AC 2009-850: TEACHING DSP BEFORE ANALOG SIGNALS: SOME UNEXPECTED CONSEQUENCES

Jay Wierer, MSOE

Dr. Jay Wierer is Assistant Professor of Electrical Engineering at the Milwaukee School of Engineering (MSOE). He received his Ph.D. degree from the University of Wisconsin - Madison in 2008. He is a Member of the IEEE and enjoys teaching courses in communications, signals and systems, DSP, controls, and circuits.

Steven Reyer, MSOE

Dr. Reyer is Professor of Electrical Engineering at the Milwaukee School of Engineering (MSOE). He received his Ph.D. degree from Marquette University in 1978 (candidate at the University of Illinois). He has done consulting in digital signal processing for the broadcast industry (digital stereo FM radio and digital television) and power industry. He is a Senior Member of the IEEE and typically teaches courses in digital signal processing, circuits and senior design.

Teaching DSP Before Analog Signals – Some Unexpected Consequences

Abstract

For many years our electrical engineering program's required analog signal analysis course was taught before the Digital Signal Processing (DSP) elective. That has been the tradition at many universities. But while students would do an acceptable job in the analog course they would often express displeasure regarding the level of rigor required by the course. It was suspected that the calculus content of this first course dealt a blow making the material somewhat abstract. Plus, the course had no laboratory, so the only exposure to signals problems was "on paper."

Four years ago the EE program was changed significantly[1,2] to a model that includes teaching material on an as-needed basis. For example, we teach the ideal op amp topic to freshmen, delaying the details of the internal workings to a later course. The freshmen could then see the utility of, and use in simple designs, a powerful circuit tool.

Another change was to institute DSP as a required course, and to be taught *before* the analog signals course. While this is somewhat non-traditional, it appeared to be a logical choice. The faculty generally believed that the mathematics in DSP was simpler than in analog signals – there is no calculus, and the math is mostly algebra with some infinite series concepts. It was believed that students would more readily grasp ideas of frequency content, spectrum, and filtering. Additionally, teaching DSP first[3] has been proven to be successful at other institutions.

After two years of the new approach, the situation was assessed. As one measure, student grades in the analog signals course were examined in both the pre-DSP and post-DSP programs. Somewhat to our surprise, grades in the analog course decreased slightly, as a whole, with the DSP-first approach. The decrease was small but, more significantly, it was not the expected increase. Interestingly, examination of individual students showed that those who took DSP first had analog course grades that were distributed normally relative to their DSP grades – some improved, some declined. Personal interviews with these students revealed a variety of opinions on the merits of DSP-first and how that affects performance in the analog course.

This assessment is a work in progress, and efforts have been identified to contribute to improved analog course performance success in using the DSP-first approach.

Background

For many years the signals and systems thread was taught in the same sequence as at other major universities: a required analog signals and systems course first, followed by digital signal processing (an elective) and communication systems. In 2004, the EE curriculum[1,2] at the Milwaukee School of Engineering (MSOE) was modified significantly so that topics were being taught on an “as-needed” basis; for example, ideal operational amplifiers are now covered in the freshman DC circuit analysis course. Similarly, it was felt that the signals and systems concepts could better be introduced by teaching the digital signal processing (DSP) course first, since the mathematics of DSP are relatively simple – linear algebra with a sprinkle of infinite series sums. The rigor of analog signals and systems, with its considerable dependence on integral calculus, was then pushed into the term following DSP.

What Was Expected

It was expected that student performance, as measured by their course grades, in the analog signals and systems course would improve slightly, having been introduced to concepts such as signal spectra, sampling, sinusoidal steady-state system response using superposition, and discrete Fourier series and transforms. The data below, however, indicate a slight decrease in student grades in the years where DSP is now taught previous to analog signals and systems.

A decrease in DSP-only grades because of changing DSP from an elective course to a required one might be expected, so that is not the surprising item here. In the years before DSP was a required course, large numbers of students took both the first and second DSP electives, and many pursued careers in the signal processing area. In the years since the change, it has been observed that some students lose their interest after the first DSP course and “slack” their way through the signals and systems and communications systems courses. This is not a complete surprise, as the former students elected to take DSP, whereas now all electrical engineering and computer engineering students must do so.

In spite of the unusual grade change explained below, many students have anecdotally expressed approval of the new approach with its somewhat simpler and more practical introduction to signals and systems concepts. This is well-appreciated by the number of students who come to MSOE for its “hands-on” curriculum.

What Really Happened

In the 2006-2007 and 2007-2008 academic years, 34 and 20 students, respectively, enrolled in EE-3220 (Digital Signal Processing) and EE-3031 (Signals & Systems) in consecutive terms. The change in grade point from EE-3220 to EE-3031 was calculated for each student (on a 0.5-grade point basis), and the following results were obtained:

Grade point change	Number of students with grade point change		
	2006-2008	2006-2007	2007-2008
-2.5	1	1	0
-2	1	1	0
-1.5	3	2	1
-1	9	6	3
-0.5	6	5	1
0	15	9	6
0.5	8	2	6
1	7	5	2
1.5	3	2	1
2	1	1	0

Table 1: Grade point change between EE-3220 (DSP) and EE-3031 (Signals & Systems) during academic years 2006-2008.

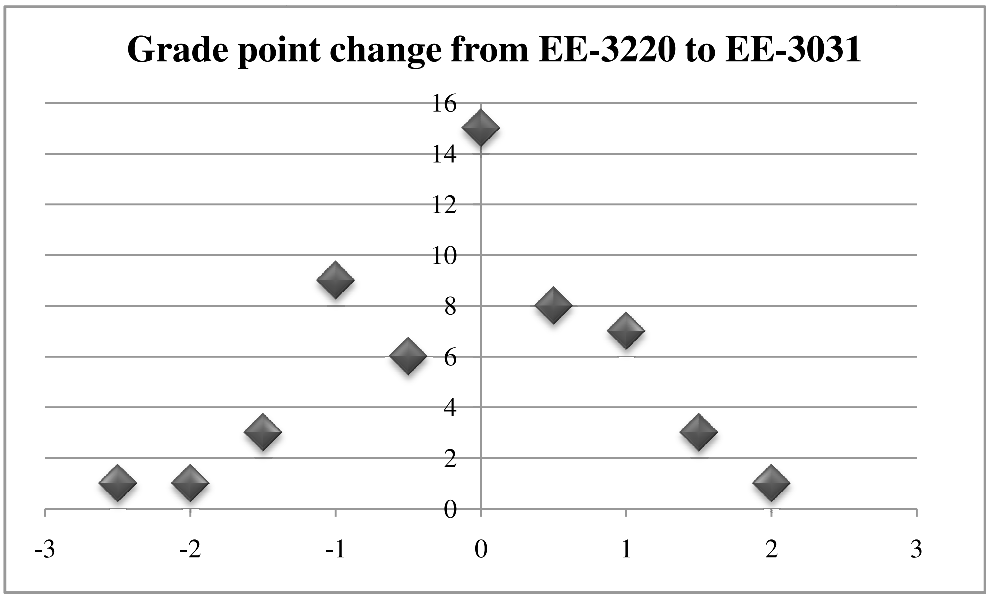

Figure 1. Grade point change between EE-3220 (DSP) and EE-3031 (Signals & Systems) during academic years 2006-2008.

The average grade point change for all 54 students who took EE-3220 and EE-3031 in consecutive terms during academic years 2006-2008 was calculated to be -0.0648. The average grade point change for all 2006-2007 students was calculated to be -0.1471. The average grade point change for all 2007-2008 students was calculated to be +0.075. One possible explanation for the improvement in 2007-2008 was that all students were enrolled in the same section of EE-3031, whereas in 2006-2007 two sections of EE-3031 were offered, and there may have been a significant difference in grading strategy between instructors of the course.

Since it is recognized that grades are not a complete indicator of student learning, further understanding of the situation can be extracted from the formal assessment process applied to each course. The list of learning objectives for EE-3220 (DSP) is given in the table below. Included with the objectives are numerical assessment data indicating the number of students (in the 2007-2008 academic year) who met the learning objectives at an adequate (A) level, a marginally (M) acceptable level, and an inadequate (I) level. Performance on an exam problem was classified as adequate if only mathematical or minor theoretical errors (not related to the theory of the problem) were committed, marginally acceptable if multiple mathematical or theoretical errors were committed, and inadequate if a major theoretical error (related to the theory of the problem) was committed.

Objective	Adequate	Marginal	Inadequate
Represent a signal as a sum of impulse functions	20	0	0
Determine the impulse response, given the difference equation	19	1	0
Perform convolution sum	17	2	1
Sketch spectra of sampled signal	18	0	2
Perform a DFT	15	4	1
Perform an FFT	19	1	0
Find the z-transform of a signal	14	1	5
Determine the transfer function of a filter	14	5	1
Determine system response and stability	19	1	0
Determine sinusoidal steady-state response	14	1	5
Design an IIR filter by bilinear transform	15	5	0
State tradeoffs of FIR vs. IIR	16	4	0

Table 2. Learning objectives assessment data for EE-3220, Winter 2007/8.

The list of learning objectives for EE-3031 (analog signals & systems) is given in the table below. Included with the objectives are numerical data indicating the number of students (in the 2007-2008 academic year) who met the learning objectives at an adequate (A) level, a marginally (M) acceptable level, and an inadequate (I) level.

Objective	Adequate	Marginal	Inadequate
Compute Fourier series coefficients	18	1	1
Reconstruct a signal from its Fourier series coefficients	17	3	0
Plot the spectra of a signal using Fourier transform	12	4	4
Compute Fourier transform from tables of pairs and properties	19	0	1
Determine the bandwidth of a signal or filter	14	6	0
Convolution integral	13	6	1
Design an analog filter (LPF, BPF, etc.)	17	2	1
Sinusoidal steady-state response	18	2	0

Table 3. Learning objectives assessment data for EE-3031, Spring 2008.

It should be noted that, during the 2007/8 academic year, the DSP course was taught in two sections led separately by the two coauthors of this paper, and the signals and systems course was taught solely by the primary author of this paper. Additionally, since the primary author was a first-year instructor during this academic year, the coauthors worked together and led nearly identical sections of DSP (in terms of topics and the syllabus). Hence the students were provided a great deal of continuity in taking DSP and signals and systems in consecutive terms.

Because of their previous DSP experience, students proved adept at computing Fourier representations of signals and determining the sinusoidal steady-state system response. Two traditionally difficult topics in which students proved less successful, however, were plotting the magnitude and phase spectra of a signal and calculating the output of a system via the convolution integral. Even after being introduced to the concept of signal spectra in the DSP course, some students remained confused about the distinction between the time- and frequency representations of a signal. The deficiencies in computing the convolution integral were largely due to setting up the limits of integration and identifying the correct function to be integrated. Overall, students simply have more trouble with the calculus-dependent analog signals topics than they do with DSP. This appears to be true whether they have the DSP-first experience or not.

Conclusions

Our initial hope and expectation was, with students being exposed to DSP first, with its somewhat simpler non-calculus mathematics requirements, that grades and learning in analog signals and systems would improve. This has not been the case. In fact, grades appear to have decreased slightly, although possibly insignificantly. An examination of assessment results shows what may just be an unfortunate fact of teaching signals, whether DSP or analog. That is, both courses contain topics that are somewhat abstract and difficult for students to grasp, and translating any mastery in the discrete-time world to the continuous-time world is a high-level objective that not all students can master. Anecdotal information directly from the students indicates that they favor the new approach, and that *overall*, they have a better understanding of the signals topics.

Future successes will be dependent on several things. Assessment results show that certain methods are difficult in either domain, and that mastery in one does not always translate to the other. Furthermore, it may be necessary for the professor to deliberately "connect" the topics between the courses, in a formal way, rather than assume that students are able to see the connections themselves.

Another change that may contribute to future students' success in analog signals and systems would be the inclusion of a lab for the course. A survey of students indicates the desire for a lab associated with the course to help reinforce lecture material. Many students are sensors – they need to perform and see the results of an experiment before they will believe and completely understand the theoretical results presented in lecture. The instructors are often intuitors, though, and occasionally do not see why just presenting the mathematical result is not sufficient. This may be particularly true at MSOE, where our students are accustomed to courses that comprise both lecture and lab experiences.

Finally, thorough communications between the faculty teaching the two courses is necessary, so that those concepts that students found difficult in the DSP course can be further addressed in the analog course.

Bibliography

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