General Course Information

Motivation and overview

Imaging is essential to scientific progress. With the innate human ability for visual information processing, seeing is believing, seeing is understanding, and seeing is even central to hypothesizing. Unconventional sensing, sophisticated modeling, and abundant computational resources are revolutionizing imaging. Beyond images for human consumption, whatever is worth measuring is often measured as a function of space and thus is also imaging. A prime example is the imaging in an autonomous vehicle that is used by that vehicle’s navigation system rather than viewed by a person. Many of today’s emerging imaging modalities have no analogue to the use of optics to produce a focused image; instead, spatial resolution in two or more dimensions comes from solving an inverse problem. Make no mistake: techniques such as synthetic aperture radar, computed tomography, MRI, and others have existed for decades; however, the essential role of sophisticated signal modeling, information representation, and computation is only recent.

The purpose of this course is to create a learning community that is focused on the topic of computational imaging. Since computational imaging is at the intersection of signal processing, computation, vision, statistics, and optics, along with other areas of physics for certain modalities and electronics for the understanding of device behavior, many backgrounds are welcome and potentially valuable to this community. The instructor’s contributions will focus on the signal processing aspects of computational imaging, including the formulation and solution of inverse problems. However, all students should be aware that the instructor is merely a guide. Students will be expected to make contributions to the learning of the entire group, for example through presentation of papers.

Catalog description

Principles and methods of reconstructing images and estimating multidimensional fields from indirect and noisy data; general deterministic (variational) and stochastic (Bayesian) techniques of regularizing ill-posed inverse problems; relationship of problem structure (data and models) to computational efficiency; impact of typically large image processing problems on viability of solution methods; problems in imaging and computational vision including tomography and surface reconstruction. Computer assignments.

Prerequisites

The formal prerequisites are ENG EC 416 (Introduction to Digital Signal Processing) and ENG EC 505 (Stochastic Processes). Informally, background in linear algebra is essential, even though there is no prerequisite chain that includes linear algebra; those without good working knowledge of linear algebra should expect to review intensively in the first few weeks of the semester.

As an advanced graduate subject, there is an implicit commitment to understanding concepts in depth and contributing to the education of the entire group.

Texts

Several texts may be used in part, including the following (none required for purchase):

- Mario Bertero, Patrizia Boccacci, and Valeria Ruggiero, Inverse Imaging with Poisson Data: From cells to galaxies (IOP Publishing, 2018)
- Per Christian Hansen, Discrete Inverse Problems: Insight and Algorithms (SIAM, 2010)
- Frank Natterer and Frank Wübbeling, Mathematical Methods in Image Reconstruction (SIAM, 2001)
- Curtis R. Vogel, Computational Methods for Inverse Problems (SIAM, 2002)
Web resources and web-enabled interaction

The Blackboard system at https://learn.bu.edu will be the primary means for distributing course materials.

Staff

Vivek Goyal
goyal@bu.edu
Office hours: Tuesdays 5:30pm–6:30pm PHO 442 (chosen to avoid conflicts for all registered students)

Lectures

Tuesdays and Thursdays 1:30 pm – 3:15 am Room EPC 203

An online document with a rough schedule of lecture topics will be updated throughout the semester.

Homework

Tentatively, there will be 5 homework assignments, assigned approximately every other week in the first half of the semester. Working through the problems carefully is a crucial part of the learning process. Collaboration in the form of joint problem solving with classmates is permitted and even encouraged. All written submissions should reflect your understanding; do not copy a solution from any other source.

Exam

There will be one exam well before the end of the semester (likely on March 19). The intention in not having a final exam is that course effort in the latter part of the semester should be focused on the research project.

Term project

The term project is your opportunity to supplement the fundamental material covered in the homework assignments with in-depth study of one topic. The instructor will attempt to guide you so that the project is an effective learning experience and yields significant results. You may choose any topic related to the tools and techniques of the course. Your project may overlap with your current thesis research; in fact, this is encouraged. However, it is a violation of academic conduct standards if you:

• use work completed before the current semester;
• use the same project for more than one course;
• include joint work without clearly indicating your contribution (e.g., you should inform the instructor if your research advisor has provided significant guidance on your project); or
• use the work of others (including co-authored work) without attribution.

If you are in doubt about scholarly standards for citing prior work, ask the instructor. If plagiarism is noticed, it will not be tolerated. More subtle than the issues above: hold yourself to a standard of completing work for the term project that you would not have done otherwise. You may work individually or in groups of two. A group of two should produce a single final report; whether groups of two are given longer presentation time slots will be determined later. Groups of two will be held to a higher standard, and group members are not guaranteed equal grades.

Deliverables. The project has several deliverables to ensure that you keep the instructor up to date on progress.

• Feb 20: Project concept (1 page) – very short description
• Mar 5: Project proposal (1 page) – description including details on project scope
• Apr 9: Project update (3 pages) – update
• Apr 30: Project report – in the style of a conference paper, with length appropriate for the necessary detail

Course grade

The scores on graded elements will be combined with the following weighting to give a preliminary grade:

Class participation: 20%
Homework: 20%
Midterm exam: 20%
Term project: 40%