

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

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Lecture 0

Intro to the Course

Course name: Medical Image Science: Mathematical and Conceptual Foundations

Course number: Medical Physics 573

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Teaching Assistant: Brayden Schott

Session: Fall 2022

Credits: 3

0.1 Overview

This course will cover a set of mathematical fundamentals required for medical imaging science, therapy planning, and other biomedical applications. These fundamentals include: signal analysis (with an emphasis on Fourier transforms) in one and multiple dimensions, and mathematical optimization (including applications, formulations, and algorithms). 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, biomedical engineering, 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
- Illustrate the limitations of the Fourier transform, and recall the advantages of alternative signal analysis tools (eg: wavelet transform) [grad only]
- Distinguish between types of optimization problems, including convex vs non-convex, and unconstrained vs constrained
- Recognize the relative performance of basic optimization algorithms
- Formulate image reconstruction as an optimization problem
- Formulate therapy planning as an optimization problem
- Implement practical optimization algorithms using computational methods

0.3 Prerequisites

Undergraduate calculus, matrix algebra, undergraduate physics.

0.4 Related courses at UW

Med Physics / BME 574 describes probability and stochastic concepts that are complementary to the mathematical foundation provided in this course. Various other courses, particularly in Engineering and Computer Sciences, cover signal analysis and processing, as well as mathematical optimization. Feel free to come talk to me if you are interested in follow-on courses to dig deeper into the materials covered in this course.

0.5 Motivation

Why take this course?

- Learn mathematical foundations to understand 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.

- White board lectures describing fundamental concepts and examples.
- Computational examples in Python.
- 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 may devote part of the following lecture to reviewing a subset of the homework set questions.

0.7 Grading

0.7.1 Grade composition

- Midterm exam: 25%
- Final exam: 25%
- Homework sets: 45%
- Quizzes and in-class participation: 5%

0.7.2 Grading rubric

- 90.0-100.0: A
- 85.0-89.9: AB
- 80.0-84.9: B
- 75.0-79.9: BC
- 70.0-74.9: C
- 60.0-69.9: D
- <60.0: F

0.7.3 Late homework policy

Each student will get one free 2-day late pass. In other words, you can hand in a single homework set up to two days after the deadline, with no grade penalty. For example, if the homework was due on Friday at 11am, you could hand it in on Sunday at 11am. Once you use this free pass on one homework set, the deadline will be strictly enforced, i.e.: any subsequent homework sets handed in after the deadline will not be graded.

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 Computational examples

Computational examples for the materials covered in this course will be made available using shared Jupyter notebooks. The goal of these notebooks is to enable the students to “kick the tires” of concepts such as Fourier transforms, convolutions, sampling, aliasing, wavelets, as well as optimization problems in imaging and in therapy. These notebooks will be shared throughout the course (typically one notebook per lecture), and some of them will be reviewed in class to highlight specific concepts. Students are expected to review the notebooks on their own and bring any questions to office hours.

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 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.

