

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
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Phone: 434-924-4271 (x4-4271 from UVA phone)

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

Office Hours: Tuesdays, Thursdays
11:00 AM – 12:00 PM
Rice Hall 309

Teaching Assistant: Haris Jeelani (office hours: TBA)

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: Please consult the following important policy messages and read them carefully. If you have concerns about course policies, about accessibility, religious accommodations, or other policies, please contact the instructor as early as possible.

Late assignments: Late assignments generally will not be accepted; extensions must be approved by the instructor in advance of the due date.

Final presentations: 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. Requests made after this date will only be honored in extreme circumstances, and at the discretion of the instructor. Travel, holidays, or other commitments do not exempt students from this requirement.

Accessibility: The University of Virginia strives to provide accessibility to all students. If you require an accommodation to fully access this course, please contact the Student Disability Access Center (SDAC) at (434) 243-5180 or sdac@virginia.edu. If you are unsure if you require an accommodation, or to learn more about their services, you may contact the SDAC at the number above or by visiting their website at <http://studenthealth.virginia.edu/student-disability-access-center/faculty-staff>.

Preventing Violence and Assault: The University of Virginia is dedicated to providing a safe and equitable learning environment for all students. To that end, it is vital that you know two values that I and the University hold as critically important:

1. Power-based personal violence will not be tolerated.
2. Everyone has a responsibility to do their part to maintain a safe community on Grounds.

If you or someone you know has been affected by power-based personal violence, more information can be found on the UVA Sexual Violence website that describes reporting options and resources available - www.virginia.edu/sexualviolence.

As your professor and as a person, know that I care about you and your well-being and stand ready to provide support and resources as I can. As a faculty member, I am a *responsible employee*, which means that I am required by University policy and federal law to report what you tell me to the University's Title IX Coordinator. The Title IX Coordinator's job is to ensure that the reporting student receives the resources and support that they need, while also reviewing the information presented to determine whether further action is necessary to ensure survivor safety and the safety of the University community. If you would rather keep this information confidential, there are *Confidential Employees* you can talk to on Grounds (See http://www.virginia.edu/justreportit/confidential_resources.pdf). The worst possible situation would be for you or your friend to remain silent when so many here are willing and able to help.

Religious Accommodations: It is the University's long-standing policy and practice to reasonably accommodate students so that they do not experience an adverse academic consequence when sincerely held religious beliefs or observances conflict with academic requirements.

Students who wish to request academic accommodation for a religious observance should submit their request in writing directly to me by email as far in advance as possible. Students who have questions or concerns about academic accommodations for religious observance or religious beliefs may contact the University's Office for Equal Opportunity and Civil Rights (EOCR) at UVAEOCR@virginia.edu or 434-924-3200.

Accommodations do not relieve you of the responsibility for completion of any part of the coursework missed as the result of a religious observance.

Honor Code: I trust every student in this course to fully comply with all of the provisions of the University's Honor Code. By enrolling in this course, you have agreed to abide by and uphold the Honor System of the University of Virginia, as well as the following policies specific to this course.

- All graded assignments must be pledged.
- Collaboration and discussion is encouraged, but all assignments submitted for grading must be your own work, written individually.
- You must properly cite any sources (published or unpublished) that you use, in both written assignments, and in your project more generally.

All suspected violations will be forwarded to the Honor Committee, and you may, at my discretion, receive an immediate zero on that assignment regardless of any action taken by the Honor Committee.

Please let me know if you have any questions regarding the course Honor policy. If you believe you may have committed an Honor Offense, you may wish to file a Conscientious Retraction by calling the Honor Offices at (434) 924-7602. For your retraction to be considered valid, it must, among other things, be filed with the Honor Committee before you are aware that the act in question has come under suspicion by anyone. More information can be found at <http://honor.virginia.edu>. Your Honor representatives can be found at: <http://honor.virginia.edu/representatives>.

***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

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| 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 |