EE 5561 - Image Processing and Applications
From Linear Filters To Artificial Intelligence
Fall 2023

University of Minnesota, Electrical and Computer Engineering

Course Description: This course provides an in-depth coverage of topics in modern image processing, motivated by electrical engineering applications. Topics that will be covered include multi-dimensional signals & systems, image pre-processing, image enhancement, denoising, segmentation, registration, and computational imaging. 2D image transforms, linear filtering, sparsity and compression, statistical modeling, optimization methods, multiresolution techniques, artificial intelligence concepts, neural networks and their applications in classification and regression tasks in image processing will be studied.

Format:	In-person(Tu - Th 1:00-2:15 pm, Mechanical Engineering 102) Course Website on Canvas
Instructor:	Associate Professor Mehmet Akçakaya Keller Hall Rm. 5-159 Phone: 625-1343 E-mail: akcakaya@umn.edu Office Hours: Wednesday 11:00 am - 12:00 pm
Teaching Assistant:	Merve Gülle E-mail: glle0001@umn.edu Office Hours: Thursday 10:00 am-12:00 pm, Keller Hall Rm. 2-276 & Zoom
Prerequisites:	EE 4541, 5581, grad student or instructor consent [Official]. Familiarity with linear algebra and probability is assumed.

Topics and Tentative Schedule:

- Introduction to image processing, 2D Signals & Systems ($\sim$ 2 weeks)
- Non-statistical methods:
  - Basic image enhancement, image pre-processing and interpolation ($\sim$ 1 week)
- Statistical methods:
  - Linear algebra, random vectors, optimization review ($\sim$ 1 week)
  - Basic image restoration ($\sim$ 1 week)
  - Image compression, sparsity, wavelets, image denoising, deblurring, super-resolution ($\sim$ 1.5 weeks)
  - Image registration ($\sim$ 1 week)
- Machine learning methods:
  - Machine learning concepts, artificial neural networks, backpropagation, convolutional neural networks, regularization ($\sim$ 2 weeks)
  - AI methods in image classification, segmentation, denoising, super-resolution ($\sim$ 1 week)
  - Generative models (GAN, VAE, diffusion/score-based), attention, vision transformers ($\sim$ 2 weeks)

Textbook: I will use my own notes to cover a number of topics. Thus, **there is no required textbook** for the course. The following text books are recommended, but not required.

- R. C. Gonzalez & R. E. Woods, "Digital Image Processing," 4th Edition, Pearson, 2018.
- S. Theodoridis, "Machine Learning: A Bayesian and Optimization Perspective," 2nd Edition, Academic Press, 2020.

Homeworks: Problem sets will be assigned ~biweekly on Canvas. Some problem sets may require the use of Python. You may discuss solution strategies with other students taking the class. *However, all of the submitted work must be entirely yours.*

Lectures and Quizzes: A series of online quizzes will be released on Canvas after each lecture. These quizzes cover the lecture materials and can be re-taken a maximum of two times prior to its deadline, which will be the midnight on the day of the lecture. The quizzes should be done independently.

Mini-projects: There will be two mini-projects that focus on image enhancement and statistical image processing, respectively. For each mini-project, one scientific paper will be assigned to everyone, i.e. same paper for all students. The project will involve understanding this paper, and implementing the processing techniques proposed in the work in Python/MATLAB (or similar software), using either numerical or real-life datasets. Each student will submit a written report in IEEE conference format, along with the Python/MATLAB source files to re-generate the results. The report should include an abstract, and the following sections: Introduction, Methods, Results, and Discussion; should be approximately 4-pages in two-column format, excluding references. The Discussion section should identify the limitations of the technique (regardless of the success of your own MATLAB/Python implementation).
The first mini-project will be due on **Oct. 19**, and the second one will be due on **Nov. 16**.
All of the submitted work, including the text and the code, must be entirely yours.

Course Project Information: There will also be a more in-depth project focusing on recent approaches in image processing that utilize deep learning technique. This will involve reading scientific papers, implementing the techniques and writing a report in the format described for mini-projects, but with more details and for approximately 8-pages in two-column format. The implementation will need to use a deep learning framework, such as PyTorch. Since this project is more involved, you will work in **groups of 2** (depending on the final enrollment numbers).
Different than mini-projects, you will have to propose your own topic for this project, i.e. you will not be given a set of papers from which you will get to choose. Hence, you will need to propose your topic with a detailed description of which papers you will read, which methods you will implement, and what you expect to learn. This will be reviewed by me and our TA, and your proposal will either be approved or we will ask it to be revised. The project proposals will be due on **Nov. 20**.
Your final written report (8-page two-column with the following sections: Abstract, Introduction, Methods/Theory, Results, Discussion and Conclusion), as well as your implementation source files to re-generate the results will be due on **Dec. 17**.
All of the submitted work, including the text and the code, must be entirely yours.

Grading:

Quizzes	15%
Mini-projects	30%
Homework	30%
Course project	25%

Other Important Information:

Student Academic Integrity and Honesty: The ECE Department has an expectation that all students will be honest in their actions and communications. Individuals suspected of committing academic dishonesty will be directed to appropriate university offices as per University policy. More information regarding Academic Misconduct is available.

Professionalism Statement: The ECE Department has an expectation that all students will behave in a professional manner during all interactions with fellow students, faculty, and staff. Treating others with respect and having constructive communications are examples of being professional.

Mental Health: As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a students ability to participate in daily activities. University of Minnesota services are available to assist you with addressing these and other concerns you may be experiencing. You can learn more about the broad range of confidential mental health services available on campus via the Student Mental Health Website.

Disability Resources: If you have a documented disability and need special accommodations, feel free to contact the instructor or the Disability Resources Center.

Classroom Conduct: You are strongly encouraged to ask questions. You should be in class to participate and learn, and activities that do not promote learning should be kept to a minimum. Please respect the rights of the other students in class to hear the lecture and to participate in classroom discussions. Please be courteous by not using your cell phones during class.

Email Correspondence: Some of you may prefer to send the instructor or the TA emails for short questions. You should understand that although we will respond to all the emails we receive, it may not be possible for us to give you a reply within 24 hours. If you need immediate feedback, you are encouraged to talk to us during office hours.