Summary

ECE 6250 is a general purpose, advanced DSP course designed to follow an introductory DSP course. The central theme of the course is the application of tools from linear algebra to problems in signal processing.

Prerequisites

An introductory course in digital signal processing. Students should be familiar with the fundamentals of linear algebra and have had exposure to basic probability and statistics. Students should also have basic MATLAB programming skills.

Instructor

Mark Davenport
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Office: Centergy 5212
Office phone: 404-894-2881
Office hours: I will generally hold office hours on Wednesdays from 3–4pm in Centergy 5212. I will also available via WebEx during that time, and also to meet in Centergy 5212 by appointment.

Teaching Assistant(s)

Andrew McRae
Email: admrca@gatech.edu
Office hours: Thursdays from 10-11:45 in Van Leer C449.
Grading

Your grade will be based on the following factors, with the following allocations:

- **Homework (30%)**: There will be 11 ± 1 homework assignments. See further details below.
- **Quiz #1 (20%)**: Tentatively scheduled for September 29.
- **Quiz #1 (20%)**: Tentatively scheduled for November 3.
- **Final exam (25%)**: The final exam will be comprehensive and will occur at the designated time during the finals period: **December 13, 2:50pm–5:40pm**.
- **Participation (5%)**: This part of your grade is based on my assessment of your engagement in the course. This will be based on factors such as attendance, full completion of homeworks, participation in classroom discussions, and engagement outside of the classroom (such as during office hours and/or on Piazza).

Unauthorized use of any previous semester course materials, such as tests, quizzes, and homework, is prohibited in this course. Furthermore, redistributing materials from this semester (e.g., contributing to test banks, CourseHero, or similar sites) is also prohibited. For any questions involving these or any other Academic Honor Code issues, please consult me or [www.honor.gatech.edu](http://www.honor.gatech.edu).

Homework

Homework will be assigned weekly (approximately). **Homework will be turned in at the beginning of lecture. Late homework will get zero credit.**

Students are strongly encouraged to discuss homework problems with one another. Homework assignments may consist of a mixture of problems to be worked individually, together with some problems to be worked in a small group of 3–4 students. However, for any individual problems each student must write up and turn in their own solutions written in their own words. Cases where solutions appear to be identical or nearly identical will be immediately referred to the Office of Student Integrity.

The homework assignments will be hard; many of them will require significant amounts of time and effort to complete. But this is really where most of the learning takes place. You will get out of the assignments what you put into them. Students who complete all of the assignments in full will be rewarded with a deep understanding of the role that linear algebra plays in modern signal processing (among other things).

Effectively, homework is worth much more than 30% of your grade. In teaching graduate courses over the years, I have yet to see a case where a student does not put effort into the homework assignments but does well on the exams.
Lecture

Lectures are Monday, Wednesday, and Friday from 1:55-2:45pm in Klaus 1456.

Lecture attendance is mandatory and will count towards your grade. A sign in sheet (starting in week 2) will be passed around at every lecture; please sign next to your name and your name only. Please inform the TA (in advance if possible) of any excused absences.

Dead week

As per Institute policy, I am required to inform you on the syllabus that there will be a homework assignment due during the last week of class.

Online resources

The course webpage is at:

mdav.ece.gatech.edu/ece-6250-fall2017

This page will provide general course information, copies of the lecture notes, and homework assignments.

I will also post homework assignments and solutions in T-square, as they become available.

I also plan to make exclusive use of Piazza to make announcements and answer questions. This site can be accessed via T-square or via:

piazza.com/gatech/fall2017/ece6250/home

Piazza is a great platform for you to work with your fellow students to discuss problems, find study groups, etc. Please direct any questions you might have to Piazza (I generally do not respond to direct email). Unless your questions are personal in nature, please do not make private posts – if you have a question you are probably not the only one, and other students may benefit from seeing the discussion.

Finally, as this course also has an online enrollment, all of my lectures are being recorded. These lectures will be made available to the on-campus students as well and can be accessed through T-square. I am providing access to the recorded lectures because they might be useful as study materials and to help out when reviewing material or if missing class is unavoidable. I am not meaning to suggest that you can simply watch the online lectures in lieu of attending class.
Distance learning

Distance learning students (Section Q) will be required to complete the same assignments as the on-campus students, but with a delay of up to three days for homeworks and one week for quizzes/exams. Please note that if you would like to receive your official grade promptly, you should aim to submit your final exam by December 15. If you submit your final exam later than this, your grades are entered manually through a paper system which can take several additional weeks to process.

Text

There is no required text. Below is a list of books that I have found helpful over the years for learning (and teaching) the material in this class.

Linear algebra and function spaces:

- Strang: *Linear Algebra and its Applications*  
  http://amzn.to/2vYq6eL
- Strang: *Computational Science and Engineering*  
  http://amzn.to/2vCexJu
- Horn and Johnson: *Matrix Analysis*  
  http://amzn.to/2fJ9fWY
- Young: *An Introduction to Hilbert Space*  
  http://amzn.to/2vZEx2b

Mathematics of signal processing:

- Moon and Stirling: *Mathematical Methods and Algorithms for Signal Processing*  
  http://amzn.to/2uGMkSI
- Vetterli et al: *Foundations of Signal Processing*  
  http://amzn.to/2vGqsnF
- Scharf: *Statistical Signal Processing*  
  http://amzn.to/2x2px0y

Outline

The outline below should be treated as an approximation; it is subject to (small) changes.

A very tentative schedule can be viewed at bit.ly/2x2vsT4. This schedule is subject to complete and arbitrary revision at any moment, but it should give you a rough idea of what to expect this semester.
1. Signal representations in vector spaces
   (a) Introduction to discretizing signals using a basis: The Shannon-Nyquist sampling theorem
   (b) Linear vector spaces, linear independence, and basis expansions
   (c) Norms and inner products
   (d) Orthobases and the reproducing formula
   (e) Parseval’s theorem and the general discretization principle
   (f) Important bases: Fourier, discrete cosine, lapped orthogonal, splines, wavelets
   (g) Signal approximation in an inner product space
   (h) Gram-Schmidt and the QR decomposition

2. Linear inverse problems
   (a) Introduction to linear inverse problems, examples
   (b) The singular value decomposition (SVD)
   (c) Least-squares solutions to inverse problems and the pseudo-inverse
   (d) Stable inversion and regularization
   (e) Weighted least-squares and linear estimation
   (f) Least-squares with linear constraints

3. Computing the solutions to least-squares problems
   (a) Cholesky and LU decompositions
   (b) Structured matrices: Toeplitz, diagonal+low rank, banded systems
   (c) Large-scale systems: Steepest descent
   (d) Large-scale systems: The conjugate gradient method

4. Low-rank updates for streaming solutions to least-squares problems
   (a) Recursive least-squares
   (b) The Kalman filter
   (c) Adaptive filtering using LMS

5. Matrix approximation using least-squares
   (a) Low-rank approximation of matrices using the SVD
   (b) Total least-squares
   (c) Principal components analysis
   (d) Signal and noise subspaces in array processing

6. Beyond least-squares (topics as time permits)
   (a) Approximation in non-Euclidean norms
   (b) Regularization using non-Euclidean norms
   (c) Recovering vectors from incomplete information (compressed sensing)
   (d) Recovering matrices from incomplete information (matrix completion)