Bishop's University Summer 2021 semester (May 10 – August 23)

Medical Imaging (listed as CS 463/516 Volumetric image processing and Computer Vision)

Outline: Medical images capture anatomical and physiological details non-invasively in-vivo. Medical images have the potential to yield direct insight into various pathologies and abnormalities, as well as healthy function. Obtaining this information from the images, however, is not so easy. Medical imaging techniques must be combined into image processing pipelines that ensure accuracy and reproducibility of results. This course will cover: 1) basic reconstruction transforms and acquisition methods 2) de-noising and pre-processing, 3) advanced processing (segmentation, tractography, inverse EEG modeling, machine learning) and 4) visualization. The programming language will be primarily python using the numpy libraries, and the visualization component will be in Unity using C# programming language.

Course organization details:
Instructor: Russell Butler rbutler@ubishops.ca
Office hours: the office hours will be conducted through Wednesday morning "breakfast-club" type discussions. Details to follow.

- Lectures will be delivered by video recording, accompanying slides will be provided on moodle.
- Video presentation recordings from top experts at international conferences will also be shown, when relevant.
- I am also trying to recruit some experts in the field to give live presentations (Details to follow).
- You can expect to work roughly 10-15 hours per week to complete this course.

Detailed plan:

1) Medical image acquisition and reconstruction
    a. History of medical imaging, common modalities
    b. Principles of tomographic reconstruction (Back projection)
    c. 2D Radon Transform2D and 3D Fast Fourier Transform
    d. Accelerated MRI acquisition and reconstruction
    e. Cardiac and brain specific MRI acquisitions

2) De-noising and pre-processing
    a. Noise and SNR
    b. Common medical imaging artifacts
    c. Image Registration (alignment)
    d. Independent Component Analysis (ICA)
    e. Nuisance regression and bandpass filtering

3) Advanced processing
    a. Medical image segmentation specific problems
    b. Tractography, Inverse modeling, and ill-posed problems
    c. Graph theory and functional/structural connectivity
    d. Machine learning for medical imaging
    e. Group (multi-subject) analysis, parametric statistics (t-test, p-value)

4) Visualization
    a. Common medical imaging formats
    b. Surface reconstruction
    c. Surface and Volumetric rendering
    d. Real time rendering

An undergraduate mathematical and programming background is assumed (basic Calculus, Linear Algebra, familiarity with at least one programming language).

Prerequisites: CS211, MAT209 (but any motivated CS student should be able to do well in this course).

Evaluation:
4 assignments (60%) and a final project (40%)
Assignments 1-4 (15% each). Each assignment will cover one of the topics in the outline. The assignments will be given roughly 2 or 3 weeks to complete. Assignments will cover basic medical imaging problems and be done in python.
Final Project (40%): for the final project, you will work on an advanced research problem and will have roughly 1 month to solve your problem. The best solutions will be candidates for publication in a journal.

Assignments may be completed in pairs (2 people) or individually. Group sizes of 3 or more are *not* permitted. Final project group size will be determined at a later date.

Academic integrity:
Sharing of assignments between groups and copying from the internet is not allowed. Plagiarized assignments will be given mark of 0%. Group sizes intentionally kept small (2 people or less) to ensure all students do the work.

Resources:
The majority of the course will be taught using freely available academic publications and software.

Two optional textbooks are:

1) Fundamentals of Medical Imaging. 2nd or 3rd Edition
2) Guide to Medical Image Analysis – Methods and Algorithms. 2nd Edition

I also borrowed some material from Maxime Descoteaux's course IMN530: http://scil.usherbrooke.ca/en/teaching/