TO: The Faculty of the College of Engineering

FROM: Elmore Family School of Electrical and Computer Engineering

RE: ECE 64100 Changes in Title, Number, and Description

The faculty of the School of Electrical and Computer Engineering has approved the following changes in ECE 64100. This action is now submitted to the Engineering Faculty with a recommendation for approval.

From: ECE 64100 – Model Based Image and Signal Processing
Sem. 1. Lecture 3, Cr. 3
Prerequisite: graduate student standing

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.

To ECE 60141 Foundations of Computational Imaging:
Sem 1. Lecture 3, Cr. 3
Prerequisite: graduate student standing

This class presents a collection of mathematical and statistical methods that form the foundation of modern computational imaging research and applications. Computational imaging seeks to form images from sensor data and is widely used in applications including consumer imaging, scientific imaging, industrial inspection, and security imaging. This class provides an advanced treatment of computational imaging based on an inverse-problems framework and blends perspectives from applied math, statistics, physics, and applications. The topics covered include stochastic modeling of images, Bayesian estimation, inverse methods, optimization, convexity, majorization techniques, constrained optimization and proximal methods, plug-and-play methods for advance prior models, the EM algorithm, Bayesian networks, Markov chains, hidden Markov models, and stochastic simulation. The underlying theory is presented in the context of applications including image restoration, tomographic reconstruction, clustering, classification, and segmentation.

Reason: The title change is motivated by the fact that in 2022, the course instructor published a book with the name Foundations of Computational Imaging. Prof. Bouman has been teaching ECE 64100 for about 30 years, and this book was written from the notes on the class. It is also the first book on the topic of computational imaging that presents the mathematical foundations of the field as opposed to a treatment of the hardware systems.

A course number change is needed to reflect ECE's course numbering policy.

Required Text(s): Formal class notes

Recommended Text(s): Charles A. Bouman, Foundations of Computational Imaging: A Model-Based Approach, SIAM 2022.

Lecture Outline:

Lectures	**Topics**
4	Probability, estimation, and random processes
4	Causal and Non-causal Gaussian models
4	Image restoration using MAP estimate
4	Continuous non-Gaussian MRF image models
5	MAP estimation with non-Gaussian Priors
4	Constrained optimization and ADMM
4	Plug-and-play and advanced prior methods
5	The expectation-maximization (EM) algorithm
4	Markov chains and hidden Markov models
4	Discrete valued Markov random fields (MRF) and segmentation
3	Stochastic simulation methods

Mithuna Thottethodi,
Associate Head for Teaching and Learning
Elmore Family School of Electrical and Computer Engineering

Course Information:

BME 695 / ECE 60141 – Foundations of Computational Imaging (Formerly named ECE641 "Model-Based Image and Signal Processing" and "Digital Image Processing II")
CRN: 15628 / 15630
Meeting time: MWF ~~2:30~~
Meeting location: ~~SCHM 308~~
Course credit hours: 3
Course prerequisites: None
Areas of Specialization(s): Communications, Networking, Signal & Image Processing
Normally Offered: Fall semesters

Instructor Contact Information:

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

Course Description:

Catalog Description:
This class presents a collection of mathematical and statistical methods that form the foundation of modern computational imaging research and applications. Computational imaging seeks to form images from sensor data and is widely used in applications including consumer imaging, scientific imaging, industrial inspection, and security imaging. This class provides an advanced treatment of computational imaging based on an inverse-problems framework and blends perspectives from applied math, statistics, physics, and applications. The topics covered include stochastic modeling of images, Bayesian estimation, inverse methods, optimization, convexity, majorization techniques, constrained optimization and proximal methods, plug-and-play methods for advance prior models, the EM algorithm, Bayesian networks, Markov chains, hidden Markov models, 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 CT scanners to cell-phone sensors. The basic theme of the course is the formulation of computational imaging 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 several 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:

Recommended Books:

- 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.

Academic Guidance in the Event a Student is Quarantined/Isolated:

If a student is quarantined/isolated, the student should make the course instructor aware of the situation immediately and should work with the instructor to find appropriate ways in which to complete required course work while in quarantine. Moreover, the student will be expected to continue participating in the class by a) reading and responding to instructor emails; b) watching posted lecture videos; c) performing required assignments; and d) taking online exams.

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.

Classroom Guidance Regarding Protect Purdue:

Any student who has substantial reason to believe that another person is threatening the safety of others by not complying with Protect Purdue protocols is encouraged to report the behavior to and discuss the next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights and the Violent Behavior Policy under University Resources in Brightspace.

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:

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life.

For further information, you may refer to Purdue's nondiscrimination policy statement 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 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 sample language:

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.

Emergency Preparation:

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.

In the event of an emergency, students can get information from the following sources:

- The following web page:
  https://www.purdue.edu/ehps/emergency_preparedness/flipchart/index.html
  provides resources in case of emergencies that affect the West Lafayette campus.
- Keep your cell phone on but with the ringer and buzzer off to receive a Purdue ALERT text message.
- Log into a Purdue computer connected to the network to receive any Desktop Popup Alerts.

In an emergency, students are also welcome to contact Prof. Bouman by phone at his office or home.

Violent Behavior Policy:

Purdue University is committed to providing a safe and secure campus environment for members of the university community. Purdue strives to create an educational environment for students and a work environment for employees that promote educational and career goals. Violent Behavior impedes such goals. Therefore, Violent Behavior is prohibited in or on any University Facility or while participating in any university activity.

For further information, you may refer to Purdue's violent behavior policy at: University's full violent behavior policy at: https://www.purdue.edu/policies/facilities-safety/iva3.html .

Diversity and Inclusion Statement:

In our discussions, structured and unstructured, we will explore a variety of challenging issues, which can help us enhance our understanding of different experiences and perspectives. This can be challenging, but in overcoming these challenges we find the greatest rewards. While we will design guidelines as a group, everyone should remember the following points:

- We are all in the process of learning about others and their experiences. Please speak with me, anonymously if needed, if something has made you uncomfortable.
- Intention and impact are not always aligned, and we should respect the impact something may have on someone even if it was not the speaker's intention.
- We all come to the class with a variety of experiences and a range of expertise, we should respect these in others while critically examining them in ourselves.

Course Evaluation:

During the last two weeks of the course, you will be provided with an opportunity to evaluate this course and your instructor. Purdue uses an online course evaluation system. You will receive an official email from evaluation administrators with a link to the online evaluation site. You will have up to two weeks to complete this evaluation. Your participation is an integral part of this course, and your feedback is vital to improving education at Purdue University. Students are strongly encouraged to participate in the evaluation system.