Challenges in Teaching a Digital Signal Processing Course to International Graduate Students

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Introduction

Founded more than 60 years ago by a true educational pioneer, Dr. Peter Sammartino, Fairleigh Dickinson University has gained an international reputation for innovation and adaptation. In the year 2000, the University renewed and formalized the long-standing emphasis on global themes through the adoption of a new mission: to prepare students for world citizenship through global education [1]. Fairleigh Dickinson University (FDU) being a leader in global education welcomes international students of diverse backgrounds to its engineering degree programs every semester. Most of these students possess high analytical abilities but have certain backgrounds that make them struggle to conform to the US academic norms. This author teaches a core Digital Signal Processing (DSP) course, EENG6633 [2] taken by first semester graduate students as well as follow-up advanced courses on DSP applications (EENG7753) and DSP implementations (EENG7852). This paper outlines some of the challenges posed by these students in our DSP as well as Digital Communication courses and a few remedial actions we take to circumvent them.

FDU Digital Signal Processing Curriculum

A few words about Digital Signal Processing and Communications specialization area at Fairleigh Dickinson University are in order. All graduate students admitted to FDU Electrical Engineering program have a core requirement of completing four courses that include EENG6633 – Digital Signal Processing and EENG6747 – Digital Communications. EENG6633 introduces fundamentals of Digital Signal Processing culminating in the design of Finite-duration Impulse Response (FIR) and Infinite-duration Impulse Response (IIR) filters [3-4] both analytically and by using MATLAB [5-6] with various toolboxes. There is a lot of emphasis on actual design and visualization in addition to mathematical derivations. Towards the end of the course, digital signal processing algorithm implementations on commercial digital signal processors [7] are introduced.

After the successful completion of EENG6633, graduate students get exposed to advanced topics and various applications of digital signal processing in speech and communications in the EENG7753 [8] course. Multiple projects are assigned to be completed on MATLAB in EENG7753.

Subsequently implementation of applications of DSP on commercial digital signal processors is taught in EENG7852 [9]. Relevant algorithms and applications are first simulated on MATLAB. Then students use C as the language of choice for application development with some assembly language coding. The applications are downloaded onto a development system and run in real
time to experience run time debugging, code optimization, and other issues faced in real-time DSP application development.

Formulae Memorization versus Derivation

Approximately two-thirds of our international students have been well trained in the theoretical aspects of DSP fundamentals in their undergraduate curriculum. Many of them are used to remembering complex formulae and not well conversant with their applications. Here at FDU, we encourage them not memorizing theory and guide them through hints in solving a design problem from the first principles. For example, finding the order of a Butterworth lowpass filter can be attempted from the magnitude response equation by applying the specifications. More than 50% of the students try to memorize the formula for order calculation without paying close attention to the parameters needed by the formula, thereby coming up with erroneous results. Additionally, the formulae tend to be different depending upon the underlying assumptions. Some of them are based upon a certain set of parameters than the other. As an example, filter design can be undertaken based either on absolute magnitude or dB specification [5]. The frequency values could be either in Hz or in radians/sec. Depending upon the specification, the formula for order calculation will be different.

For a relative specification, the order $N$ of a Butterworth lowpass prototype is given by:

$$N = \left\lfloor \frac{\log_{10} \left( \frac{10^{R_p/10} - 1}{10^{A_s/10} - 1} \right)}{2 \log_{10} \left( \frac{\Omega_p}{\Omega_s} \right)} \right\rfloor,$$

where $R_p$ denotes the passband ripple in dB, $A_s$ denotes the stopband attenuation in dB, $\Omega_p$ is the passband edge angular frequency in radians/s, and $\Omega_s$ is the corresponding stopband edge angular frequency in radians/s.

In the case of absolute specifications in terms of 3-dB cutoff frequency $\Omega_c$, the order $N$ is given by

$$N = \left\lfloor \frac{\log_{10} \left( \frac{1}{\delta_2^2} - 1 \right)}{2 \log_{10} \left( \frac{\Omega_s}{\Omega_c} \right)} \right\rfloor,$$

where $\delta_2$ is the absolute attenuation factor.

Both of the formulae will work if applied correctly. The second one is slightly restrictive in that 3-dB cutoff frequency is used instead of a passband edge frequency.

Even when we provide the correct formula for order calculation, students make mistakes in mapping parameters properly to match the formula. As for example, if the first formula is provided and 3-dB cutoff frequency is specified, many students do not map the cutoff specification to passband edge correctly and solve for the filter order. This happens due to the complexities associated with the formulae and diverse parameters they use.

However, most of the time we at FDU provide fundamental relation for filter magnitude and ask students to use it for calculating the order or finding attenuation, etc. after proper mapping of parameters and simple derivations. The students who solve problems based upon fundamental relations make fewer mistakes than those who use memorized formulae. Note that our domestic students are used to solving problems from first principles or by following the hints supplied with the problem. So we rarely see such issues with our local students.

Visualization and Tool Usage in DSP

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To teach the principles of application of DSP, we emphasize graphing and plotting the results both manually and using industry standard MATLAB. Many international graduate students enrolled in our class do not have the habit of drawing figures for visualization and problem solving. They have learnt problem solving by plugging in to equations. However, like in any engineering discipline, drawing figures and plotting curves is essential for the complete understanding of digital signal processing concepts. As for example results of convolution, correlation, filtering, etc. are better understood when underlying sequences or spectra are plotted and deductive logic is applied to draw some conclusions.

To corroborate the power of visualization in digital signal processing, we cite the example of computing the response of a Linear Time Invariant (LTI) system characterized by the impulse response \( h(n) = (0.9)^n u(n) \) when a rectangular pulse \( x(n) = u(n) - u(n - 10) \) is applied at its input and \( u(n) \) is the unit step sequence. Of course, analytically using the convolution relation one can compute the response \([6]\) as follows:

\[
y(n) = \begin{cases} 
0, & \forall n < 0 \\
10[1 - (0.9)^{n+1}], & 0 \leq n < 9 \\
10(0.9)^{n-9}[1 - (0.9)^{10}], & n \geq 9 
\end{cases}
\]

The above set of equations provides little engineering insight into the convolution process and the result. However by using a graphical technique where a folded-and-shifted version of \( h(k) \) can be moved from left to right, a lot more is learnt about convolution operation. This movement operation will generate a non-zero output \( y(n) \) only when both \( x(k) \) and \( h(n-k) \) have some overlap. Since the folded-and-shifted version of \( h(k) \) is moved from left to right and \( h(k) \) is an exponentially decaying sequence, the output \( y(n) \) will grow exponentially from \( n = 0 \), reach a peak at a point and decay exponentially thereafter. Thus by drawing the sequences using MATLAB as shown below more insight into the result is obtained.
MATLAB is also used for complex designs and system simulations. Many of our international students prefer solving digital signal processing problems using formulae directly. Some of them think MATLAB as yet another programming tool which is not essential for day to day engineering work or can be learnt on the job, as needed. As we all know, small and mid-sized corporations do require working knowledge of the tools needed for the work. By highlighting the visual feedback aspect of graphical techniques, system level simulation, and complex designs throughout the course, we have been able to demonstrate the criticality of tool usage in application development. We assign homework problems that need to be solved using MATLAB. Additionally we assign multiple projects based upon MATLAB and work with the students in the laboratory to take their fear out of the usage of the tool and turn them into tool champions. As an example, our speech processing projects demonstrating the effects of decimation, interpolation, sound mixing, and filtering using MATLAB provide almost real time feedback (via sound playback) helping students grasp the effects of these operations. A simple example of noise filtering by a median filter in the laboratory helps students appreciate the complexity and power of real time signal processing.

Note in the above filtering example, almost a million median computation operations are involved in a few seconds of speech signal which obviously cannot be done manually. Also the Median Filtered Speech does sound almost the same as the Original Speech when played back. But a close examination of the Median Filtered Speech waveform shows a spike that was absent from the Original Speech waveform. Thus by proper real-world assignments at FDU, we have been able to turn the international graduate students into real MATLAB users and appreciate the power of visualization and simulation.
Continuous Student Evaluation

Some of the international students find our system of continuous evaluation through multiple homework assignments, projects, and examinations somewhat daunting since they are used to taking one final examination for a course. A single examination based evaluation does not help the student improve her/his grades while the course is being taught. Here at FDU, we assign a dozen set of homeworks, multiple laboratory projects, and 3 examinations at a minimum. We even assign students’ graded examinations (other than the final) as homeworks so that they can learn from their mistakes in a non threatening environment. Recitation sessions are regularly held to go over the solutions. This effort bolsters students’ problem solving skills and sensitizes them to various trade-offs in solving problems. Thus through continuous learning, evaluation, and feedback, we take the pressure off the student from the final examination and help mastering the subject.

Time Management

Since our DSP courses engage students all throughout the semester, time management is critical to their success. Apart from analytical problems, students need to spend a considerable amount of time in the computer laboratory working with MATLAB. During the first semester of international students, we noticed some of them solving homework problems in the computer laboratory at the last moment and missing out parts of recitations and lectures. We encourage them to start working on their assignments as soon as possible and ask for faculty help prior to the due date. Off-hours access to the computer laboratories is also available to avoid last moment scrambling. In the case of laboratory projects, the students need to show the progress of their work to the Teaching Assistant during the assigned hours leading to a disciplined approach to completion.

REFERENCES


[8] EENG7753 Course Description, Fairleigh Dickinson University Graduate Studies Bulleting, p. 126, 2005-07. (Also on the web at http://www.fdu.edu/cgi-bin/courses/longpage.pl?course=EENG7753 )