ECE 7776: Advanced Digital Signal Processing
Collab: 15F ECE 7776 (ENGR)

Summary: This course begins with modern formulations of classical signal processing concepts, including signal representations, filtering, and sampling and quantization. Then, recent extensions and generalizations are presented, including sparse approximation and signal recovery, optimization techniques for nonlinear processing of signals, and connections to estimation theory and modeling. Theoretical topics will be connected to applications in communications, imaging, biomedical signal analysis, astronomy, geology, remote sensing, crystallography, big data, and other areas. As time permits, additional topics such as signal processing on graphs and matrices may be introduced. Students will be expected to read scholarly papers from the published literature and complete a course project. A background in probability may be helpful but is not required.

Instructor: Daniel Weller
Assistant Professor, ECE
Rice Hall, Room 309
Email: dweller@virginia.edu (put "ECE 7776" in the subject to ensure your email is read)
Phone: 434-924-4271 (x4-4271 from UVA phone)

Location: Tuesdays, Thursdays
3:30 – 4:45 PM
Thornton D-115

Office Hours: Mondays, 3-5 pm, in Rice 309

Textbook: mainly course notes/papers. Recommended reference texts include:

- S Mallat, *A Wavelet Tour of Signal Processing*
- M Vetterli, J Kovacevic, and V Goyal, *Foundations of Signal Processing*
- J Kovacevic, V Goyal, and M Vetterli, *Fourier and Wavelet Signal Processing* [in draft]
- S Boyd and L Vandenberghe, *Convex Optimization*
- J Nocedal and S Wright, *Numerical Optimization*
- YC Eldar and G Kutyniok, eds, *Compressed Sensing: Theory and Applications*
- YC Eldar, *Sampling Theory Beyond Bandlimited Systems*

Learning Objectives: This course aims to provide the tools to be a signal processing researcher. By the conclusion of this course, students should be familiar with recurring signal processing topics and ideas, be able to understand and critique published work, and be confident in pursuing and presenting a new signal processing research idea.

Lectures/Discussion: The first lectures of the course will be almost entirely devoted to reviewing important concepts from mathematics and signal processing that we will rely on as we explore the literature. The remaining lectures will feature brief overviews of a topic area, followed by an in-depth discussion of one or two papers related to an earlier topic. In order to have a productive discussion, it is imperative that all students complete the readings in advance of lecture. At the beginning of each discussion, a student (or students) will provide a brief presentation (10 minutes) to the group outlining the contributions of the paper and providing interesting questions to provoke discussion. The discussion portion of the course grade will be based on both these presentations as well as participation in all the other discussions.

Homework: In the first part of the course, before paper discussions begin, three homework assignments will be given out to help ascertain comfort with the material. No late homeworks will be accepted once solutions are posted online.

Midterm: The midterm exam (on 10/8) will be given in class and will cover concepts from the preceding lectures and readings. Exam questions will range from exercises like those in the early homeworks to more reflective questions concerning topics we discussed in class.

Final project: The most significant component of the course will be a semester-long individual research project. This project should focus on an area of signal processing and involve original research (simply reproducing published work is not sufficient). The project grade will be based on (1) a written proposal outlining the research idea and providing a preliminary survey of the literature, (2) three written reports (one for each milestone) describing in detail the ideas explored during that milestone and presenting and discussing results supporting those ideas, (3) a written paper in double-column single-space IEEE conference format, no more than 4 pages, and a formatted bibliography, and (4) a final presentation given during the assigned final exam time (12/18). Any components of the project (except the presentation) turned in late will have subtracted from the grade up to 10% per day after the deadline. No late presentations will be accepted. If you are unable to present during the assigned final exam period, you must arrange with me before 10/1 an alternate time to present your work directly to me.

Grading: 3 homeworks (15% total), midterm (15%), discussions (20% total), final project (3 milestones, 10% each; written report, 15%; presentation, 5%)

Frequency: Every other fall, starting Fall 2015

Prerequisites: ECE 6750 or permission of instructor

Policies: All students are expected to abide by the UVA honor code policy. If you have concerns about this policy, or about accessibility or other issues, please contact me as early as possible.

Course Schedule (Tentative)

Date	**Topic**
8/25	Lecture 1: Linear algebra and signal processing review **HW 1 out**
8/27	Lecture 2: ML, MAP, and MMSE estimation; Cramér-Rao bound
9/1	Lecture 3: Representations of signals **HW 1 due; HW 2 out**
9/3	Lecture 4: Multi-rate processing and interpolation
9/8	Lecture 5: Sampling and interpolation of signals **HW 2 due; HW 3 out** *SEAS Add Deadline*
9/10	Lecture 6: Quantization and compression
9/15	Lecture 7: Time-frequency analysis of signals; wavelet transform
9/17	Lecture 8: Parametric estimation; EM algorithm and MC methods **HW 3 due**
9/22	Lecture 9: Kalman filtering and smoothing **Project Proposal due**
9/24	Lecture 10: Sparse representations and basis pursuit
9/29	Lecture 11: Compressed sensing theory
10/1	Lecture 12: Greedy algorithms for compressed sensing
10/6	*Reading Day (no classes)*
10/8	**Midterm Exam**
10/13	Lecture 13: Linear programming and compressed sensing *SEAS Drop Deadline*

Date	Topic
10/15	Lecture 14: Least squares (quadratic) problems **Project Milestone 1 due**
10/20	Lecture 15: Regularization and constrained quadratic problems *SEAS Withdrawal Deadline*
10/22	Lecture 16: Nonlinear least squares problems
10/27	Lecture 17: Lagrangian methods for constrained optimization
10/29	Lecture 18: Lagrangian-based methods (continued)
11/3	Lecture 19: Graphical models and inference
11/5	Lecture 20: Belief propagation and message-passing algorithms **Project Milestone 2 due**
11/10	Lecture 21: Approximate message passing
11/12	Lecture 22: Discrete signals on graphs; spectral graph theory
11/17	Lecture 23: Distributed processing and estimation
11/19	Lecture 24: Matrix completion and sensing
11/24	Lecture 25: Dictionary learning **Project Milestone 3 due**
11/26	*Thanksgiving (no classes)*
12/1	Lecture 26: Phase retrieval and magnitude least squares
12/3	Lecture 27: Phase retrieval (continued)
12/8	Wrap up **Project written reports due**
12/18 9 AM-12 PM	**Final Presentations**