Course name: **Medical Image Science: Mathematical and Conceptual Foundations**
Course #: **Medical Physics 573 / Biomedical Engineering 573**
Instructors: **Diego Hernando, PhD, Assistant Professor (dhernando@wisc.edu)**
Sean Fain, PhD, Professor (sfain@wisc.edu)
Assistant: **Lawrence Lechuga, MS (llechuga@wisc.edu)**
Session: **Fall 2020**
Credits: **3**
Lectures: **MWF 11:00AM-11:50AM**
Office hours: **TBD**
Location: **Canvas/Blackboard Collaborate Ultra/WIMR 1022**
Canvas URL: **https://canvas.wisc.edu/courses/210920**

Instructional mode: **Hybrid**
Course designations and attributes: **Graduate level, general education**

Course description: 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 (via lecture notes, as well as on the white board during face-to-face office hours) 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.

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

Prerequisites: Undergraduate calculus, matrix algebra, undergraduate physics, basic statistics. Please see section 0 under course contents below.

Homework: Homework sets will be due every 2-3 weeks, and will include both theoretical derivations and proofs, as well as computational exercises.

Exams: There will be two exams: one midterm and one final exam.

Grading: The midterm exam will count 20% of the final grade. The final exam grade will count for 20%. Homework problems will count for 35%. In-class participation and quizzes will count for the remaining 25%.

Course credit information: This class meets for three 50-minute class period each week over the fall/spring semester and carries the expectation that students will work on course learning activities (reading, writing, problem sets, studying, etc) for about 2 hours out of classroom for every class period. This syllabus includes additional information about meeting times and expectations for student work.

Related courses at UW: This course's materials are continued and complemented in Medical Physics 574 (Fain).

Required texts: No texts are required for this course. Some relevant texts and resources include:

- **Medical Imaging Signals and Systems** by Jerry L. Prince, Jonathan Links, Pearson Education, 2nd Edition.
- **The Fourier Transform & Its Applications** by Ronald Bracewell, McGraw-Hill.
- Additionally, Prof. Barry van Veen's excellent video lectures are available on the **AllSignalProcessing YouTube channel**: https://www.youtube.com/channel/UCooRZ0pxedi179pBe9aXm5A

Academic Integrity:

By enrolling in this course, each student assumes the responsibilities of an active participant in UW-Madison's community of scholars in which everyone's academic work and behavior are held to the highest academic integrity standards. Academic misconduct compromises the integrity of the university. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these acts are examples of academic misconduct, which can result in disciplinary action. This includes but is not limited to failure on the assignment/course, disciplinary probation, or suspension. Substantial or repeated cases of misconduct will be forwarded to the Office of Student Conduct & Community Standards for additional review. For more information, refer to studentconduct.wiscweb.wisc.edu/academic-integrity/.

Accommodations for Students with Disabilities:

McBurney Disability Resource Center syllabus statement: "The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility. Students are expected to inform faculty [me] of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. Faculty [I], will work either directly with the student [you] or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including

instructional accommodations as part of a student's educational record, is confidential and protected under FERPA." http://mcburney.wisc.edu/facstaffother/faculty/syllabus.php

Diversity & Inclusion:

Institutional statement on diversity: "Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals.

The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world." https://diversity.wisc.edu/

Academic Calendar & Religious Observances:

See: https://secfac.wisc.edu/academic-calendar/#religious-observances

Course Evaluations:

Students will be provided with an opportunity to evaluate this course and your learning experience. Student participation is an integral component of this course, and your feedback is important to me. I strongly encourage you to participate in the course evaluation.

Digital Course Evaluation (AEFIS)

UW-Madison now uses an online course evaluation survey tool, AEFIS. In most instances, you will receive an official email two weeks prior to the end of the semester when your course evaluation is available. You will receive a link to log into the course evaluation with your NetID where you can complete the evaluation and submit it, anonymously. Your participation is an integral component of this course, and your feedback is important to me. I strongly encourage you to participate in the course evaluation.

COVID 19: UW-Madison Face-Covering Guidelines

While on campus all employees and students are required to wear appropriate and properly fitting face coverings while present in any campus building unless working alone in a laboratory or office space.

Face Coverings During In-person Instruction Statement (COVID-19)
Individuals are expected to wear a face covering while inside any university building. Face coverings must be worn correctly (i.e., covering both your mouth and nose) in the building if you are attending class in person. If any student is unable to wear a face-covering, an accommodation may be provided due to disability, medical condition, or other legitimate reason.

Students with disabilities or medical conditions who are unable to wear a face covering should contact the McBurney Disability Resource Center or their Access Consultant if they are already affiliated. Students requesting an accommodation unrelated to disability or medical condition, should contact the Dean of Students Office.

Students who choose not to wear a face covering may not attend in-person classes, unless they are approved for an accommodation or exemption. All other students not wearing a face covering will be asked to put one on or leave the classroom. Students who refuse to wear face coverings appropriately or adhere to other stated requirements will be reported to the Office of Student Conduct and Community Standards and will not be allowed to return to the classroom until they agree to comply with the face covering policy. An instructor may cancel or suspend a course in-person meeting if a person is in the classroom without an approved face covering in position over their nose and mouth and refuses to immediately comply.

Quarantine or Isolation Due To Covid-19:
Student should continually monitor themselves for COVID-19 symptoms and get tested for the virus if they have symptoms or have been in close contact with someone with COVID-19. Student should reach out to instructors as soon as possible if they become ill or need to isolate or quarantine, in order to make alternate plans for how to proceed with the course. Students are strongly encouraged to communicate with their instructor concerning their illness and the anticipated extent of their absence from the course (either in-person or remote). The instructor will work with the student to provide alternative ways to complete the course work.

Related courses at other institutions:

UCL: MPHY3893 - Mathematical Methods in Medical Physics (Jem Hebden)
http://www.ucl.ac.uk/medphys/prospective-students/modules/mphy3893

UT: GS02 1183 – Applied Mathematics in Medical Physics
http://www.uthgsbsmedphys.org/GS02-0183/Syllabus%20Math%20Med%20Phys%2009-07-2012.pdf

U Chicago: MPHY 34900 - Mathematics for Medical Physics
http://medicalphysics.uchicago.edu/program/descriptions.html

Duke: MP 530 - Modern Medical Diagnostic Imaging System.
https://medicalphysics.duke.edu/courses

Stanford: EE369C - Medical Image Reconstruction (Pauly)
http://web.stanford.edu/class/ee369c/index.html

USC: EE 592 - Computational Methods for Inverse Problems (Haldar)
https://web-app.usc.edu/soc/syllabus/20173/30794.pdf

Michigan: Bioengineering/Math 464 – Inverse Problems
http://bme.umich.edu/course/biomede-464/

Michigan: EECS 755 - Topics in Signal Processing: Model-based image reconstruction methods (Fessler)
https://web.eecs.umich.edu/~fessler/course/755/index.html