ECE 6250: Advanced Topics in Digital Signal Processing
Fall 2026 Syllabus

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 covering concepts such as Fourier transforms, filtering, and sampling. Students should also be familiar with the fundamentals of linear algebra and should be very comfortable with the use of matrices to represent systems of equations-some existing familiarity with eigenvalues, eigenvectors, and eigenvalue decompositions will be extremely helpful. While most of the course will adopt a deterministic perspective, many of the models and algorithms we will discuss also have alternative probabilistic interpretations, and hence familiarity with the basics of probability and statistics (especially random vectors) will be useful for gaining a deeper appreciation for the material. Finally, students should also have basic MATLAB or Python programming skills.

Instructor

David Anderson
Office Hours: TBA. Also available by appointment.

GTA: TBA
Office Hours: TBA

GTA: TBA
Office Hours: TBA

Use Piazza to contact the instructor and teaching assistants.

Learning outcomes

Upon successful completion of this course, students should be able to:

- Represent signals using various basis expansions, including Fourier, discrete cosine, and wavelets, while applying the Shannon-Nyquist sampling theorem.
- Calculate signal approximations and representations within inner product spaces using Gram-Schmidt orthogonalization and QR decomposition.
- Formulate and solve linear inverse problems by applying the singular value decomposition (SVD) and the pseudo-inverse.
- Implement stabilization and regularization techniques to resolve ill-posed or unstable linear inversion problems.
- Evaluate structured matrix systems using Cholesky and LU decompositions, specifically for Toeplitz and banded systems.
- Solve large-scale signal processing systems using iterative computational methods such as steepest descent and the conjugate gradient method.
- Find low-rank matrix approximations and use Principal Component Analysis (PCA) to identify signal and noise subspaces in noisy signals.
- Analyze multirate signal representations, including filterbanks and biorthogonal transforms.
- Apply advanced recovery techniques, such as compressed sensing and matrix completion, to reconstruct signals from incomplete information.
- Develop signal models using ARMA (Auto-Regressive Moving Average) frameworks and structured matrix factorizations.

Course Format

This course will be offered in a flipped classroom format. Lectures are delivered via video uploaded to Canvas under the Modules section. While the lectures are not delivered synchronously, you should view the lectures for each week during that week, prior to coming to class. The class period will be devoted to working examples, answering questions, and working on problems individually or as a group. The in-class discussion will be recorded for asynchronous viewing by remote students (DL & Shenzen sections).

Grading

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

- **Homework (25%):** There will be ≈ 11 homework assignments. See further details below.
- **Online mini quizzes (20%):** Online quizzes will be due weekly covering that week's lecture materials. See further details below.

- **Midterm exam #1 (15%):** in early October
- **Midterm exam #2 (15%):** in mid November
- **Final exam (25%):** The final exam will be comprehensive and will occur on the date designated by the Institute for the final exam for ECE 6250A.

Alternatively, you may elect to skip the final exam, in which case your grade will be based on the following factors, with the following allocations:

- **Homework (33.33%):** There will be ≈ 11 homework assignments. See further details below.
- **Online mini quizzes (26.67%):** Online quizzes will be due weekly covering that week's lecture materials. See further details below.
- **Midterm exam #1 (20%):** in early October
- **Midterm exam #2 (20%):** in mid November.

Grade requirements:

- **A >= 90.0%**
- **B >= 80.0%**
- **C >= 70.0%**
- **D >= 60.0%**

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, Chegg, or similar sites) is also prohibited. For any questions involving these or any other Academic Honor Code issues, please consult me or https://osi.gatech.edu/students/honor-code.

Homework

Homework will be assigned weekly (approximately). **Homework will be turned in online as PDFs. The quality of the scans should be very good-if using a pencil, make sure the writing is dark enough to scan well. Use a flatbed scanner or scanning software on your phone so that the finished scan is printable and easy to read. Late homework will get zero credit.**

Each homework assignment will be worth 100 points. Over the course of the semester, **the maximum number of homework points that you can be credited is 100 less than the total available** (*e.g.*, if there are 12 assignments, then the maximum homework points will be 1100)-this serves a similar role to allowing you to drop one homework assignment, but should encourage you to still submit a partially completed one (and avoid panic if there is occasionally a problem that you do not finish in time.) Homework problems may be randomly selected for grading-not all problems may be graded on each assignment.

Students are *strongly* encouraged to discuss homework problems with one another.
However, **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 difficult; 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 25% of your grade. In teaching many graduate courses over the years, **the instructor has ever seen a case where a student does not put effort into the homework assignments but does well on the exams**.

Online Quizzes

The mini quizzes are online quizzes in Canvas to help you assess your understanding of the lecture material. Each week is structured as a Module in Canvas with lectures, quizzes, and support material (reading). The mini quizzes are generally due by the end of each week. You may take a mini quiz three times before the due date/time and your grade will be the highest of your three attempts.

Dead week

As per Institute policy, we are required to inform you on the syllabus that **there will be a homework assignment and mini quiz due during the last week of class**.

Online resources

The course webpage is here on Canvas. This page will provide general course information, copies of the lecture notes, and homework assignments. Homework assignments and solutions will also be posted in canvas, as they become available. Piazza will be used exclusively to make announcements and answer questions. 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. 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.

Distance learning

Distance learning students (Section Q) will be required to complete the same assignments as the on-campus students. Due dates for distance learning students will be delayed several days relative to on-campus students. Lecture material and assignments will be made available at least a week in advance so that, if you have a planned interruption (such as travel or a work project), you can prepare by working ahead.

Text

There is no required text. Below is a list of books that the instructors 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.

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. Signal Approximations and Representations
    a. Cosine transforms
    b. Wavelet transforms
    c. Block transforms
    d. Filterbanks
    e. Biorthogonal transforms
    f. Splines
    g. ARMA models
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)
7. Structured matrix factorization
    a. Source separation (using ICA and constant modulus)
    b. Dictionary learning (KSVD and related methods)
    c. Non-negative matrix factorization
    d. Computational techniques & gradient descent

Attendance Policy

This class will be recorded for remote delivery; however, students are strongly encouraged to be present for the live lecture. Students are responsible for all material covered in class, including changes in schedules announced in class. Students who come to class will be given priority during office hours; the professor is not responsible for repeating information already given in class.

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. Review Georgia Tech's Honor Code and the student Code of Conduct. Any student suspected of cheating or plagiarism on a quiz, exam, or assignment will be reported to the Office of Student

Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services (404-894-2563) as soon as possible to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Student-Faculty Expectations Agreement

At Georgia Tech, we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. The Student-Faculty Expectations articulate some basic expectations that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class