Medical Physics 573 - Medical Image Science: Mathematical and Conceptual Foundations

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Fall 2020

Lecture 0

Intro to the Course

Course name: Medical Image Science: Mathematical and Conceptual Foundations

Course number: Medical Physics 573

Instructors: Diego Hernando, PhD, and Sean Fain, PhD

Teaching Assistant: Lawrence Lechuga

Session: Fall 2020

Credits: 3

0.1 Overview

This course will cover the mathematical fundamentals required for medical imaging science. These fundamentals include: signal analysis (with an emphasis on Fourier transforms) in one and multiple dimensions, noise in imaging, and image reconstruction. This will be a hands-on course with a combination of theoretical foundations, and computational exercises (using a computational environment such as Jupyter Notebook/Python or Matlab) on real and simulated datasets. Mathematical concepts will be presented in the context of real-world clinical and research challenges. Upon completion of this course, students should gain a working understanding of a core set of mathematical and computational techniques with multiple applications in medical physics and beyond.

0.2 Learning objectives

Upon completion of this course, students should be able to:

- Summarize the utility of signal analysis in one and several dimensions
- Identify and apply convolutions and Fourier Transforms in one and several dimensions

- Apply signal analysis techniques for medical image reconstruction and identify the corresponding image artifacts
- Illustrate the limitations of the Fourier transform, and recall the advantages of alternative signal analysis tools (eg: wavelet transform)
- Illustrate the stochastic nature of imaging, and recall various noise distributions
- Calculate image signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR)
- Apply signal analysis and stochastic signals concepts in medical physics scenarios, including in imaging and therapy planning

0.3 Prerequisites

Undergraduate calculus, matrix algebra, undergraduate physics, basic statistics.

0.4 Related courses at UW

This course's materials are continued and complemented in Medical Physics 574 (Fain/Hernando).

0.5 Motivation

Why take this course?

- Learn mathematical foundations for understanding medical imaging and therapy planning concepts
- Become better at research: reading papers, solving problems, and writing papers

0.6 Course Structure

This course will consist of a combination of:

- Individual review of lecture notes.
- Group review of mathematical concepts during a portion of the lectures.
- Presentations with real-world examples to illustrate mathematical concepts.
- Flipped-style solution of conceptual and computational problems during lectures.
- Homework.

- Proof-based exercises. These are pen-and-paper type questions, typically dealing with the fundamental properties of the concepts studied in class.
- Computational exercises. *Important note: The examples given in class will be based on Jupyter Notebook/Python. However, computational exercises can be solved using each student's preferred computational environment (eg: Matlab, C, etc). Nevertheless, support from the instructors will be limited in non-Python, non-Matlab solutions.*
- Relevant readings. You will be asked to read several relevant research or review papers throughout our homework sets, and then summarize these papers or connect them to your own research.
- *Homework review during class:* After each homework set is handed in, we will devote part of the following lecture to reviewing a subset of the homework set questions.

0.7 Grading

- Midterm exam: 20%
- Final exam: 20%
- Homework sets: 35%
- Quizzes and in-class participation: 25%

0.8 Online Interaction

0.8.1 Canvas

This course will rely on Canvas for important communication, content distribution, and assignments. Make sure you are familiar with Canvas (`http://canvas.wisc.edu`) and able to access this course's materials.

0.8.2 Blackboard Collaborate Ultra (BBCU)

BBCU is an easy-to-use web conferencing tool that enables us to create virtual classrooms and meeting spaces. People at various sites can participate as if they are attending in person. Our online lectures will be based on BBCU, which is accessible directly from Canvas.

BBCU enables presentations (slides, PDF documents), white-board like interaction, polls, sharing screen, and several other functionalities that are helpful for online lectures.

0.9 Expectations

You can expect the instructors:

- To highlight the importance of the course materials, both the mathematical and computational aspects
- To work to ensure that all students have a chance to learn the material, given adequate effort on the students' part.
- To assign homework that adequately covers the material and meets the learning objectives of the course while adhering to the time expectations for a 3 unit course.
- To assign exams that accurately reflect the material covered in class and assigned in homework.
- To start and end class on time.

We can expect you:

- To come to class on time.
- To be attentive and engaged in class.
- To spend an adequate amount of time on each homework set, making an effort to solve and understand each problem.
- To engage with both the mathematical and computational sides of the material.
- To seek help when appropriate.