Course Information

- **ECE 60141/BME 695-062 – Foundations of Computational Imaging**
- **CRN: 29402 / 29402**
- **Meeting time: MWF 1:30**
- **Meeting location: Brown Hall 222**
- **Course credit hours: 3**
- **Course prerequisites: None**
- **Areas of Specialization(s): Communications, Networking, Signal & Image Processing**
- **Normally Offered: Fall semesters**

Instructor(s) Contact Information

- **Prof. Charles A. Bouman**
- **Office: MSEE 320**
- **Phone: 765 494-0340**
- **Email: bouman@purdue.edu**

Course Description

Catalog Description:

An advanced treatment of the methods in model-based signal and image processing including stochastic modeling of multidimensional signals, Bayesian estimation, inverse methods, doubly stochastic models, regularized inversion, the EM algorithm, Bayesian networks, Markov chains, optimization, convexity, majorization techniques, and stochastic simulation. The underlying theory is presented in the context of applications including image restoration, tomographic reconstruction, clustering, classification, and segmentation.

Supplementary Information:

The course presents the basic analytical and algorithmic tools used for processing information from a wide variety of physical sensors and applications ranging from medical CT scanners to speech signals. The basic theme of the course is the formulation of signal processing problems as inverse problems, and the solutions of inverse problems using the techniques of signal and system modeling along with parameter and signal estimation. The course also incorporates a number of computer-based laboratory exercises so that students can better understand how to implement the methods discussed in the class. The course is intended to be accessible to students with a variety of applications backgrounds, but they should have basic familiarity with probability, random variables, and random processes at the level of ECE 600 or ECE 302.

Learning Resources, Technology & Texts

Required Text:
- Charles A. Bouman, Foundations of Computational Imaging: A Model-Based Approach, SIAM 2022.
  https://engineering.purdue.edu/~bouman/publications/FCI-book/

Recommended supplementary course material:
- Class web site:
  https://engineering.purdue.edu/~bouman/ece641/
- Online class lectures:
  https://www.youtube.com/playlist?list=PL3ZrjaBngMS0mTSoMsy7P6rTFSgsmsMw3

Learning Outcomes

A student successfully completing this course will be able to:
- *Understand how to model an imaging system.*
- *Understand widely used methods for solving inverse problems in imaging applications.*
- *Be able to implement an image reconstruction algorithm for applications such as deconvolution and denoising.*
- *Understand how probability can be used to model imaging systems and images.*
- *Understand basic approaches to optimization of quadratic and non-quadratic functions*
- *Understand MAP and ML estimation methods*

Assignments

Students are graded based on a combination of approximately four computer-based laboratories and two exams. The exams are based on homework problems contained in the notes and done independently by the students. Homeworks must be performed independently by each student. The following weightings are used when combining exam and computer laboratory scores.

Computer-based laboratories	30%
Midterm	30%
Final exam	40%

Grading Scale

This class is graded on a curve. A total score will be computed for each student according to the point weighting above. Then based on the assessment of the professor possibly with input from a teaching assistant, and in consideration of both the overall class performance and individual student performance, cut-offs will be determined separating grade levels, and students will be assigned individual grades based on those cut-offs.

Attendance Policy

Attendance at lectures is mandatory. No exam makeups will be given, so please check your calendar at the beginning of the semester. Any exam absence due to extreme circumstances will be made up through a weighting of the remaining grades.

Course Schedule

The following lists out the topics that will be covered in their approximate order:

Topic 1:	Probability, estimation, and random processes
Topic 2:	Causal and Non-causal Gaussian models
Topic 3:	Image restoration using MAP estimate
Topic 4:	Continuous non-Gaussian MRF image models

Topic 5:	MAP estimation with non-Gaussian Priors
Topic 6:	Constrained optimization and ADMM
Topic 7:	Plug-and-play and advanced prior methods
Topic 8:	The expectation-maximization (EM) algorithm
Topic 9:	Markov chains and hidden Markov models
Topic 10:	Discrete valued Markov random fields (MRF) and segmentation
Topic 11:	Stochastic simulation methods

A more detailed outline of lectures will be posted on the class web site.

Academic Integrity

Every member of the Purdue community is expected to practice honorable and ethical behavior both inside and outside the classroom. Any actions that might unfairly improve a student's score on homework, quizzes, labs, or examinations will be considered cheating and will not be tolerated. Examples of cheating include (but are not limited to):

- Sharing results or other information during an examination.

- Bringing forbidden material or devices to an examination.

- Working on an exam before or after the official time allowed.

- Requesting a re-grade of answers or work that has been altered.

- Submitting a homework or laboratory report that is not your own work, or engaging in forbidden homework or laboratory report collaboration.

- Possession of another person's laboratory solutions or report from the current or previous years.

- Use of another person's laboratory solutions or report from the current or previous years during the preparation of a laboratory solution or report.

- Allowing another person to copy your laboratory solutions or report.

- Representing as your own work anything that is the result of the work of someone else.

All homeworks and laboratories must be performed independently by each student. Violation of this rule will be considered a form of cheating. At the professor's discretion, cheating on an assignment, or examination will result in a failing grade for the entire course, or a reduced grade, or a zero score for the assignment or exam. If there is any question as to whether a given action might be construed as cheating, please see the professor or the TA before you engage in any such action.

For further information, you may refer to Purdue's student guide for academic integrity at:
https://www.purdue.edu/odos/osrr/academic-integrity/index.html .

Nondiscrimination Statement

This course follows the Purdue Nondiscrimination Policy Statement listed at:
https://www.purdue.edu/purdue/ea_eou_statement.php .

Accessibility

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center by email at drc@purdue.edu or by phone at 765-494-1247.

Purdue has assistance available to help you make learning materials accessible. Some examples include:
- Information on Universal Design for Learning at:
  - https://www.purdue.edu/innovativelearning/accessibility/universal-design-and-accessibility.aspx

- Guidance on creating accessible documents:
  - https://www.purdue.edu/innovativelearning/accessibility/accessible-documents.aspx .

Mental Health/Wellness Statement

- If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, you might try contacting WellTrack at https://www.purdue.edu/caps/services/WellTrack.html . Sign in and find information and tools at your fingertips, available to you at any time.
- If you need support and information about options and resources, please see the Office of the Dean of Students for drop-in hours (M-F, 8 am- 5 pm) at https://www.purdue.edu/odos/ .
- If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should consider contacting Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed, and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday.

Student- and Safety-Related Policies

Purdue University provides numerous policies related to students. A hyperlink to this list of Student-Related Policies is on the Brightspace landing page. I suggest you review these policies, particularly those under Ethics and Facilities and Safety. For example, see the Violent Behavior Policy that focuses on our efforts to provide safe and secure campus environments for members of the university community. Therefore, violent behavior is prohibited in or on any University facility or while participating in any university activity. Another example, is the policy prohibiting Amorous Relationships between a student and any University employee who has educational responsibility over the student. These and similar policies are in place as part of Purdue's commitment to maintaining an environment in which learning, discovery, and engagement take place in safe and professional environments.

Emergency Preparedness

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting me via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Disclaimer

This syllabus is subject to change. You will be notified of any changes as far in advance as possible via an announcement on Brightspace. Monitor your Purdue email daily for updates.