Computational Image Formation and Enhancement

CMSE890
Michigan State University
Fall 2020, MWF, 9:10-10 am EST
https://msu.zoom.us/j/98732731952
https://msu-cmse-courses.github.io/cmse890-F20-ComputationalImaging/

Instructors:	Saiprasad Ravishankar	Adam Alessio
Email:	ravisha3@msu.edu	aalessio@msu.edu
Office Hours:	(Wednesday 2-3pm EST)	(Monday 1-2pm EST)
Office Hours Location:	(https://msu.zoom.us/j/97297478013)	(https://msu.zoom.us/j/96086002056)

1 Course Description

This course introduces students to mathematical, statistical, and machine learning methods for image generation and enhancement in computational imaging, with a focus on major medical imaging modalities. The course will review foundational topics in multidimensional signals and systems, optimization, and image quality. We will cover the background physics and image formation process for several systems including magnetic resonance imaging, X-ray computed tomography, positron emission tomography, and optical imaging. The theory and application of image reconstruction methods for these modalities will be extensively discussed. Coverage will span both classical methods and more recent iterative techniques and machine learning methods, appropriate for limited and noisy data. Students will receive hands-on experience implementing methods with programming assignments, mathematical problem solving, and review of recent papers in the field. We will have visits to imaging facilities as well as talks by experts from the industry on recent advancements and emerging challenges in diverse imaging and image processing applications. Prior programming experience is required and some previous experience in physics, linear algebra, linear systems, probability, Fourier transforms, and optimization is encouraged.

2 Required Reading Materials

This class will use a collection of reading materials for different topics. Students will be assigned required reading prior to all class periods. Readings will be drawn from scientific publications, publicly available texts, and from books available via the MSU libraries. There should be no cost for these readings.

3 Suggested Textbooks

Although the course materials will be based on a variety of sources, students will find the following textbooks particularly useful for parts of the course.

1. Richard Blahut, *Theory of Remote Image Formation*, Cambridge University Press, 2004.

2. Avinash C. Kak and Malcolm Slaney, *Principles of Computerized Tomographic Imaging*, IEEE Press, 1988. (Online: http://www.slaney.org/pct/pct-toc.html)

3. Zhi-Pei Liang and Paul C. Lauterbur, *Principles of Magnetic Resonance Imaging: A Signal Processing Perspective*, Wiley-IEEE Press, 1999.

4. Michael Elad, *Sparse and Redundant Representations: From Theory to Applications in Signal and Image Processing*, Springer-Verlag New York, 2010.

5. Ian Goodfellow and Yoshua Bengio and Aaron Courville, *Deep Learning*, MIT Press, 2016. (Online: https://www.deeplearningbook.org/)

6. Jürgen Beyerer and Fernando Puente León and Christian Frese, *Machine Vision: Automated Visual Inspection: Theory, Practice and Applications*, Springer-Verlag Berlin Heidelberg, 2016.

4 Other Required Materials

In-class and homework programming assignments are a critical part of the learning process in this course. To that end, you are expected to have a functioning computer to complete this programming. The class strongly recommends completing these assignments in Python using Jupyter notebooks/lab. That said, other programming languages (for example Matlab) would also be acceptable. Furthermore, the majority of this course will rely on several virtual communication tools (Zoom, Slack, D2L, etc).

If you do not have the necessary technology and/or equipment to adequately participate, the College of Engineering will make every attempt to assist you in obtaining access by loaning this technology for use during the semester. Please be aware that supplies are limited, and we may not be able to fulfill all requests. If you need assistance securing technology (laptops, tablets, web cams, hotspots), please contact Theodore Caldwell, Assistant Dean for Equity and Inclusion, by email at tc@msu.edu.

5 Course Meeting Times and Locations

This class will meet virtually on Mondays, Wednesdays, and Friday from 9:10-10:00 a.m. EST on Zoom (https://msu.zoom.us/j/98732731952). There will also be weekly virtual office hours (https://msu.zoom.us/j/97297478013 for Ravishankar; https://msu.zoom.us/j/96086002056 for Alessio) for instructors. Class and office hour Zoom access will be via passwords. The single exam will be a midterm held near the beginning of November during our class period. Final projects will be presented at the end of the semester during the regular class period.

6 Course Activities

Class participation: Active class participation (led both by the instructors and by students) is critical to the success of this course. As such, students are expected to attend class (virtually) every day, read the required reading materials prior to class, and engage in the in-class active learning activities.

Active learning assignments: Class sessions will be held three times a week, and will contain presentations, discussions, and programming activities that will allow students to implement (and get immediate feedback on) what they have learned. Active learning assignments will be due in D2L approximately 4 days after they are assigned.
Homework: There will be periodic homework assignments (every two or three weeks) that will provide a more in-depth exploration of the materials covered in class. Students are welcome to work in teams for understanding and brainstorming these assignments, but all submitted work must be personally completed by each individual student.
Guest Lectures: There will be a few guest lectures in the course, given by speakers from the imaging industry.
Semester Projects: This class will have a semester project that will involve studying approaches and theory in recent papers and implementing them or applying some subset of techniques learned in class to problems of personal or research interest. The project should include substantial programming or mathematical/theoretical rigor. Students will submit a project report and make a presentation at the end of the semester. More details will be available near the middle of the semester. Projects can be done individually or in groups of two.
Study Groups: Students may be divided into study groups. The study groups will meet on a bi-weekly basis to review and discuss course materials and assignments.
Slack: Students and study groups are encouraged to interact with each other and with the instructors via the course's Slack channel (see details further below).

7 Course Outline/Schedule

Please see additional file for schedule: CMSE890_Computational_Image_Formation_Schedule.pdf

8 Other Important Information

8.1 Hybrid Instruction Tools

This course will be taught as a hybrid course. The primary method of communication will be through the course Slack discussion channel (`#compimage-f20`) on the MSU CMSE Slack group, http://cmse-courses.slack.com. If you need an invitation to the Slack group, please contact Adam Alessio and he will issue one (if you use your @msu.edu email address, you should be able to sign up at https://cmse-courses.slack.com/signup). Once you've logged into Slack, join the course channel by clicking "Channels" and then searching for the channel.

This course will use Desire2Learn at (http://d2l.msu.edu) for distributing and collecting assignments and for keeping track of grades. We will also have a course website (`https://msu-cmse-courses.github.io/cmse890-F20-ComputationalImaging/`), where important course information will be posted. Finally, lecture notes and additional reading materials will be shared through Google drive: (`https://drive.google.com/drive/folders/1CCzydKKZyhbnMrVDjEutpzVK9zgsIJsI?usp=sharing`).

Personal interaction with instructors will take place through our Zoom class and Zoom office hours. As the semester progresses, we may be able to offer in-person office hours and other in-person interactions depending on the COVID-19 situation.

8.2 Contingency Planning for COVID-19

During class periods, if you experience connectivity issues please use the course Slack channel for realtime communication and to receive help with connection. If you become sick during this semester and need to miss classes, please contact the instructors via slack as soon as possible to support your education and/or devise a plan for your semester. If the instructors become sick this semester and are unable to teach, another CMSE instructor will fill in as quickly as possible to minimize the possible disruption to the course.

8.3 Course Recordings

Meetings of this course may be recorded. The recordings may be available to students registered for this class. This is intended to supplement the classroom experience. Students are expected to follow appropriate University policies and maintain the security of passwords used to access recorded lectures. Recordings may not be reproduced, shared with those not in the class, or uploaded to other online environments. Doing so may result in disciplinary action.

8.4 Public and Campus Health

Campus health and safety depends on all of us. As part of the essential effort to slow the spread of COVID-19, Michigan State University is directing everyone to take personal responsibility to protect the health and safety of all MSU faculty, staff, students and visitors. (https://msu.edu/together-we-will/keeping-spartans-safe/?utm_source=reopening-email&utm_medium=email&utm_campaign=faculty-staff). This includes wearing a face covering indoors and outdoors and maintaining a 6-foot physical distance. Please refer to the MSU Community Compact, "Together We Will" (https://msu.edu/together-we-will/).

8.5 Inclusive Classroom Behavior

Respectful and responsible behavior is expected at all times, which includes not interrupting other students and not using offensive or demeaning language in our discussions. Flagrant or repeated violations of this expectation may result in ejection from the course, grade-related penalties, and/or involvement of the university Ombudsperson. In particular, behaviors that could be considered discriminatory or harassing, or unwanted sexual attention, will not be tolerated and will be immediately reported to the appropriate MSU office (which may include the MSU Police Department).

In addition, MSU welcomes a full spectrum of experiences, viewpoints, and intellectual approaches because they enrich the conversation, even as they challenge us to think differently and grow. However, we believe that expressions and actions that demean individuals or groups compromise the environment for intellectual growth and undermine the social fabric on which the community is based. These demeaning behaviors are not welcome in this course.

8.6 Academic Honesty

Intellectual integrity is the foundation of the scientific enterprise. In all instances, you must do your own work and give proper credit to all sources that you use in your papers and oral presentations – any instance of submitting another person's work, ideas, or wording as your own counts as plagiarism. This includes failing to cite any direct quotations in your essays, research

paper, class debate, or written presentation. The MSU College of Natural Science adheres to the policies of academic honesty as specified in the General Student Regulations 1.0, Protection of Scholarship and Grades, and in the all-University statement on Integrity of Scholarship and Grades, which are included in Spartan Life: Student Handbook and Resource Guide. Students who plagiarize will receive a 0.0 in the course. In addition, University policy requires that any cheating offense, regardless of the magnitude of the infraction or punishment decided upon by the professor, be reported immediately to the dean of the student's college.

It is important to note that plagiarism in the context of this course includes, but is not limited to, directly copying another student's solutions to assignments that are expected to be completed individually (pre-class assignments, homework problems, and exams); copying materials from online sources, textbooks, or other reference materials without citing those references in your source code or documentation, or having somebody else do your individual assignments (pre-class assignments, homework problems, and exams) on your behalf. Any work that is done in collaboration with other students should state this explicitly, and their names as well as yours should be listed clearly. When collaborating with other students, you should still be coding/writing your own solutions to the assignments and should limit your collaboration to conceptual discussions about how one might go about solving the problems, not sharing exact solutions.

More broadly, Students should adhere to the Spartan Code of Honor academic pledge, as written by the Associated Students of Michigan State University (ASMSU): "As a Spartan, I will strive to uphold values of the highest ethical standard. I will practice honesty in my work, foster honesty in my peers, and take pride in knowing that honor is worth more than grades. I will carry these values beyond my time as a student at Michigan State University, continuing the endeavor to build personal integrity in all that I do."

9 Grading Information

Activity	Grade percentage
Participation/attendance	15
In-class programming assignments	20
Homework assignments	25
Midterm	15
Semester project	25
Total:	100

Grading Scale

$4.0 \geq 90\%$
$3.5 \geq 85\%$
$3.0 \geq 80\%$
$2.5 \geq 75\%$
$2.0 \geq 70\%$
$1.5 \geq 65\%$
$1.0 \geq 60\%$
$0.0 < 60\%$