-building activities exists. This effect limits the scalability of the course.

5. CONCLUSION

Georgia Tech has 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 TMS320C6x platform; and online feedback, testing, and exercises.

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 of 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, and to 65 students in September 2000. 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.

6. REFERENCES

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