Western University
Faculty of Engineering
School of Biomedical Engineering

BME 9507 – Advanced Imaging Principles

COURSE OUTLINE 2021-2022 (Winter term)

DESCRIPTION

Medical imaging plays a critical role in modern medicine and medical research. This course describes how image quality is degraded by system performance that introduce errors into measurements from image data, and how to minimize these errors. Results are applicable to all imaging modalities, and examples are given for digital radiography, MRI, CT, and ultrasound. A strong emphasis is placed on the effective use of linear-systems theory and the Fourier transform to describe system characteristics including image signal and noise.

PREREQUISITES

Basic understanding of Fourier transform and principles of medical imaging systems. Contact course instructor for further details if desired.

TOPICS

Topic #	Description	Learning Activities	Tentative timeline
1	Linear-Systems Principles and Noise-Free Imaging Systems		
	Linear-systems concepts, impulse-response, superposition integral, convolution integral	• Two lectures (3 hrs) • Additional reading material	Week 1
	Properties of convolution integral, system characteristic function, Fourier transform and spatial-frequency domain	• Two lectures (3 hrs) • Additional reading material	Weeks 2
	Fourier pairs, Fourier theorems and properties of Fourier transform	• Two lectures (3 hrs) • Additional reading material	Week 3
	Sampling, aliasing and aperture MTF	• Two lectures (3 hrs) • Additional reading material	Week 4
	Discrete Fourier transform, data windows and post-processing in the Fourier domain	• Two lectures (3 hrs) • Additional reading material	Week 5

2	Imperfect Imaging Systems and Image Noise		
	Image noise and the Wiener-Khinchin theorem	• Two lectures (3 hrs) • Additional reading material	Week 6
	Signal and noise in CT imaging	• Two lectures (3 hrs) • Additional reading material	Week 7
	Signal and noise in MR imaging	• Two lectures (3 hrs) • Additional reading material	Week 8
	Signal and noise in ultrasound imaging	• Two lectures (3 hrs) • Additional reading material	Week 9
3	Applications and Measurements in Modern Medical Imaging		
	Project ideas and discussion, problems and applications	• Two lectures (3 hrs)	Week 10
	Signal and noise problems and applications	• Two lectures (3 hrs)	Week 11
	Project presentations		Week 12

SPECIFC LEARNING OUTCOMES

I) Linear-Systems Principles and Noise-Free Imaging Systems

- Develop an understanding of basic concepts and metrics used to describe image quality and the performance of imaging systems, including the point-spread function, convolution integral, line-spread function, Fourier transform and theorems, characteristic function, and modulation-transfer function.
- Be able to make versatile and effective use of the Fourier transform in solving imaging problems. Be able to solve problems in both spatial and spatial-frequency domains, and to move fluently between domains. Understand concepts encountered in each domain, including ringing, Gibb's phenomenon, sampling, aliasing, and apertures.
- Understand principles of the discrete Fourier transform (FFT), including how it differs from the Fourier transform, and how to minimize common errors encountered in its application including aliasing, spectral leakage, side lobes, data windows and zero padding.

II) Imperfect Imaging Systems and Image Noise

- Understand the principles of random variables, random functions and random processes in the description and characterization of image noise.
- Develop an understanding of why medical images are generally noisy, and be able to solve image-noise problems using concepts such as the Wiener noise power spectrum, correlated processes, correlation functions, quantization noise, noise aliasing, filtered noise processes, Parseval's theorem and the Wiener-Khinchin theorem.

III) Applications and Measurements in Modern Medical Imaging

- Develop an understanding of the principles that affect image signal, noise and signal-to-noise ratio in CT, MRI, US and DR.
- Be able to solve image-noise problems with equal fluency in both spatial and spatial-frequency domains.
- Understand the effects and limitation caused by image noise on measurements made using digital images.

A project is required in which the student prepares a 20-min lecture and written summary (5-10 pages plus figures) on a topic related to the course. For example:

a) start with a concept discussed in the course and apply or extend it to solve a problem in your research

b) prepare a lecture on a topic that could have been part of the course (similar content, level of complexity) related to your research.

An electronic reference document will be provided.

ASSESSMENTS

Assessment Type	Material Covered	Tentative Due Date	Weight
Homework Assignments (five)			50%
Participation	Attendance and participation in class activities		20%
Project Submission			15%
Project Presentation			15%

Activities in which collaboration is permitted:

- Assignments may be worked on in collaboration with other students, but each student must submit their own answers and solutions.

Activities in which students must work alone (collaboration is not permitted:

- Project preparation and presentation

CONTACT INFORMATION

Course instructor: Dr. Ian Cunningham (plus Dr. Jim Lacefield)
Email address: icunningham@robarts.ca

Contact policy:

- Contact instructor via email (above) or through messages in OWL
- Weekly Office hours are held via Zoom

- A general FAQ section on the 'forums' section of OWL will be used for students to pose course-related questions so that all have the same information.

REQUIRED TEXTBOOK
None

OPTIONAL COURSE READINGS
A pdf reference document for much of the course material will be provided.

COURSE CONTENT
The lecture notes and online lecture videos are copyrighted to the instructor and legally protected. Do not post these videos and lecture notes on any other website or online forums. The recording of the live/synchronous sessions of the course without the permission from the instructor is prohibited. The illegal posting and sharing of the copyrighted course content could be subjected to legal actions.

CHEATING, PLAGIARISM/ACADEMIC OFFENCES
Academic integrity is an essential component of learning activities. Students must have a clear understanding of the course activities in which they are expected to work alone (and what working alone implies) and the activities in which they can collaborate or seek help; see information above under "Assessments" and ask instructor for clarification if needed. Any unauthorized forms of help-seeking or collaboration will be considered an academic offense. University policy states that cheating is an academic offence. If you are caught cheating, there will be no second warning. Students must write their essays and assignments in their own words. Whenever students take an idea or a passage of text from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence. Academic offences are taken seriously and attended by academic penalties which may include expulsion from the program. Students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence (see Western's scholastic discipline regulations for graduate students).

SYNCHRONOUS LEARNING ACTIVITIES
Students are expected to participate in synchronous learning activities as outlined in the course syllabus and/or described by the instructor. If you have issues that will impede your ability to participate in synchronous activities, please discuss with the course instructor at the beginning of the course.

CONDUCT
Students are expected to follow proper etiquette during synchronous and asynchronous activities to maintain an appropriate and respectful academic environment. Any student who, in the opinion of the instructor, is not appropriately participating in the synchronous and asynchronous learning activities and/or is not following the rules and responsibilities associated with the online learning activities, will be reported to the Associate Dean (Graduate) (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Associate Dean (Graduate), the student could be debarred from completing the assessment activities in the course as appropriate.

HEALTH/WELLNESS

As part of a successful graduate student experience at Western, we encourage students to make their health and wellness a priority. Western provides several health and wellness related services (remotely accessible) to help you achieve optimum health and engage in healthy living while pursuing your graduate degree. Information regarding health- and wellness-related services available to students may be found at http://www.health.uwo.ca/.

Students seeking help regarding mental health concerns are advised to speak to someone they feel comfortable confiding in, such as their faculty supervisor, their program director (graduate chair), or other relevant administrators in their unit. Campus mental health resources may be found at http://www.health.uwo.ca/mental_health/resources.html
https://www.uwo.ca/health/psych/index.html

SICKNESS

Students should immediately consult with the Instructor (for a particular course) or Associate Chair (Graduate) (for a range of courses) if they have problems that could affect their performance. The student should seek advice from the Instructor or Associate Chair (Graduate) regarding how best to deal with the problem. Failure to notify the Instructor or the Associate Chair (Graduate) immediately (or as soon as possible thereafter) will have a negative effect on any appeal. Obtaining appropriate documentation (e.g., a note from the doctor) is valuable when asking for accommodation due to illness.

ACCESSIBLITY

Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Accessible Education at 661-2111 x 82147 or http://academicsupport.uwo.ca/accessible_education/index.html, for any specific question regarding an accommodation.