BIOE 483 Biomedical Computed Imaging Systems

3/4 credit hours, **Fall 2025**

Course Website: https://canvas.illinois.edu/courses/62711
Instructor: Prof. Hongqiang Ma, mhq@illinois.edu; 4025 Beckman Institute
Classes: Tuesday/Thursday, 9:30-10:50AM, 2101 Everitt Laboratory
Office hours: By Appointment (Zoom for online students)

Computed imaging is a modern process by which medical images are acquired, optimized, and displayed for diagnosis. This course describes the physics of radiographic, magnetic resonance, nuclear imaging, ultrasound and optical imaging modalities with a focus on computational modeling, image formation and performance analysis. Image science and signal detection/estimation principles that are common to all modalities are covered in the context of specific biomedical imaging scenarios. Integration of physics-based modeling, computation, and iterative reconstruction techniques are covered in depth.

Student Learning Objectives: Upon completion of this course, students will be able to

- Understand the canonical imaging physics that underlies X-ray radiography and CT, nuclear imaging, MRI, ultrasound and optical imaging modalities
- Identify the physical factors that limit diagnostic performance of each technique
- Understand image quality metrics as a motivation for technology development
- Develop mathematical and numerical models of data acquisition and image formation processes
- Articulate the mathematical principles of image reconstruction from projections
- Describe iterative image reconstruction methods and their relative advantages over filtered backprojection approaches
- Acquire/build and apply the computational skills needed to form and evaluate medical images

Prerequisites:
Skills and knowledge in foundational math including linear algebra, calculus and probability
Beginner to intermediate level skill with scientific computer programming (Matlab and/or Python)

Preferred: ECE/BIOE 380 or equivalent

Required Textbooks (See instructor on required book purchase)

- Course notes distributed on Canvas.
- Jerry L. Prince, Jonathan Links, *Medical Imaging Signals and Systems*, 2nd Edition, Pearson, 2015
- Jerrold T. Bushberg, John M. Boone, J. Anthony Seibert, Edwin M. Leidholdt, *The Essential Physics of Medical Imaging*, Lippincott Williams & Wilkins, 2002

Recommended Textbooks

- Paul Suetens, *Fundamentals of Medical Imaging*, Cambridge University Press, 3rd Edition, 2017

You can use either Matlab or Python to complete the assignments. **Computing results, descriptions and analysis** are to be included in the homework submission. Code is not necessary. Course notes include Matlab and Python examples.

Grading

Homework Assignments	50%
In-Class Quizzes	10%
Participation (lectures and labs)	10%
Final Project	30% (15% presentation and 15% final report)

>90% = A >87% = A- >84% B+ >80% = B >77% = B- >74% = C+ >70% = C >65% = C-

Preliminary Schedule

Date	Class Meeting	Lecture Topics	Notes
08/26	**1**	Course Introduction and Computational Imaging	
08/28	**2**	Mathematical Preliminaries for Image and System Modeling	
09/02	**3**	Mathematical Representations of Images	
09/04	**4**	General Equations for Image Acquisition	
09/09	**5**	Fourier Analysis and its Connection to LSI Systems	
09/11	**6**	Introduction to Image Reconstruction and Resolution	HW1 Due
09/16	**7**	Introduction to Radiographic Imaging, X-Ray	
09/18	**8**	Modeling Radiographic Imaging Systems	
09/23	**9**	Image Quality Metrics for Linear Imaging Systems	
09/25	**10**	Vector Space Treatment and Linear Inverse Problem	
09/30	**11**	Introduction to X-Ray CT	HW2 Due
10/02	**12**	Modeling CT Acquisition: Projections and Radon Transform	
10/07	**13**	Classic CT Reconstruction Methods	
10/09	**14**	Fan Beam Acquisition and Reconstruction	
10/14	**15**	Iterative and Model-Based Reconstruction	
10/16	**16**	Nuclear Imaging, Isotope Decay Modes and Statistics	HW3 Due
10/21	**17**	Instrumentation for Planar Scintigraphy	
10/23	**18**	Image Equation for Gamma Camera Acquisition.	
10/28	**19**	SPECT Acquisition and Reconstruction	
10/30	**20**	PET Acquisition and Reconstruction, Image Quality	
11/04	**21**	MRI Imaging Physics	HW4 Due
11/06	**22**	MRI Imaging Physics	
11/11	**23**	MRI Imaging Physics and image formation	
11/13	**24**	Classic MRI Reconstruction Methods	
11/18	**25**	Optimization Based MRI Reconstruction	
11/20	**26**	Introduction to Ultrasound imaging	HW5 Due
11/25	**27**	No class (Fall break)	
11/27	**28**	No class (Fall break)	
12/02	**29**	Ultrasound imaging and reconstruction	
12/04	**30**	Introduction to Optical imaging and reconstruction	
12/09	**31**	Final presentation session	

Attendance and Class Participation

- Attendance is required.
- All lectures will be recorded and made available to online students (request needed for on campus students).
- Need to seek instructor's approval for absence due to health or other personal issues.
- Students need computer/smartphone for in-class quizzes administered via Canvas.
- Students are expected to respect and contribute to the classroom environment. Cell phones must be silenced during class time.

Homework Assignments

- Homework is to be submitted in a pdf format. This is a good opportunity to learn LaTeX.

- You are encouraged to work together on assignments. However, everyone must submit an individual report with clear figures. All plots and images must be clear labeled.

Statement on Academic Integrity

The university's policy on Academic Integrity can be found in the *Code of Policies and Regulations Applying to All Students* under Article One, Part IV which can be found at: https://studentcode.illinois.edu/article1/part4 . The following policies support and reinforce that policy.

1. Science cannot exist without honesty. We hold all students to the highest standards of scientific and academic conduct. Any form of cheating or plagiarism on graded work is unacceptable, and will be dealt with as outlined below, and in accordance with the University-wide standards in the *Code of Policies and Regulations Applying to All Students. Cite your sources as you would in a publication.*
2. All graded work must be entirely your own. Anything you write using the words of other writers be correctly attributed. Some specific points follow:

   On assignments and presentations, the answers that you report for grading must be written in your own words, formulated from your own understanding of the material. Even working within a group, you must contribute to the group's effort and not just have one person do all the work. Since we cannot monitor you as you complete your work, we have only the appearance of your work from which to judge. If the work you submit resembles that of another student/team too closely, we may conclude the report is not your original work. Failure to adhere to these standards may result in a grade of *zero for the entire assignment*, *for all persons involved.*

   On assignments, if you use another source to obtain the facts and/or opinions necessary to complete your assignment, you must credit the source (see next point below) and rephrase the information so that your assignment is entirely your own words. A good practice is to read the source until you have a thorough understanding of the material, and then put the source away. Write your assignment as if you are explaining the information you learned from reading the source to a classmate or a teaching assistant. You may wish to look at the source again for clarification but be certain that you do not use statements taken directly from the text in your assignment. Your entire assignment should be in your own words. Furthermore, paraphrasing does NOT mean replacing key words in a statement with synonyms. For an example of proper paraphrasing of a statement, consult the University's Code of Policies and Regulations Applying to All Students.

   Failure to adhere to these standards may result in zero credit for the entire assignment.

   On assignments, if you use the ideas and/or opinions from another author or source, you must provide the appropriate citation. That is, you must place a parenthetical reference to the source that provided you the information necessary to complete that portion of the assignment.

   Failure to adhere to these standards may result in zero credit for the entire assignment.

   On assignments, if you use a statement taken directly from any book or other publication, including the course textbook, you must provide a citation. That is, you must put the text in quotes and place a parenthetical reference to the source at the end of the quote. Direct quotations should be severely limited in your assignments; they should be used ONLY in the following situations:

   - A definition of a term.
   - A profound statement made by an expert in the field

   Furthermore, any direct quotation should then be restated in your own words in order that your instructor may evaluate your understanding of the material.

   Failure to adhere to these standards may result in zero credit for the entire assignment.