# Math 4931/MSSC 5931 – Mathematics of Medical Imaging
# Spring 2022

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**Lectures:** MWF 9-9:50 am, Cudahy Hall 143
**Course Website:** D2L https://d2l.mu.edu/d2l/home/465849

**Office Hours:** Mon 1-2 pm, Wed 2-3 pm, Fri 12-1 pm, and by appointment.
*Note: Office hours will be held virtually on Teams. Search for "Prof. Ongie's Virtual Office Hours [Spring 22]".*

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## Course Description

This course introduces the mathematical foundations of medical imaging, from mathematical modelling of measurement systems to numerical reconstruction algorithms. The main focus will be on image formation in computed tomography (CT): the Radon transform, the Fourier transform, filtered back projection, and iterative reconstruction techniques. Additionally, we will cover basics of magnetic resonance imaging (MRI).

## Textbook

**Required:** *The Mathematics of Medical Imaging: A Beginner's Guide* by Timothy G. Feeman, 2nd Ed. Springer 2010.

I will also occasionally post additional notes and supplementary materials on D2L. You are not responsible for textbook material or any other material that is not covered in lecture.

## Assessments

### Grading Scale

Grades will be based on homework (50% of final grade), quizzes (10% of final grade), a midterm exam (15% of final grade), and a final project (25% of final grade).

Letter grades will be assigned using the following scale:

| | | | |
|---|---|---|---|
| **A** | $93\% \leq$ Percentage $\leq 100\%$ | **C** | $73\% \leq$ Percentage $< 77\%$ |
| **A-** | $90\% \leq$ Percentage $< 93\%$ | **C-** | $70\% \leq$ Percentage $< 73\%$ |
| **B+** | $87\% \leq$ Percentage $< 90\%$ | **D+** | $67\% \leq$ Percentage $< 70\%$ |
| **B** | $83\% \leq$ Percentage $< 87\%$ | **D** | $60\% \leq$ Percentage $< 67\%$ |
| **B-** | $80\% \leq$ Percentage $< 83\%$ | **F** | Below 60% Percent |
| **C+** | $77\% \leq$ Percentage $< 80\%$ | | |

## Homework

- Homework will be assigned every 1-2 weeks, for a total of $\sim 7$ HW assignments (subject to change).
- Each homework assignment will be worth 20 points, and will consist of a mix of textbook problems and MATLAB coding exercises.
- Some homework problems will be labelled [MSSC] and only the students enrolled in MSSC 5931 need to do these problems. Students in MATH 4931 may attempt these problems for extra credit.
- All homework will be submitted virtually to a D2L dropbox. **Your homework must be uploaded as a single pdf file.** There are several free apps to help with this, including Genius Scan and CamScanner among others. Please make sure your scanned homework is legible before uploading. Scanned homework that cannot be read or that is uploaded as multiple files and/or in the wrong format (i.e., not a single pdf) will not be graded and given an automatic 0. Occasionally, you may need to merge pdfs before uploading to D2L. There are several free online apps to do this as well, such as combinepdf.com.
- **Collaboration Policy**: It can be very helpful to study and work with a group. This type of cooperative learning is encouraged. However, be sure that you have a thorough understanding of the concepts as well as the steps used to solve an exercise. You must be able to work through the exercises on your own. Each student must write up their assignment individually and independently and must turn in their own work.
- It is acceptable to consult external resources (like the internet) while doing your homework. **It is not acceptable to copy large chunks of math or code from these external resources.** Solutions copied verbatim from Math StackExchange or similar forums will receive an automatic zero. **You are required to list all external resources used to complete your assignment. This includes names of any classmates you worked with. Failure to do so may be considered plagiarism.**
- No late work will be accepted. However, **your single lowest homework score will be dropped at the end of the semester**.

## Quizzes

- At the end of each class period, I will assign a D2L quiz consisting of one short answer question that will be due before the next class period.
- Each quiz is pass/fail.
- Your three lowest quiz scores will be droppped at the end of the semester.

## Midterm Exam

- There will be one midterm exam given in-person and taken during regular class period. If you are unable to attend class on the day of the midterm due to quarantine/illness, please let me know and I can make accommodations.
- Students are permitted to use one side of a (8.5 inches by 11 inches) paper on the exam to be submitted with the exam.
- Make-up exams will not be given unless the student informs, and has a come to a written agreement with, the instructor regarding the absence no later than the day before the exam day. The student is responsible for scheduling their make-up exam.

### Final Project

- Following the midterm exam, you will begin to prepare your final project.
- Your project may investigate any topic that relates to any mathematical and/or computational methods in medical imaging not covered in the lectures. This can include:
  - A summary of an imaging modality not discussed in lectures (e.g., Ultrasound, SPECT, PET, EIT, fMRI, & many others)
  - Image segmentation algorithms, or other image analysis techniques used in medical imaging.
  - Advanced non-linear image reconstruction algorithms, such as based on using deep learning/CNN's.

  The project does not need to be "original" work (i.e., you do not need to devise a new algorithm yourself), but must involve a mathematical or computational aspect.
- The final project has three components:
  - **A project pitch**, in the form of a 1-2 pg document submitted roughly one month before the project is due, outlining the goals of the project and identifying key references.
  - **A class presentation**, 20 minutes in length, that highlights the key findings of your project.
  - **A written report**, $5-10$ pages in length describing in detail the project aims, methods, and outcomes, with a complete bibliography.
- Students enrolled in MATH 4931 may (optionally) work in pairs. If working in pairs, this must be specified during the project pitch stage.
- Students enrolled in MSSC 5931 must give an individualized project. The project for students in MSSC 5931 must be more in-depth.
- More details about the final project will be available following the midterm.

## Course Technology

### MATLAB

- Several assignments will use the MATLAB computing toolbox. However, no previous experience with MATLAB is expected or required.
- Marquette University students may download MATLAB onto their personal computers: http://www.marquette.edu/its/help/matlab/. MATLAB is also available in the computer labs of Cudahy Hall and in Engineering and the library.
- Some homework assignments will make use of the **Image Processing Toolbox**. To add this toolbox to your MATLAB installation, click on the "APPS" tab at the top of the interface, then click the "Get More Apps" button, and search for "Image Processing Toolbox".
- You are encouraged to check access to MATLAB by Friday Sept 10, 2021 to ensure proper access moving forward. Please contact ITS with questions about downloading and installing MATLAB on your device.

### LaTeX

- LaTeX (pronounced "lay-tech" or "law-tech") is a text editor that enables you to create professional-looking mathematical documents. It is very commonly used in mathematics, computer science,

physics, engineering, and other STEM fields. **I highly recommend writing up your homework and/or the take-home exam in LaTeX.** Overleaf (https://www.overleaf.com/) is a free, easy-to-use, online LaTeX editor (and is, in fact, what I used to create this document).

- I have posted some tutorial information and templates on D2L to help you get started, and I'm always more than happy to help out in office hours.

## Course Policies

**Masking** Per the current University rules, all students (and the instructor) will be required to wear a face mask that covers the mouth and nose, and engage in social distancing when possible. Students who do not comply will be asked to leave the classroom – no exceptions.

**Attendance** Students are expected to attend the in-person lectures. However, due to the ongoing COVID-19 pandemic, I realize that this may not be possible for all students at all times. In the event of a prolonged absence (two or more consecutive in-person lectures), please contact me as soon as possible so that I can make reasonable accommodations, especially if the absence includes an exam date.

**Grading Disputes** If you believe that I have made an error in scoring an assignment, you must bring it to my attention **within one week** of the graded assignment being returned. I will carefully reread, and if necessary rescore, the assignment.

**Accommodations for Disabilities** If you have a disability and will require accommodations under the Americans with Disabilities Act, you need to provide appropriate documentation to the Office of Disability Services. They will supply you with a letter to give to me detailing the accommodations. If you are unsure of whether you qualify for services, visit the Office of Disability Services' website, http://www.marquette.edu/disability-services, or contact them at (414) 288-1645. If you qualify for special accommodations you must work with the course instructor and come to an agreement no less than 7 days prior to the needed accommodation.

# Course Schedule [Tentative]

| | | |
|---|---|---|
| | Mon, Jan 24 | Syllabus, Intro to Med Img |
| Week 1 | Wed, Jan 26 | X-ray Imaging (Ch.1) |
| | Fri, Jan 28 | X-ray Imaging (Ch.1) |
| | Mon, Jan 31 | The Radon Transform (Ch.2) |
| Week 2 | Wed, Feb 2 | The Radon Transform (Ch.2) |
| | Fri, Feb 4 | The Radon Transform (Ch.2) |
| | Mon, Feb 7 | The Radon Transform (Ch.2) |
| Week 3 | Wed, Feb 9 | The Radon Transform (Ch.2) |
| | Fri, Feb 11 | The Radon Transform (Ch.2) |
| | Mon, Feb 14 | Back Projection (Ch.3) |
| Week 4 | Wed, Feb 16 | Back Projection (Ch.3) |
| | Fri, Feb 18 | Back Projection (Ch.3) |
| | Mon, Feb 21 | Complex Numbers (Ch. 4) |
| Week 5 | Wed, Feb 23 | The Fourier Transform (Ch. 5) |
| | Fri, Feb 25 | The Fourier Transform (Ch. 5) |
| | Mon, Feb 28 | The Fourier Transform (Ch. 5) |
| Week 6 | Wed, Mar 2 | Two Big Theorems (Ch. 5) |
| | Fri, Mar 4 | Two Big Theorems (Ch. 6) |
| | Mon, Mar 7 | Review |
| Week 7 | Wed, Mar 9 | Review |
| | Fri, Mar 11 | In-class Midterm Exam |
| | Mon, Mar 14 | No Class – Spring Break |
| Week 8 | Wed, Mar 16 | No Class – Spring Break |
| | Fri, Mar 18 | No Class – Spring Break |
| | Mon, Mar 21 | Filters and Convolution (Ch. 7) |
| Week 9 | Wed, Mar 23 | Filters and Convolution (Ch. 7) |
| | Fri, Mar 25 | Filters and Convolution (Ch. 7) |
| | Mon, Mar 28 | Discrete Image Reconstruction (Ch. 8) |
| Week 10 | Wed, Mar 30 | Discrete Image Reconstruction (Ch. 8) |
| | Fri, Apr 1 | Discrete Image Reconstruction (Ch. 8) |
| | Mon, Apr 4 | Discrete Image Reconstruction (Ch. 8) |
| Week 11 | Wed, Apr 6 | Iterative Reconstruction (Ch. 9 & Supplements) |
| | Fri, Apr 8 | Iterative Reconstruction (Ch. 9 & Supplements) (Final Project Pitch Due) |
| | Mon, Apr 11 | Iterative Reconstruction (Ch. 9 & Supplements) |
| Week 12 | Wed, Apr 13 | No Class |
| | Fri, Apr 15 | No Class - Easter Break |
| | Mon, Apr 18 | MRI basics (Ch. 10) |
| Week 13 | Wed, Apr 20 | MRI basics (Ch. 10) |
| | Fri, Apr 22 | MRI basics (Ch. 10) |
| | Mon, Apr 25 | Advanced Iterative Reconstruction (Supplement) |
| Week 14 | Wed, Apr 27 | Advanced Iterative Reconstruction (Supplement) |
| | Fri, Apr 29 | Advanced Iterative Reconstruction (Supplement) |
| | Mon, May 2 | Final Project Presentations |
| Week 15 | Wed, May 4 | Final Project Presentations |
| | Fri, May 6 | Final Project Presentations |
| Week 16 | Mon, May 9 | Final Project Presentations |