AN APPLICATION-BASED APPROACH TO PRESENTING RANDOM DSP CONCEPTS TO A NON TRADITIONAL STUDY BODY[1]

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ABSTRACT

Naval Postgraduate School (NPS) students have on average been out of school for several years and come from a wide range of backgrounds but also have a common work experience. This paper discusses the challenges faced by faculty in teaching a first year graduate-level discrete time random signals course offered for students enrolled towards the MSEE Degree at NPS and the steps taken to facilitate student understanding of the topics covered in the course. We describe our student hands-on approach designed to emphasize applications and report our findings.

Index Terms— Signal processing, education

1. INTRODUCTION

The Electrical and Computer Engineering at the Naval Postgraduate School (NPS) offers graduate level programs to military officers and DOD employees with a wide variety of backgrounds. Students attending NPS are on average older than students typically found at other universities, and have a significant number of years of work experience in the military or federal agencies. However, they have been out of school for up to 6 to 8 years, and may have undergraduate backgrounds in areas other than engineering (for example only 42% of the MSEE students enrolled during 2007 have BSEE degrees). Students are allocated between one and two and a half years to complete a Master's program in ECE depending on their specific undergraduate backgrounds. Thus, programs of study leading towards the MSEE Degree are on average heavier than those found at traditionally universities, as a significant portion of the time may be spent transitioning to the discipline and acquiring the undergraduate level background needed to undertake the graduate program. Such wide range of backgrounds has significant impacts on teaching approaches followed by NPS faculty, as students tend to favor teaching styles which emphasize applications as motivation tools to theoretical concepts. Finally, class sizes in the ECE Department at NPS are small by comparison to other universities, currently from 7 to 15 on average.

As a result of the student audience characteristics, signal processing courses offered by the ECE department tend to put early and heavy emphasis on applications to keep students' attention and allow them to better grasp links between various theoretical concepts, and their applications to real-world problems. The DSP specialization track offers three basic graduate-level courses; 1) Digital signal processing, 2) Discrete time random signals, 3) Statistical signal processing, and 4) various advanced graduate level courses covering DSP-related domain applications. This paper describes the efforts developed in the discrete time random signals course to better match the student audience and facilitate student understanding.

2. COURSE METHODOLOGY

The discrete time random signals processing course offers students their first exposure to the fundamentals of random processes and applications to Wiener and matched filtering at the graduate level. The prerequisite to this course is an undergraduate-level course covering foundations of probability and statistical concepts for electrical engineering applications. The course has three 50mn lectures and a two-hour lab session for 11 weeks. The discrete random signals course has over the years represented a significant challenge to its instructors, as theoretical concepts covered within are difficult for students to grasp and relate to, and definitions and theorems quite dry for an audience more used to practical problems than that may be found in a typical university.

Thus, the course has gone over the years through multiple changes and iterations in an effort to better target the specific audience. Recent offerings have organized the course in such a way that basic questions such as "why do we need this tool?" "what does this concept address?" "what should we care about this assumption?" "what does this really mean?" get addressed immediately when theoretical concepts are presented in an effort to better help

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[1] The views expressed in this document are those of the author and do not reflect the official policy or position of the U.S. Government.

students to understand basic concepts. As a result, recent offerings have de-emphasized derivations of theoretical concepts and proofs in favor of a heavier applications-oriented approach with applications discussed throughout the quarter to illustrate the concepts introduced in class. This approach is nothing new, as it is commonly being used throughout various ECE programs over the world to motivate students [1-3].

Each course offering historically included 4 computer projects which addressed most of the concepts discussed in the classroom environment at that point and students are given about three weeks to work on each project. However, previous offerings also showed that some students did not keep up with the material on a weekly basis, and as a result, struggled to do the projects when those were assigned. Thus, simple computer-based activities were also recently added in an effort to address this issue. The basic idea behind this addition was originally to partition these activities into small chunks to motivate students to keep up with the material on a more regular basis than they may have done in the past, as these basic assignments need to be turned around within a few days. MATLAB is the software used for the course.

The second major change has been in re-instating structured weekly lab sessions. Historically, lab sessions were left open for students to work on their projects, without the instructor attending the lab sessions. Over the last few offerings, these sessions were transformed into structured lab sessions headed by the instructor, where students work on assigned activities and/or projects while the instructor is present to answer questions or issues which routinely pop up during hands-on activities.

The reason for the change in the lab activities structure was two-fold; 1) to provide a structured learning environment leading to a more efficient use of student time, and 2) keep a close pulse on the level of student understanding before more lengthy computer-based projects or tests are handed out later on.

3. COURSE ORGANIZATION

The most recent summer quarter 2008 offering of the course was split in three main sections. The first section reviews random concepts. Table 1 highlights the concepts covered in this section which is mainly designed to re-familiarize students with basic random concepts and to show them how these can be useful in practical applications. Examples and project activities included in this section are listed in Table 1 and are designed to address various applications of the concepts covered in the given section. Theoretical concepts discussed are shown in black. Specific applications discussed in the 2008 course offering are shown in blue, and assigned computer-based activities shown in brown. These activities are assigned immediately after relevant concepts and applications are described. Note

the overlap between the different assignments and multiple looks of the same types of problems to give students multiple changes to absorb the material. Computer-based activities are data driven to emphasize a hands-on approach to the concepts described in-class and designed to take under two hours of student time. For example, Section I activities investigated evaluating estimated moments and the impact of data length on the quality of the estimates, sensor correlation and independence issues, estimating data pdf, estimating confidence intervals to data mean, etc... More lengthy projects are also assigned during the quarter to reinforce understanding. The first project assigned in Section I investigated the detection of underwater mammal sounds in a noisy recording.

The second section of the course focuses on random processes and presents applications in signal processing areas, as illustrated in Table 2. This section specifically introduces random processes and concepts of stationarity, wide-sense stationarity (wss), ergodicity, correlation for wss processes, and power spectral density concepts. Examples and project activities included in this section are listed in Table 2. Again, examples are data-driven and were designed for students to investigate issues dealing with correlation between measurements, wss behavior, periodicity of measurements, etc…The second project investigated issues dealing with correlation estimates and estimating the number of stationary tones present in a noisy environment.

The third section brings together concepts covered in the first two sections and covers matched and FIR Wiener filtering concepts. Examples and project activities included in this section are listed in Table 3. The third project investigated the application of FIR Wiener filter to channel equalization and noise distortions.

The course, as currently designed, requires a heavier student hands-on participation than other comparable courses taught in the department, which required some students to adapt to the different rhythm. Course contents and data used for the various examples discussed during the summer 2008 offering are available at: http://faculty.nps.edu/fargues/teaching/ec3410/ec3410material.htm

4. LESSONS LEARNED

Research into students learning has shown the importance of keeping student involved in the classroom and giving them responsibilities in their learning. Projects are now routinely used to allow students to apply theoretical concepts with such activities being facilitated by user-friendly software [1-3]. However, previous offerings of the course showed that computer-based projects alone were not sufficient to insure students' understanding of the material. Students reported they thought they understood the material, but realized that they did not only after starting to work on the projects. Changes in the random DSP course instructional style reported here are the results of efforts

done to better match the teaching approach to unique NPS student-related issues, such as: 1) wide student backgrounds and specific work experience; 2) potentially heavy programs of study; and 4) small class size. The main changes in the instructional style were:

o Course activity modularization
The number of projects offered in the course was reduced to three to make space for small computer-based application activities assigned on average twice a week to keep students' attention on the material on a weekly basis. These activities were originally designed to split course concepts in small "chunks" which appeared less daunting for students to handle. In addition, same concepts were considered more than once to build student confidence levels in handling the problems. Activities were designed to take under 2 hours and to be turned around within a few days.

o Hands-on activities
The number of conventional homework assignments more theoretical in nature and traditionally used to assignments to evaluate students' understanding was significantly reduced to make space for hands-on MATLAB-based activities. Data analysis was made the center of these activities to motivate students in investigating how concepts are applied in practical scenarios.

o Structured lab sessions
Instructor-led lab sessions were set-up to allow for better interaction between students and the instructor on the course concepts. Note that NPS instructors do not have access to teaching assistants. However, multiple lab sessions are not needed due to the small class size environment. Lab attendance was not compulsory, but on average 80% of the students attended each lab session.

5. STUDENT FEEDBACK

An anonymous student questionnaire was passed to students at the end of the 2008 summer quarter offering to gather feedback on the contribution of the activities to the overall understanding of the course material, and to find out how students spent their time while working on course related activities. The 2008 course offering had 13 students, and 11 surveys were returned.

Figure 1 presents student feedback on the usefulness of 13 different computer-based activities. Feedback indicates that students felt computer based activities helped in understanding the various concepts covered in the course. Feedback also indicates additional activities are required to illustrate a few concepts such as confidence intervals and the use of correlation matrices in extracting signal

information. Figures 2 and 3 present student feedback on the amount of time spent on various course-related activities. Feedback indicates that 7 students (64%) spent under 5 hours on each computer activities, while 4 (36%) spent above that amount, reflecting potential problems in understanding concepts and/or MATLAB programming abilities by a portion of the students enrolled in the course. Feedback also indicates students spent fewer hours on the projects as the course progressed.

Figure 3 indicated that the textbooks selected for the course were rarely used, reflecting the fact students mostly used the partially filled in power point slide notes which the students have access to, while textbooks selected for the course, [4] and [5], were mostly used as references only by the students. Figure 3 also indicates that 45% of the students spent under 6 hours a week on course related activities, reflecting the fact that most questions were handled during class and lab sessions. This finding is also confirmed by the relatively small number of times students contacted the instructor outside these class or lab sessions.

6. CONCLUSIONS

This paper reported recent changes made in the instructional style used to teach the discrete time random signals course in the ECE Department at the Naval Postgraduate School. Conventional homework assignments were scaled down to make space for hands-on computer-based activities selected to be the main tool to help students understand theoretical concepts. This approach also led to a "modularization" of the course activities and used to keep students' motivation up. Student feedback collected at the end of the quarter indicates that these activities were viewed positively in their learning process. We plan to increase their usage in future offerings of the course to address the current deficiencies pointed out in student feedback.

Over the last 15 years, the common thread behind DSP education at the university level has been to emphasize applications and project activities to motivate student learning. One of the main challenges for NPS faculty is to assist students of widely different background to understand concepts and build a solid foundation from which they can expand their technical knowledge in the future. However, one of the potential pitfalls with heavy hands-on projects/activities is the resulting increased reliability on canned software. Heavy hands-on approaches are usually attractive to students as they get to see the applications side faster and those have been well received at NPS. However, this instructional style also has its own potential pitfall; it allows students to potentially follow more of a trial-and-error approach to problems by trying schemes or processes without fully understanding their associated assumptions or limitations. Thus, we need to carefully monitor whether there is a point at which applications and projects are emphasized to the point that students get a false sense of

understanding the material while at the same time they are unable to build on the concepts specifically covered in these activities. One main issue which remains to be carefully considered in this course is how to insure that such a crucial point does not get reached.

7. REFERENCES

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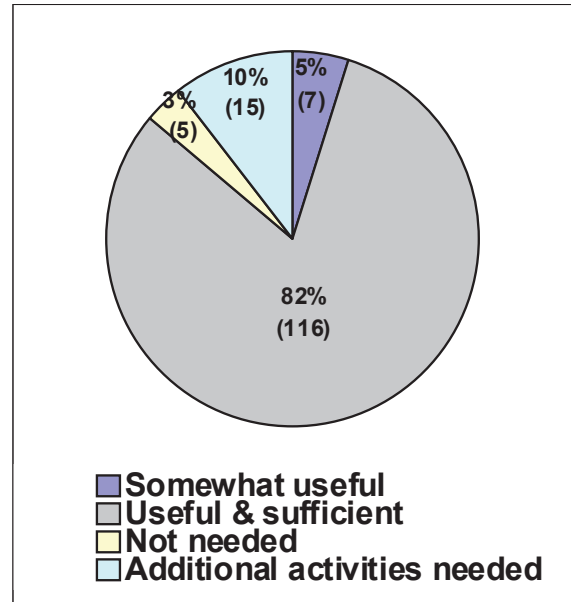
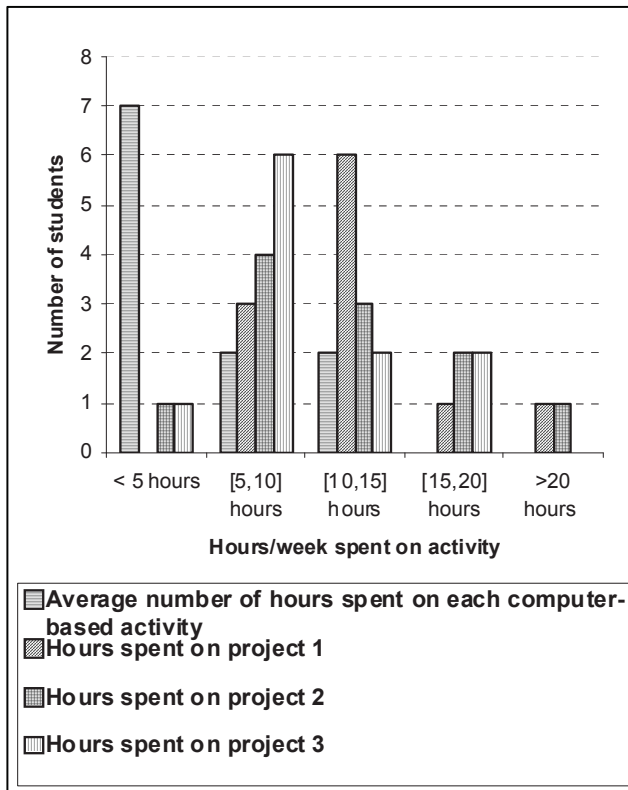Figure 1. Student feedback regarding usefulness of the computer-based activities in understanding course material.

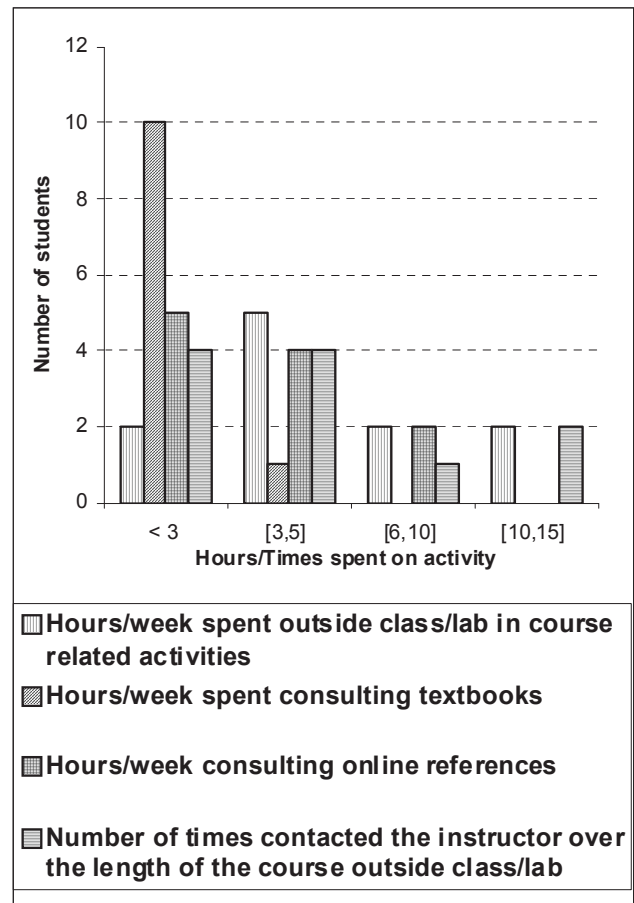Figure 2. Hours spent by students on computer-based activities and projects.

Figure 3. Hours/time spent on activity specified.

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RANDOM CONCEPTS – APPLICATIONS TO SIGNAL PROCESSING		
	Theoretical Concepts & *Applications Discussed*	**Examples/Projects** **(Assigned after concepts and applications listed have been covered)**
Course Progression	♦ Concept of probability & random variable (RV) ♦ Mean, moment, skewness, kurtosis ♦ *Application: Using kurtosis & skewness to check normality*	• Compute kurtosis & skewness for wireless sensor data. Impact of data length on kurtosis & skewness estimates
	♦ Useful random variable densities: uniform, Gaussian ♦ Concept of correlation coefficient ♦ Random vector definition & statistical description ♦ (Cross) Correlation/covariance matrices: definition & properties ♦ Random vector: normal pdf and linear transformation	• Evaluate correlation between 2 sensors from collected measurements • Evaluate mean and covariance matrix of 2-dim sensor measurements • Evaluate correlation between the coordinates of 2-dim normal sensors.
	♦ *Application: how to use the covariance matrix information of a normal random vector to infer properties on its components.* ♦ Central limit theorem ♦ Specific pdf (normality) data check. ♦ Visual tests for normality: Histogram, & qq plot. ♦ *Application: evaluate normality claim.* ♦ Goodness of fit test for normal data.	• Evaluate covariance matrix for 2-dim sensor measurements. • Evaluate trend behavior between components of a 2-dim sensor from the covariance matrix information. • Evaluate normality of measurements collected from wireless sensors. • Evaluate independence of two sets of measurements. • Evaluate normality for collected measurements.
	♦ *Application: Evaluate mean, variance, and confidence interval (CI) for the mean.* ♦ *Application: Data rescaling, how to re-introduce normality in the pdf.* ♦ *Application: Minimum sample size determination for a mean CI.* ♦ *Application to hypothesis testing: Applying CI concepts to verify/accept/reject specifications*	*• Project 1: Detect whale sound present in noisy underwater signal; evaluate noise segments and whale sound pdf type, investigate whether whale sounds can be detected by tracking changes in pdf, short-time skewness or kurtosis* • Rescale data to transform to normal pdf. • Evaluate CI for data mean obtained from independent file transfer times over a computer network. • Evaluate whether computer file transfer time data are Gaussian and rescale if not • Evaluate whether to accept or reject a claim for a given set of specifications

Table 1: Course contents, Applications, and computer-based examples for Section I of the course.

RANDOM PROCESSES – APPLICATIONS TO SIGNAL PROCESSING		
	Theoretical Concepts & *Applications Discussed*	**Examples/***Projects*
Course Progression	♦ Random signals/sequence definition ♦ Signal variance, autocorrelation, autocovariance, & normalized cross-correlation sequence. ♦ Statistical characterization of random signals; stationarity, wide-sense stationarity (wss), ergodicity, IID, white noise, Bernouilli process, random walk ♦ Random process properties; orthogonality, wss cyclostationarity, periodicity ♦ Correlation function for wss processes	• Compute mean and correlation sequence expression of the output of a FIR filter • Evaluate whether data collected from a thermal sensor can be considered wss or not • Evaluate correlation between measurements obtained from 2 sensors. • Evaluate maximum correlation lag between measurements
	♦ *Application to data analysis: Assessing signal stationarity using short time mean and variance* ♦ *Application to data analysis: Checking IID assumption via autocorrelation / lagplot* ♦ *Application: target range detection* ♦ *Application: periodic tone detection in noisy environments*	• Evaluate target distance from send /receive data. • Evaluate periodicity in measurements collected from 2 sensors.
	♦ Correlation matrix properties for a stationary process ♦ *Application: Detection of the number of tonal components in a signal*	• Evaluate number of complex tones in noisy signal using correlation information
	♦ How to estimate correlation lags; biased/unbiased estimator issues ♦ Frequency domain description for a stationary process; power spectral density (PSD) definition & properties ♦ Complex PSD; definition & properties ♦ Innovation representation of random vectors; PCA ♦ *Applications to biometrics (face recognition)*	• *Project 2a: Evaluate estimated correlation lags of IIR filter output to white wss noise, Investigate impact due to data size.* • *Project 2b: Estimate the number of stationary tones present in noisy signal; evaluate impact of SNR level on estimates.*

Table 2: Course contents, Applications, and computer-based examples for Section II of the course.

MATCHED and FIR WIENER FILTERS		
	Theoretical Concepts & *Applications Discussed*	**Examples/***Projects*
Course Progression	♦ Matched filter: deterministic/random signal in white and colored noise cases ♦ *Application: matched filter output when desired signal is a pulsed cosine signal* ♦ Orthogonality principle ♦ FIR Wiener filter; definition and filter coefficient derivations	• Detect finite-time tone occurrence in white noise. • Investigate impact of frequency mismatch on matched filter output • Identify bit stream contained in noisy signal. • *Project 3: Application of FIR Wiener filtering to channel equalization; transmission channel and additive noise impacts*

Table 3: Course contents, Applications, and computer-based examples for Section III of the course.