INTRODUCTION TO MEDICAL IMAGING
MDPH607 (3 credits) – Fall 2017

LOCATION: ROOM TBD
Cedars Cancer Centre, Royal Victoria Hospital, Glen Site MUHC
1001 Decarie Boulevard
Métro: Vendôme

SCHEDULE TBD
First class: TBD

Instructor: Prof. Ives Levesque, PhD
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Office Hours: By appointment.

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Evaluation: There will be a number of assignments (problem sets, writing, programming, readings), a mid-term exam (in class), a final exam (during the exam period), and a project from each student. See page 3 of this document for more detail.

Texts:
Magnetic Resonance Imaging – D. Nishimura (available from www.lulu.ca)
Medical Imaging Systems – *A. Macovski*, Prentice-Hall
The Physics of Medical Imaging – *S. Webb*, Institute of Physics Publishing
The Fourier Transform and its Applications – *R. N Bracewell*, McGraw Hill

Handouts: Class notes and other handouts will be made available.

Course Description: This course is concerned with the acquisition and reconstruction of medical images, including filtering and post processing. Four medical imaging modalities will be considered: projection radiography, X-ray computed tomography (CT), positron emission tomography (PET) and magnetic resonance imaging (MRI). The course emphasizes a linear system approach to the formation, processing, and display of medical images. A strong background is required in both physics and mathematics.

Pre-requisite: Approval of the instructor is required for students not registered in Medical Physics or Biological & Biomedical Engineering at McGill.

NOTE: Under extreme circumstances, the contents of this document can be modified by the instructor to allow for adjustments in the course.

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LEARNING OUTCOMES

By the end of this course, the student should be able to:

1. Apply basic linear systems theory to the study of medical imaging systems
2. Demonstrate an understanding of approaches to tomographic (CT, PET) medical image reconstruction
3. Understand the principles of NMR physics, MR imaging, and the basic architecture of an MRI system
4. Discuss applications of PET and MRI in human medical imaging along with the underlying physical principles
5. Read and understand scientific papers in the field of medical imaging, especially in PET and MRI

OUTLINE OF CONTENT

I. **Linear Systems:** Linear systems, Dirac delta function. Multi-dimensional functions and function discretisation. Sinusoids, impulses and linear shift-invariant (LSI) systems. Function decomposition and Fourier series. The Fourier transform, multi-dimensional and discrete Fourier transforms. The convolution theorem. Blur and resolution, point-spread function, line spread function, modulation transfer function. Diagonalisation: eigenvectors and eigenvalues, singular value decomposition (SVD). Image reconstruction by deconvolution. The Fast Fourier transform (FFT). Sampling and aliasing.

II. **Radiographic imaging:** Contrast. Beer-Lambert law. Film characteristic response. Digital detector response. Detector resolution (film, computed radiography, digital radiography). Projection radiography, magnification. Unsharpness: motion, system, and geometric. Scatter, effect on image contrast. Grids and aliasing. X-ray noise spectrum. Poisson and Gaussian distributions. Quantum mottle. Signal-to-noise ratio. Detective quantum efficiency. Cascaded systems: signal and noise propagation. X-ray subtraction images.

III. **Tomography and Inverse Problems:** Imaging and inverse problems. Basics of positron emission tomography (PET) and computed tomography (CT). The central section theorem. Direct Fourier reconstruction, filtered backprojection (FBP) and backproject then filter (BPF). Projection sampling: Influence of detector width, detector quarter offset, reconstruction algorithm and display resolution on CT resolution. SNR and dose. Object and data representation, the system matrix and the forward model. Iterative solution to the inverse problem, and the expectation Maximisation (EM) algorithm. Maximum Likelihood (ML) and the ML-EM image reconstruction method. ML for transmission data. Iterative least squares (LS), and the algebraic reconstruction technique (ART). Direct least squares estimates, simple example of linear regression. Data correction for PET. Multi-slice, fan-beam, and cone-beam CT. Helical CT: pitch and image reconstruction.

IV. **Nuclear magnetic resonance:** Quantum mechanical and classical NMR theory. Precession. Net magnetization. Relaxation. The Bloch equation. Excitation and induction. Signal detection. Spin echo. Chemical shift. NMR spectroscopy.

V. **Magnetic resonance imaging:** Magnetic field gradients. Signal equation for MRI. Typical system description for proton imaging. Image space and k-space interpretation of MRI. Projection and 2DFT imaging. Sampling, field-of-view and resolution. R.F. and gradient pulse sequences. Selective excitation. MRI noise and noise properties. Gradient and spin echo imaging. Inversion preparation, multi-echo MRI. Image contrast. Fast imaging, spoiling, single-shot imaging. NMR spectroscopy and imaging of other nuclei. Image reconstruction techniques.

ASSESSMENT

Assignments: Short problems or open-ended questions will be assigned each week to review material or to explore certain topics in greater detail. These may include programming in MATLAB. The due date will be clearly indicated on each assignment.

Mid-term exam: The mid-term exam will be held in class, and is currently scheduled for DATE TBD.

Project: Students will be expected to submit a project on a topic approved by the instructor. The format will be a written paper (2,500-3,500 words plus figures, tables, and references) and a short in-class presentation. Details, including dates of project milestones, will be discussed in class.

Final exam: The final exam will be held during the exam period, between DATE TBD and DATE TBD. Do not make plans to travel until after the exam.

Grading:	Assignments:	20%
	Midterm:	25%
	Project:	25%
	Final Exam:	30%

Barring exceptional circumstances, late submission of assignments or the project will be assessed a penalty of 10% per day (or fraction of a day).

McGill Policies:

1) *McGill University values academic integrity. Therefore all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures (see www.mcgill.ca/students/srr/honest/) for more information).*

2) *In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded.*

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