A Follow-up to "DSP for Practicing Engineers" offered by Georgia Tech

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Abstract

This paper presents a description and assessment of an ongoing, online, continuing education course offered by Georgia Tech, covering introductory digital signal processing (DSP) and real-time programming. The target audience for this course is electrical engineers with Bachelor's or Master's degrees who are working in industry with little or no knowledge of DSP and some work experience with micro-processors and the C programming language. During the course, students are assigned several lab exercises to explore different aspects of DSP and the particular processor being used. Lecture material on DSP theory is delivered in the form of streaming video and slides on a CD-ROM. Online quizzes are given to test student comprehension of lecture material and laboratory concepts. A staff of teaching assistants was hired to provide support for students. In order to provide an extra incentive, a distance learning certificate is awarded after successful completion of all course requirements.

Keywords

online education, distance learning, digital signal processing (DSP)

I. Introduction

Digital signal processing (DSP) is a core technology in many high tech products ranging from voice coding over wireless channels to scene change detection in video analysis. Consequently, many engineers find themselves implementing DSP algorithms on DSP processors. Online education provides a means by which these engineers are able to update their technical skills in DSP. The first Georgia Tech "DSP for Practicing Engineers" course was offered two years ago[1]. Since then, this course has been offered six times for three processors. Feedback from the students has already prompted changes such as the addition of several teaching assistants (TAs), each specializing in a particular aspect of the course, as well as a streamlining of the course information via a class webpage.

II. Background

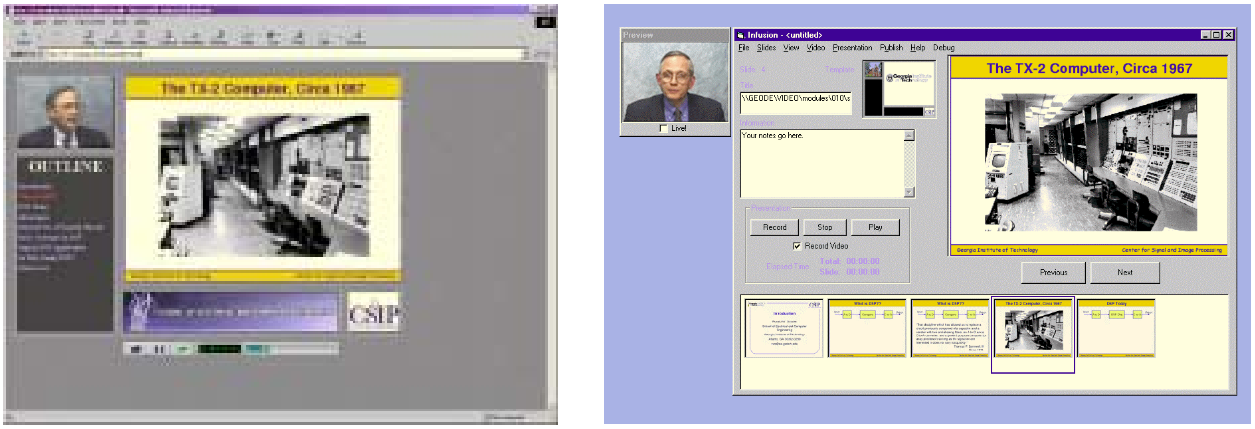
The "DSP for Practicing Engineers" course originally was designed for practicing engineers who wished to couple a theoretical foundation in DSP with a practical foundation in application implementation. The course runs 14 weeks and is web-based using WebCT, a web course tool that permits each student to have personalized access to course material and allows instructors to keep track of student information, website accesses, and student statistics. The prerequisites for the course are flexible, but math through calculus and a reasonable familiarity with the C programming language is highly recommended.

Lecture material was prepared by Georgia Tech faculty explicitly for this course. The main topics covered include linear time-invariant systems, FIR and IIR filters, quantization, profiling, DSP architecture, and the discrete Fourier transform. The lectures were designed both for students who have already been exposed to the material and wish to relearn it, as well as students who are seeing it for the first time. One of the additions made to the course concerns the lectures indirectly. Self-test questions for each lecture were posted on the course website in addition to relevant homework problems from the textbook. Unlike the homework problems, the self-test questions had posted answers and tended to be simpler and more similar to quiz problems. This major addition was well-received and is discussed below with the other results.

The course is offered remotely with the lectures sent via CD-ROM so that they can be viewed at the student's convenience. Students are sent course materials including a Texas Instruments (TI) DSP starter kit (DSK), around which all of the lab exercises have been designed. The DSK is the crux of the course, offering hands-on experience with DSP hardware as well as practical real-time DSP programming.

In order to remain current with emerging technology, the lectures provided to students are constantly updated using specialized software. Even with small, compressed video (about 150×100 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 developed. This method involves sending the students a CD-ROM that contains the lecture files (including video, html, and graphics). The course organization is provided via a webpage that links to each student's CD-ROM drive. The lectures themselves are created via inFusion, a proprietary program developed at Georgia Tech expressly for computer-based education[2]. There is an inherent advantage to providing the lectures on a CD-ROM; if a student's network connection is ever down, they are still able to view lectures according to our schedule defined at the beginning of the course. This would not be possible if the lectures were only available from the website, and is especially useful for international students. The course has been taken by students all over the world (e.g., Kuwait, Korea, etc.) and streaming to distant locations is problematic.

Additional course materials include the *Discrete-time Signal Processing* textbook by Oppenheim and Schafer, MATLAB, TI DSK reference material, and the CD-ROM containing the lectures. A screenshot from a typical lecture may be seen in Figure 1 (a). The lecture module consists of a small video of the lecturer's face, a large box containing a lecture slide, and an outline for the lecture that the student can use to advance to a specific point in the lecture. The lecture-making software inFusion is shown in Figure 1 (b).



(a) (b)

Figure 1: (a) An example of a lecture being viewed via the WebCT webpage. (b) The same lecture being made in inFusion.

III. Student Interaction

One issue pertaining to online education deals with the idea of community building. Student interaction with each other and the faculty has always been considered to be a significant component of the learning process. This course provides several methods of interaction between everyone involved.

The main channel of student interaction between students and faculty is the bulletin board offered via WebCT. The bulletin board consists of several different threads of discussions, typical of a newsgroup forum. Throughout the 14 weeks, the TAs constantly check the bulletin board for questions which range from homework problem discussions to administrative issues such as course completion requirements. Questions pertaining to the labs dominate the bulletin board.

The other primary source of feedback is a set of course surveys that are given periodically throughout the course. In order to diagnose student backgrounds and abilities, an initial course survey is offered after the first week of the course. It also serves as an indicator of how the students felt about the material and set-up of the course. A survey is also given half-way through the course to check the progress of the students. A final course survey is given at the conclusion of the course to obtain students' opinions of the entire course.

IV. Labs

As mentioned earlier, the labs form the basis of the course. Though atypical of remote courses, it was concluded that the course needed the labs for completeness. This section provides an overview of the labs as well as the adjustments made as different versions of the course were offered.

In order to keep abreast of emerging technology, the course has been made available for several, different TI hardware and software implementations. The original course used the TI ’C6211 DSK, which has since been discontinued. This discontinuation caused a migration towards the TI ‘C6711. The TI ‘C6211 was a fixed point processor, and the TI ‘C6711 is both a fixed and floating point processor. Another version of the course has been offered using the TI ‘C5402. Because of advantages such as its power efficiency, small packaging, and low cost, the ‘C5402 has become extremely popular among manufacturers of cellular phones, for example, potentially increasing the appeal of the course.

Additionally, new and old versions of code composer studio (CCS) are supported by our staff. The labs originally were all written for version 1.23, but for the TI ‘C5402, the labs were rewritten for version 2.0 since changes had to be implemented to accommodate the new hardware as well.

The labs themselves cover several topics. The first lab is coupled with lectures from TI’s one-day course on the particular DSK being used. A typical lab schedule is

- Lab 1: Equipment Set-up
- Lab 2: Compiler/Debugger
- Lab 3: Generating Digital Signals
- Lab 4: Filtering
- Lab 5: Frequency Response
- Lab 6: IIR Filtering
- Lab 7: Real-time Processing

These labs are posted evenly throughout the course; however, the students appreciate having access to all of the labs as early as possible to allow them to keep a flexible schedule with their work.

Despite the usual hardware configuration frustrations, the new feature of labs has enhanced the online experience. The feedback given with respect to the labs is discussed below.

V. Teaching Assistants

The inner workings of the course are quite diverse and require extensive attention to detail. Originally, only a single TA was hired for course maintenance, but as development issues decreased and administrative work increased, the need for more TAs became apparent. Each individual TA specializes in a particular aspect of the course. Because most of the questions pertaining to the course concern the labs, three teaching assistants were delegated to lab assignments consisting of grading lab reports, answering lab questions from students, and designing or redesigning labs. The other TAs provide administrative support regarding the course website and overall student grading. Teaching assistants are constantly available for student questions primarily via the WebCT bulletin board and e-mail.

VI. Results

The general sentiments of the students from final remarks made on the course surveys indicate a positive feeling toward the course with some areas for potential improvement. These areas were specifically targeted. For example, more attention to bulletin board questions were given with the addition of more TAs, and confusing points in the use of the DSKs were eliminated with an overhaul of each lab exercise.

However, some student suggestions were difficult to accommodate. After attempting to e-mail students who were falling behind by mid-course, it was concluded that the work schedules of the students preclude strict adherence to the course schedule. Consequently, instead of trying to follow the course outline to the week, a more flexible approach of allowing students to roll over to later courses or extending deadlines has worked well. This attitude of flexibility has increased motivation for students to see the course to completion.

According to the initial course surveys, the course is being utilized by the target audience. Students are all in industry with at least a Bachelor's degree, some with a Master's (23 of 51), and very few with a Ph.D. (2 of 51). The distributions for DSP background as well as MATLAB and C programming are fairly even ranging from no background to graduate level DSP courses and no experience to extreme proficiency, respectively. Additionally, the vast majority of students wish to have a good balance between DSP theory and application. Students tend to primarily access the course remotely from home or the office. Also, 32 out of 52 students were fully funded to take this course by a company, organization, or institution.

The final course survey results with quantitative responses may be seen in Table 1. Each box reflects the number of students who responded with that sentiment in the Fall 2000 / Summer 2001 courses where applicable (the survey itself has changed over three iterations). According to student responses from the final course surveys, the course is showing improvement with each iteration.

As for the labs, a brief report from the students is all that is required. This typically includes MATLAB and C code, but usually requires some kind of description as well. These descriptions are good indicators of a student's grasp of the procedure and its purpose. The following abstract was taken from a student asked to discuss quantization effects in a real-time application:

```
Comments: After some initial difficulty, first due to an old
version of CCS, then due to a typo, the program ran as expected. I
modified the linearQ routine as shown below.

The Quantization to 8 bits was only slightly, if at all
distinguishable from the original 16 bit input. This is likely due
to the quality of my computer speakers and the choice of music.
Any difference that could be heard was primarily in the silent
passages, where more background “hiss” could be observed.
```

```
At 10 and 12 bits of shift (or 6 and 4 bits left), the results
were dramatic. The background noise level came up significantly.
The quality of the music being played dropped. I also inserted a
statement to view the data samples in one of the various runs, in
order to prove to myself that the Quantization was proceeding as
expected. I did this using a LOG_printf, on trace, with the
quantized data sample.
```

Lab reports are obviously very informal but intended to demonstrate the student's completion of the assignment and understanding of the material.

Statements	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
The course lectures are of high quality, well delivered by the instructors, and easy to understand.	3 / 0	2 / 2	4 / 1	7 / 5	5 / 3
Overall, the administrators and TAs of this course have been prompt and accommodating to my needs and concerns.	3 / 0	0 / 0	6 / 1	6 / 1	6 / 9
The labs were effective and productive learning tools.	3 / 0	0 / 1	3 / 2	11 / 2	4 / 6
The quizzes were fair and effective in assessing my aptitude in the course material, and appropriate as a part of the criteria for determining my passing/failing of this course.	– / 0	– / 0	– / 1	– / 6	– / 4
The self-test questions (accompanying each lecture module on the website) were helpful and well designed.	– / 0	– / 1	– / 1	– / 5	– / 4
I feel that the bulletin board and private mail features have been sufficient for communicating with the administrators and other students in regard to this course.	– / 0	– / 0	– / 1	– / 3	– / 7
I feel the WebCT interface is easy to use and effectively communicates the course material.	0 / 0	3 / 0	3 / 2	13 / 4	2 / 5
I am satisfied with WebCT's speed (taking into account the speed of my Internet connection).	1 / 0	0 / 0	1 / 1	10 / 3	9 / 7
Overall, this course has been a great learning experience for me.	4 / 0	0 / 1	3 / 0	6 / 3	7 / 7

Table 1: Final course survey results for the Fall 2000 / Summer 2001 courses.

VII. Conclusions

The many iterations of this course have provided many opportunities to improve it. Several instances of course improvements have been made including the obvious debugging of Internet and software features as well as the addition of more TAs to assist in day-to-day operations. Course content has also gradually become more extensive.

Using the success of this course as a model, we intend to produce more advanced DSP-oriented courses for further study by practicing engineers.

Additional course information may be found at `http://www.conted.gatech.edu/dsp/index.html`.

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