Course Title: BIOE 599 - Fundamentals of Biomedical Imaging: X-ray and Nuclear

Instructor: Paul Kinahan

Credits: 4

UW General Catalog Course Description:
Introduction to core principles of biomedical imaging with a focus on x-ray and nuclear imaging. Fundamental concepts of the imaging equation, the inverse problem, image SNR, contrast agents, and applications are covered. Lectures will emphasize a systems approach that is reinforced though computational projects.

Detailed Course Description:
his course introduces core concepts of biomedical imaging. Biomedical imaging is a multidisciplinary field where physics, chemistry, engineering, biology, and medicine converge. As part of a sequence covering the main biomedical imaging modalities, this course focuses on x-ray and nuclear imaging methods and their applications in biology and medicine. Specifically, the course will cover the principles of the interactions of radiation with matter, the fundamental concept of an imaging equation, the inverse problem of image formation, and image SNR. In addition, key concepts in contrast agents, biomedical image processing / analysis and uses in clinical diagnosis, therapy, and research will be introduced.

Recommended Background:
Signal and systems (linear systems), Fourier transforms and/or advanced linear algebra, scientific programming (e.g. Matlab).

Textbook:
There is no required textbook for this course. Reference articles and materials will be posted on the course website. The length and number of articles will be limited to ensure students have time to thoroughly read and understand the material.

Learning Objectives:
By the end of the course, students should be able to demonstrate the ability to understand, describe, and solve problems in the following areas:

- The signal: What are we seeing and where does the noise come from?
- The imaging equation: What is the mathematical description of the raw data acquisition?
- The inverse problem: How do we form an image from the raw data?
- Contrast agents
- Signal to noise ratio and image quality
- Cost versus usefulness versus safety
- Clinical versus research applications
- Diagnosis versus therapy applications

Students should also be able to implement (using Matlab, C++, or similar methods) models of x-ray and nuclear imaging systems, image reconstruction methods, and basic image quality analysis.

Topics Covered:

1. Two-dimensional signals and systems
2. Two-dimensional imaging systems
3. The imaging equation
4. The inverse problem of image formation
5. Image signal, contrast, noise and signal to noise ration (SNR)

6. X-ray imaging physics and applications
7. Nuclear medicine imaging physics and applications
8. Contrast agents

Course Schedule:

- Lectures: 1 hr 20 min lecture, two times per week
- Computer laboratory: Available as needed for computational projects

Laboratory Projects and Computer Use:
There will be 4 computational assignments building up to the simulation and analysis of medical imaging data. For these projects students will have to use mathematical programming tools such as Matlab or C++, although other languages/tools are acceptable. Tutorials and some examples are available in Matlab. Reports will include images and should be produced in PDF format.

Course Structure and Grading Policy:

1. Computational projects (65%)
   - See above
2. Midterm exam (15%)
   - The written midterm exam will be for the first half of the course, and will cover materials that are fundamental to all biomedical imaging applications.
3. Assignments and Literature review (20%)
   - Students will have two standard assignments and two literature reviews where they will prepare a written analysis of a scientific article for discussion, and will also be graded on class participation

Weekly Schedule:

	Date	Topic	Assignment due
1	9/25	Overview: Imaging equation, inverse problem, image quality, 2D signals and systems	
2	**9/30***	2D Linear Shift-invariant imaging systems and 2D Fourier transforms	Assignment 1: Article review
3	10/2	2D Imaging systems and sampling	Assignment 2: 2D linear systems
4	**10/7***	The imaging equation	
5	10/9	The central section theorem	Project 1: 2D imag. systems
6	**10/14***	The inverse problem of image formation. Higher dimensions	
7	10/16	Contrast, noise, and image quality	
8	10/21	X-ray physics: formation and interaction	Assignment 3: 2D Fourier trans
9	10/23	X-ray detection and imaging systems	
10	10/28	Midterm Exam	Assignment 4: imaging systems and utility review
11	10/30	X-ray contrast agents and biomedical applications	Project 2: X-ray transforms
12	**11/4***	X-ray computed tomography (CT) systems	

13	11/6	Computed tomography: Biomedical applications	Project 3: Imaging system simulation
	11/11	*Veteran's Day Holiday - No class*	
	11/13	*IEEE Medical Imaging Conference in Seattle - No Class*	
14	11/18	Gamma cameras: components and systems	
15	11/20	Tomography in molecular imaging: SPECT scanners	Assignment 5: modality review
16	11/25	Positron emission tomography (PET)	
	11/27	*Thanksgiving Holiday - No class*	
17	**12/2***	Hybrid PET/CT, SPECT/CT, and PET/MR scanners	Project 4: System SNR optimization
18	**12/4***	Molecular imaging with nuclear contrast agents and biomedical applications	