ECE 7630 - Advanced Digital Signal Processing

Syllabus – Fall 2007

Course Title: Advanced Digital Signal Processing

Instructor: Dr. Scott E. Budge

Office: EL 113

Phone: 797-3433 (Office), 753-5931 (Home)

Office Hours: T-R 3:00–5:00 pm
Other hours by appointment

Lecture Time: T-R 1:30–2:45

Lecture Place: ENGR 304

Prerequisite Topics: You should have an understanding of the topics covered in ECE 5630 and ECE 6010. Prerequisites include:

1. Working knowledge of linear system theory, including convolution, Z and Fourier transforms, sampling, and the DFT.
2. Working knowledge of linear algebra.
3. Familiarity with stochastic processes and probability theory, including correlation and power spectral density functions.

Textbook: Proakis, J. G., *et al*, *Algorithms for Statistical Signal Processing*, Prentice Hall, New Jersey, 2002.

Reference: (The following may be helpful.)

1. Manolakis, D., Ingle, M., Kogon, S.,*Statistical and Adaptive Signal Processing*, McGraw-Hill, 2000.
2. Haykin, S.,*Adaptive Filter Theory*, third edition, Prentice Hall, New Jersey, 1996.
3. Proakis, J. G., Manolakis, D. G., *Digital Signal Processing Principles, Algorithms, and Applications*, third edition, Macmillan, New York, 1996.
4. DeFatta, D. J., Lucas, J. G., Hodgkiss, W. S., *Digital Signal Processing: A System Design Approach*, John Wiley and Sons, New York, 1988.
5. Oppenheim, A. V., Schafer, R. W., *Digital Signal Processing*, Prentice-Hall, New Jersey, 1975.
6. Oppenheim, A. V., Schafer, R. W., *Discrete-Time Signal Processing*, Prentice-Hall, New Jersey, 1989.
7. Scharf, L. L., *Statistical Signal Processing*, Addison-Wesley, 1991.

8. Porat, B., *Digital Processing of Random Signals*, Prentice Hall, 1994.

Course Summary: This course is a continuation of the principles taught in ECE 5630. It will include topics on advanced digital signal processing (DSP) which are used in many different fields of application. Topics include linear prediction and optimal filter design, including Weiner and Least-Squares filters. Students will select topics of interest from adaptive filtering methods, spectral estimation, and array processing.

Course Objectives: At the completion of the course the student will have a knowledge of the theory and applications of DSP in the area of optimal filtering. Other topics of interest to the class will also be covered. The student will be introduced to the theory with enough detail to be able to read and understand the literature and perform original research.

Possible outcomes – At the end of the course, students will be able to do selected items in the following list, based on content covered:

1. Demonstrate understanding of AR, MA, and ARMA models and how the parameters are estimated.
2. Demonstrate understanding of linear Minimum-Mean-Square-Error (MMSE) optimal filter design.
3. Demonstrate understanding of solutions to the normal equations, including Levinson-Durbin, Schür, and LDL.
4. Demonstrate understanding of optimal lattice and lattice-ladder structures for prediction and filtering.
5. Demonstrate understanding of optimal linear Least-Squares (LS) filter design.
6. Demonstrate understanding of LS computational techniques (orthogonalization).
7. Demonstrate basic understanding of Least-Mean-Square (LMS) and Recursive-Least-Square (RLS) adaptive filtering.
8. Demonstrate basic understanding of parametric and nonparametric methods for spectral estimation.

Course Accessibility: In cooperation with the Disability Resource Center, reasonable accommodation will be provided for qualified students with disabilities. Please meet with the instructor during the first week of class to make arrangements. Alternate format print materials (large print, audio, diskette or Braille) will be available through the Disability Resource Center.

Philosophy

DSP is by its nature a very mathematical discipline. However, the mathematics are not outside of the reach of adequately prepared engineering students. As engineers, we must also go beyond the mathematics to a deep-seated understanding of what is implied about signals in the real world, and address issues such as implementation and feasibility. Some of this knowledge comes only by years of experience and practice.

This course is intended to familiarize the student with the mathematical concepts used to design optimal filters and other advanced signal processing methods and applications. The methods studied are applicable to many areas beyond filtering, and provide a sound basis for processing stochastic signals of many types. We hope that study of these topic will provide basic analysis and optimization tools necessary for advanced research in DSP. Students in advanced graduate study should find this course a starting point for such research.

Term Project

An important way to understand principles and applications in digital signal processing is to gain hands-on experience. Therefore, a digital signal processing project chosen by the student and approved by the instructor will be required. This project can be in any topic covered by the class, and should demonstrate advanced understanding of the topic. It should be based on an article from a technical journal. The projects will be completed in a group effort, with three students to a group. In order to allow non-native English speaking students to improve their English skills, at least one person in each group (if possible) should be a native English speaking student. During the seventh week of the class, each member of the group will submit a one page report of the progress of the group, with an evaluation of how much of the effort he/she feels each member of the group has contributed.

The project report will consist of a 10 – 15 page paper discussing the theory and processing methods, and a 20 minute oral presentation to the class. The oral presentation should include slides, electronic presentations or other visual aids which will be retained by the instructor for future classes.

During the third week of the class, you will be required to submit a proposal on the topic of the project. This proposal must include a copy of an article from a technical journal upon which the project is based. This article must also be included as an appendix to the written report.

The processing required for the project can be performed in any of the computational labs available in the college using C/C++ or Matlab code. If Matlab is chosen, you will be expected to program the algorithms using only basic linear algebra (vector and matrix arithmetic, matrix inversion) operations. If in doubt, ask the instructor.

The term project will be worth 200 points. The breakdown of points will be as follows:

1. Technical Merit (80 pts)

   Each project will be evaluated for its technical merit. This includes an understanding of the topic, correct methods used in the digital signal processing algorithm development, and expected results. If the algorithm did not perform according to expectation, a reasonable explanation should be given. The project should reflect a graduate level of difficulty or a more thorough comparison of simpler methods.

2. Oral Presentation (60 pts)

   The presentation given by each member of the group should be well organized and demonstrate an understanding of the topic. Any graphics, tapes, or slides used in the presentation should clearly illustrate the steps of the algorithm or the results obtained from the algorithm. Remember that a copy of the presentation will be retained by the instructor to aid future classes. The group members should be able to answer questions from the audience about the project. Please remember that practice is important to determine the timing of the presentation, as well as help to clarify the important points to be covered. If audio signals are processed, a tape of the results will be helpful.

It is suggested, although not required, that the presentation be made using computer-aided presentation software. This helps to organize the presentation and will develop new presentation preparation skills.

3. Written Report (60 pts)

   The written report should contain an explanation of the theory behind the algorithm and the results that were expected. It should be tutorial in nature so that an uninformed reader can understand the basic concepts.

   The paper should be written in a format similar to the format used in the IEEE journals, including an abstract. You might find it helpful to use the IEEE signal processing journal style available in LaTeX. A section explaining the methods used to perform the algorithm should be included. This section might include programming methods and data preparation or acquisition, for example. A section should also be included which presents the results and conclusions of the work. The paper should include an appendix containing a listing of the computer program used to perform the signal processing, the graphics used in the oral presentation (other than those included in the original journal article), and the journal article. If audio tapes are used, a copy should also be submitted with the report.

   Finally, the report should be well written; the text should be clear and understandable. Proper English will be expected. Please note that it is difficult to express yourself in only 15 pages, so be concise. It should be written in your own words; plagiarism of the journal article *will not be acceptable*.

The project will be worth 40% of your final grade, and should be presented both orally and written as if it is intended for a technical conference. Please practice the oral presentation so it will be well prepared.

Homework

It is expected that students at the graduate level understand the importance of homework. Therefore, homework will be assigned and the student will be required to complete the assignments promptly. The homework sets will be assigned and must be turned in two class periods (one week) after it is assigned. (There may be exceptions to this.) Do not wait until the last day to try the homework.

The homework will be evaluated as follows:

$\surd$ = homework in on time with all problems completed
$\surd-$ = late or incomplete assignment

X = no assignment turned in

The effect of homework is to help the student's grade if he is close to a grade decision level. A poor homework record may lower a student's grade.

Lecture and Paper Presentations

In an advanced graduate class (7xxx level) it is appropriate to allow students to prepare and present material in the class to their peers. This allows PhD students an opportunity to try their teaching skills and gain experience toward a career in Academia. MS students will also benefit from oral presentation.

You will be required to present at least one lecture from the material in the textbook to the class during the semester. You will be graded on preparation and understanding of the material taught. Please prepare well and show courtesy to other students presenting by being attentive and asking appropriate questions during the presentation.

In addition, we will be breaking the class up into pairs and assigning students to find and prepare lectures on recent published papers in the areas we are studying. The materials will be presented as a joint presentation from each team, and will require each member of the team to participate in the presentation.

I will be available to offer assistance as you prepare for your lecture. I will not create the lecture notes for you, but help you to focus on the points you should present. It will also be helpful to you to go through your lecture (dry run) in front of the mirror or with a classmate before the day of your presentation so you can check for timing, completeness, etc.

Grading

Term Project	200
Midterm	100
Lecture and Paper Presentations	100
Final	100
Total	500

Grades will be determined based on the performance of the class as a whole.

Course Outline

This course will cover chapters 3 and 4 from the text, with the remainder of the course selected by the class from chapters 5–8.