

ECE 7776: Advanced Digital Signal Processing

Syllabus – Fall 2018 – READ BEFORE DAY 1 OF LECTURE

Summary: This course surveys recent advances in signal processing concepts, especially those related to the acquisition, formation, processing, analysis, and visualization of images, videos, and similar multidimensional signals. This course begins by reviewing representations and applications of digital signals and images, including common tasks involving such signals. Successive lectures will feature discussions of recent research papers in these areas, and activities applying and reproducing their results. These lectures will connect these concepts to applications in biomedical imaging, computational photography, image and video compression, and other areas. Graded activities will include reviewing and critiquing papers, a midterm exam, and a semester-long research project.

Instructor: Daniel Weller
Assistant Professor, ECE
Rice Hall, Room 309
Email: dweller@virginia.edu (please put “ECE 7776” in the subject)
Phone: 434-924-4271 (x4-4271 from UVA phone)

Location: Tuesdays, Thursdays
12:30 – 1:45 PM
Mechanical Engineering 305

Office Hours: Tuesdays, Thursdays
2:00 – 3:00 PM
Rice Hall 309

Textbook: No textbook is required. In addition to assigned readings from papers and review articles, related reference texts include:

- AC Bovik, *The Essential Guide to Image Processing*, 1st ed., Academic Press, 2009, ISBN 978-0123744579 [e-book available from UVA library]
- RC Gonzalez and RE Woods, *Digital Image Processing*, 3rd ed., Pearson, 2007, ISBN 978-0131687288
- S Mallat, *A Wavelet Tour of Signal Processing*, 3rd ed., Elsevier, 2009, ISBN 978-0123743701
- K Miura (Ed.), *Bioimage Data Analysis*, Wiley, 2016, ISBN 978-3527341221, [free e-book available by Olympus from <http://www.imaging-git.com/olympus-website-bioimage-data-analysis>]
- J Rittscher, R Machiraju, and STC Wong (Eds.), *Microscopic Image Analysis for Life Science Applications*, Artech House, 2008, ISBN 978-1596932364 [e-book available from UVA library]
- JC Russ and FB Neal, *The Image Processing Handbook*, 7th ed., CRC Press, 2015, ISBN 978-1498740265 [e-book available from UVA library]
- G Wu, D Shen, and MR Sabuncu (Eds.), *Machine Learning and Medical Imaging*, Academic Press, 2016, ISBN 978-0128040768 [e-book available from UVA library]

Learning Objectives: This course aims to provide the tools to use signal and image processing in research. By the conclusion of this course, students should be familiar with recent advances in signal and image processing, be able to understand and critique published work, and be confident in conducting and communicating research involving signal processing.

Lectures/Discussion: In addition to short in-class exercises, quizzes, and other activities, lectures frequently will discuss assigned readings of papers and review articles. It is essential to have read these papers *in advance of class* in order to fully benefit and contribute to these discussions. Students will be required to submit brief written reviews of these papers for a grade. Each review must include *one question/discussion point* that the student may raise in the class discussion. These reviews should relate the paper contents to material covered in the lectures, thus serving as homework for the course.

Midterm: The midterm exam will be given in-class and will cover concepts from the preceding lectures and readings. Exam questions will range from exercises like those during lectures to ideas discussed from the assigned readings.

Project: This course features a semester-long individual research project. This project should focus on an area of signal and image processing and involve original research (*reproducing published work is not sufficient*). Students will submit a written proposal describing the research idea and providing a preliminary survey of the relevant literature. Brief progress updates throughout the semester and a final report will comprise the remainder of the project grade.

Final Exam Presentations: In lieu of an exam, each student will present a brief talk describing their research project during the assigned final exam period. The final presentations will be conducted during the last week of class (December 4 and/or December 6).

Grading: Discussions/reviews (35%), midterm (15%), project (40%), and presentation (10%)

Prerequisites: ECE 6750 or instructor permission

Policies: All students are expected to abide by the UVA honor code policy. Late assignments generally will not be accepted; extensions must be approved by the instructor in advance of the due date. If there is a conflict for a scheduled final presentation, it is the student's responsibility to notify the instructor before SEAS drop/withdraw deadline (October 23) to reschedule. Travel, holidays, or other commitments do not exempt students from this requirement. If you have concerns about course policies, about accessibility, or other issues, please contact the instructor as early as possible.

Tentative Schedule

- 08/28 Lecture 1
Topic: Introduction to course; review of signals and systems; discussion of imaging and other applications
Read ahead: "What is Signal Processing?" on IEEE SPS website, and a link of student's choice. (<https://signalprocessingsociety.org/our-story/signal-processing-101>)
- 08/30 Lecture 2
Topic: Sampling theory; how cameras work
- 09/04 Lecture 3
Topic: Acquiring images with microscopes
- 09/06 Lecture 4
Topic: Sampling magnetic moments with MRI
- 09/11 Lecture 5
Topic: Sampling beyond Shannon
- 09/13 Lecture 6
Topic: Compressive sensing and reconstruction
- 09/18 Lecture 7
Topic: The single-pixel camera and CS-MRI
- 09/20 Lecture 8
Topic: Computed tomography, filtered backprojection, and the ML-EM algorithm
- 09/25 Lecture 9
Topic: Super-resolution microscopy
- 09/27 Lecture 10
Topic: Data and image compression
- 10/02 Lecture 11
Topic: Image enhancement: denoising
- 10/04 Lecture 12
Topic: Image enhancement: deblurring and sharpening
- 10/09 NO CLASS (Reading Day)
- 10/11 Midterm Exam**
- 10/16 Lecture 13 (**Drop Deadline - SEAS**)
Topic: Image restoration and inpainting
- 10/18 Lecture 14
Topic: Dictionary learning and other data-driven approaches
- 10/23, 10/25 Lectures 15-16 (**10/23 is Withdraw Deadline – SEAS**)
Topic: Image segmentation

10/30, 11/01 Lecture 17-18
 Topic: Image classification

11/06, 11/08 Lecture 19-20
 Topic: Motion tracking

11/13, 11/15, 11/20 Lecture 21-23
 Topic: Machine learning for image analysis

11/22 NO CLASS (Thanksgiving)

11/27, 11/29 Lecture 24-25
 Topic: TBD

12/04, 12/06 Final presentations