Principles of Image Science, OPTI 637, Fall 2026

Course contents: Mathematical description of imaging systems and noise. Inverse problems and image reconstruction. Statistical decision theory and model observers. Basic concepts of artificial intelligence and machine learning for image science.

Pre-requisites: A basic background in linear algebra and probability/statistics is recommended. Prior coursework in OPTI 508, 512, or 604 may be helpful but is not required. This course is a companion to OPTI 636, Noise in Imaging Systems, but neither is a prerequisite to the other.

Learning Outcomes:

- Employ a unified mathematical perspective based on linear algebra and stochastic theory to describe and analyze imaging systems.
- Design numerical experiments to simulate measurements from discrete and continuous linear systems with an understanding of the effects of relevant system parameters on the simulation results.
- Implement computational methods to solve inverse problems in imaging.
- Apply statistical decision theory and model observers to assess system performance with objective, task-based measures of image quality.
- Explain basic concepts of artificial intelligence (AI) and machine learning and their applications in image science.

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Class Hours: Tuesday & Thursday 2:00 - 3:15 pm in Meinel 422

Office Hour: Tuesday & Thursday 3:30 - 4:30 pm in Meinel 429

Brightspace (D2L) Web Site: is set up for posting problem sets and submitting homework. Homework is submitted through Brightspace. The late policy is as follows:

- Within 24 hours of due date: -10%
- Within 1 week of due date: - 20%
- More than 1 week late: -50%

i.e. the *maximum* score attainable for submissions more than one week late is 50%. All students will receive a one-time late submission grace period of one week without any grade reduction.

Please put the problem number and your name on every page to facilitate grading. Only Brightspace homework submissions will be accepted.

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Required Textbook: Barrett, H.H. and Myers, K.J. (2004), Foundations of Image Science.

UA Libraries (electronic version):

https://ebookcentral.proquest.com/lib/uaz/detail.action?docID=708238

Recommended Reference Book: Beck, A. (2014), Introduction to nonlinear optimization: theory, algorithms, and applications with MATLAB. (Available at the UA Libraries)

Grading:

Due on 11:59 PM-MST of dates listed below

• 4 Homework Assignments	40%	Tuesdays: Sep 15, Oct 6, Oct 27, Nov 24
• Project Report	30%	
1. Topic selection		Oct 29
2. Abstract submission		Nov 12
3. Final submission		Dec 3
• Project Presentations in Class (15 min each student)	30%	Dec 8

Course Outline:

Part 1 (Chapters 1 and 7 in Barrett and Myers)

- **Mathematical Background**. Basic concepts from linear algebra. Imaging systems as operators in Hilbert space. Systems of linear equations. Singular-value decomposition. Inverse and pseudoinverse. Probability and random variables.

Part 2 (Chapters 7 and 8 in Barrett and Myers)

- **The Imaging Chain**. Kinds of imaging systems. Image formation. Continuous and discrete models. Radon transform and tomography. Stochastic descriptions of objects and images.

Part 3 (Chapter 15 in Barrett and Myers; Chapters 2 and 4 in Beck)

- **Computational Methods for Inverse Problems**. Inverse problems. Algebraic Reconstruction Technique (ART). Landweber iteration. Expectation Maximization (EM) algorithm. Optimization-based approach and gradient-descent algorithm. Newton's method. Conjugate gradient method. Proximal gradient method.

Part 4 (Chapters 13 and 14 in Barrett and Myers)

- **Model Observers and Image Quality.** Statistical decision theory. Classification. Estimation. Model observers. Bayes risk and the Bayesian Ideal Observer. ROC analysis. Linear discriminants and the Hotelling Observer. Channels. An introductory overview of artificial intelligence (AI) for image science.

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Teaching Schedule:

Week	Tuesday	Thursday	Notes
1	Aug 25	Aug 27	Introduction to image science. Linear algebra review. Imaging systems as operators in Hilbert space.
2	Sep 1 (HW1 out)	Sep 3	Systems of linear equations, singular-value decomposition, and the pseudoinverse.
3	Sep 8	Sep 10	Classification of imaging systems. Image formation: continuous and discrete models.
4	Sep 15 (**HW1 due**)	Sep 17	Probability review. Stochastic descriptions of objects and images.
5	Sep 22 (HW2 out)	Sep 24	Radon transform and tomography. Filtered BackProjection (FBP).
6	Sep 29	Oct 1	Iterative methods: Algebraic Reconstruction Technique (ART), Landweber iteration, and Expectation Maximization (EM) algorithm.
7	Oct 6 (**HW2 due**)	Oct 8	Optimization-based reconstruction methods.
8	Oct 13 (HW3 out)	Oct 15	Gradient descent and constrained optimization.
9	Oct 20	Oct 22	Newton's method, conjugate gradient method, proximal gradient method.
10	Oct 27 (**HW3 due**)	Oct 29 (**Select project topic**)	Overview of statistical decision theory. Classification, estimation, and model observers.
11	Nov 3 (HW4 out)	Nov 6 (Finalize project topic)	Bayes risk and the Bayesian Ideal Observer.
12	Nov 10 (No class: Veterans Day)	Nov 12 (**Project abstract submission**)	ROC analysis and system performance evaluation.
13	Nov 17	Nov 19	Linear discriminants and the Hotelling Observer.
14	Nov 24 (**HW4 due**)	Nov 26 (No class: Thanksgiving)	Introduction to AI and machine learning for image science I
15	Dec 1	Dec 3 (**Project report submission**)	Introduction to AI and machine learning for image science II
	Dec 8		Project presentations.

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at https://catalog.arizona.edu/policy/courses-credit/grading/grading-system.

Absence and Class Participation Policy

The UA's policies concerning Class Attendance, Participation, and Administrative Drops is available at: https://catalog.arizona.edu/policy/courses-credit/courses/class-attendance-participation

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: https://deanofstudents.arizona.edu/policies/attendance-policies-and-practices

Participating in the course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all lectures and discussion section meetings. Absences may affect a student's final course grade. If you anticipate being absent, are unexpectedly absent, or are unable to participate in class online activities, please contact me as soon as possible. *To request a disability-related accommodation to this attendance policy, please contact the Disability Resource Center at (520) 621-3268 or disability@arizona.edu.* If you are experiencing unexpected barriers to your success in your courses, the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office is located in the Robert L. Nugent Building, Room 100, or call 520-621-7057.

Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog: https://deanofstudents.arizona.edu/policies/code-academic-integrity https://deanofstudents.arizona.edu/student-rights-responsibilities/academic-integrity. The UA Libraries have some excellent tips for avoiding plagiarism, available at: http://new.library.arizona.edu/research/citing/plagiarism. Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

Accessibility and Accommodations

At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268, https://drc.arizona.edu/) to establish reasonable accommodations.

Nondiscrimination and Anti-harassment Policy

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others. The UA is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

University Policies

All University policies related to the syllabus are available at https://catalog.arizona.edu/syllabus-policies

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.