Bishop's University Summer 2020 semester (May 11 – August 19)
CS 463/516 Volumetric image processing and Computer Vision

Medical Imaging

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: Virtual office hours using BlueJeans app, Thursday 10:30-11:30 am (details to follow in an email)
Lectures will be delivered by powerpoint slides, posted once a week to moodle (typically 50-70 slides per week)
Lectures and assignments will be accompanied by video demonstrations when appropriate
Video presentations from top experts at international conferences will also be shown, when relevant
You can expect to work ~6 hours per week working on assignments/final, and 3 hours per week watching slides/videos

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 exam (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 or C#.
Final Exam (40%): The final exam will be administered online and with a duration of 3 hours. Final exam is cumulative and will be a mixture of math and programming questions.
Assignments may be completed in pairs (2 people) or individually. Group sizes of 3 or more are *not* permitted. Final exam is individual.

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