ELG7173 – Topics in signal Processing II Computational Techniques in Medical Imaging

Topic 0: Course outline

Course Outline

- Medical Imaging is a vast field
- This course will cover the algorithms used to generate medical images from measurements for major medical image techniques:
- CT, MRI, PET, ultrasound, EIT

Course !outline

- the physics of medical imaging (brief)
- Image interpretation techniques
- Image communication
- Electronics / HW / signal conditioning

However,
You can present these material for projects

Description

Mathematical models of image formation based on the image modality and tissue properties. Linear models of image degradation and reconstruction. Inverse problems and regularization for image reconstruction. Image formation in Radiology, Computed Tomography, Magnetic Resonance Imaging, Nuclear Medicine, Ultrasound, Positron Emission Tomography, Electrical Impedance Tomography.

Prerequisites

One of

- ELG 4172
- CEG 4311
- Knowledge of DSP or image processing

Or

- Instructor's permission

Question

- Who are you?

- Why are you taking this course?

Or

- What do you hope to learn in this course?

Instructor

Andy Adler

- adler@site.uottawa.ca
- Office: SITE bldg 5035
- Phone: 613 562-5800 x 2345

Office Hours:

- TBA – I would prefer mon/wed afternoons
  - Email me to make appointment

Activities

- Lectures:
  - Tues 8-8:30pm CBY E015
  - Thurs 8-8:30pm CBY E015
- Tutorials:
  - At least two tutorial/labs will be given, around due dates of assignments

Text

I haven't found a single good text for the course

- First 50% of course will be from Albert Macovski, *Medical Imaging Systems*
- Copies of this text are available at Photocopy service, Morisette – price is ????

Other good reference texts are:

- Z. Cho, J.P. Jones, M. Singh, *Foundations of Medical Imaging*
  Hardcover - 586 pages (1993)
- Steve Webb *Physics of Medical Imaging*
  Hardcover (1988)
  New Edition: Not yet published Hardcover (2003)

Grading

Assignments	25%
Project	35%
Exam	40%

Assignments

- Assignments will involve writing code to explore various aspects of medical image processing and analysis.
- Submitted assignments may be in English or French, and will include an introduction, methods, results, and discussion.
- While it will be accepted to do programming in any computer language, I strongly recommend Matlab or Octave. Access to Matlab is available from almost all PCs in the graduate labs at SITE. If you wish to complete your assignments at home, you may 1) purchase the student version of Matlab, 2) use octave (free under the GNU GPL license). Information on installing octave is www.site.uottawa.ca/~adler/octave.
- Assignments will be submitted at the beginning of class on the day indicated.

Assignments #1, #2

- Work will be somewhat similar to a lab. Detailed instructions will be given. Work to be written up like a lab report.
- Topics are: Image viewing, noise, blurring, filtering, convolution, spatial domain, frequency domain, transforms, spatial resolutions, backprojection algorithms

Assignments #3,#4

- Project is to write code to implement *forward model* (#3) and *image reconstruction* (#4) for two *different* image algorithms.
- Instructor will then be able to use code from different students to verify each other

Project

- The project will include a written report and a presentation.
- The report will be 10-20 pages (double spaced) in written English or French. Reports are due at 9am on Apr 11.
- Presentations will be 15-20 minutes in length and presented in class (in English) during the period Mar 27 to Apr 8. Students are encouraged to select projects of interest or relevant to their studies.
- A list of suggested projects will be provided. Projects could be:
  - A review of a technique or topic,
  - An analysis or critique of a technique,
  - A comparison between two techniques,
  - An implementation or simulation of a technique.

Project Suggestions #1

- Radiation Detectors
- Applications of CT
- Beam hardening and its effects in CT
- Cardiovascular CT
- Specialized CT imaging systems
- Use of a specific contrast agent for CT
- Problems and limitations of CT for a specific application
- Single Photon Emission Computed Tomography

Project Suggestions #2

- Detectors and technologies for PET
- Considerations for spatial resolution of PET
- Specialized PET imaging systems
- Considerations for 3D PET imaging
- Problems and limitations of PET for a specific application
- Design considerations for MRI electronics
- Design considerations for MRI signal processing
- Fast MRI

Project Suggestions #3

- Cardiac / Respiratory gated MRI
- Specialized MRI techniques: Echo planar imaging, etc.
- Other applications of NMR
- NMR microscopy
- Physical limits to NMR resolution
- Flow MRI
- MRI of a non-water compound, ie. Xenon

Project Suggestions #4

- Electronics HW and signal processing for EIT
- Imaging algorithms for dynamic EIT
- Imaging algorithms for static EIT
- Problems and limitations of EIT for a specific application
- Ultrasound for 3D
- Dopler ultrasound
- Optical flow techniques for ultrasound
- Electronics HW and signal processing for ultrasound
- Problems and limitations of EIT for a specific application

Project Suggestions #5

- Image processing techniques for enhanced visualization
- Medical image interpretation for specific application
- Multi-modality image fusion
- Calibration approaches for multimodality images
- Virtual Environments applied to medical imaging
- Automated image classification, search, archiving
- Applications of expert systems / AI for medical imaging

Exam

- The final exam will take place on or shortly after the last day of class
- Exam will be 3 hours
- Need to find a time that works for everybody (7-10pm ??)

Warnings:

- Late work = 20% off for first week.
- More than 1 week late = don't bother submitting without good excuse
- Academic fraud will be taken very seriously. Cooperation between students for assignments is expected and encouraged, however, copying of another student's work is not. You should not be leaving a discussion with copies of another student's work.

Course Overview

Jan 7 Jan 9	Introduction to medical imaging. Principal techniques: radiology, nuclear medicine, CT, ultrasound. Models of detection. ROC curves.
Jan 16 Jan 21 Jan 23	2D and multidimensional linear systems. Sampling. Convolution. Impulse response. Transfer functions. Space and Frequency domain analysis. Wiener filters. Models of image degradation and restoration
Jan 30 Feb 4 Feb 6 Feb 11 Feb 13	Radiology. Image formation model for radiology. Acquisition of radiological images. Densitometric analysis Cardiology. Computed Tomography. Backprojection algorithm. Reconstruction artifacts. Spatial resolution.
Feb 18, 20	Study Break

Course Overview

Feb 25, 27 Mar 4	Regularization techniques for Image processing. Bayesian Regularization. Electrical Impedance Tomography. Laplace Equation and inverse Laplace Equation. Image reconstruction. Spatial resolution
Mar 6 Mar 11 Mar 13	Ultrasound. Modes of operation. Image formation model for ultrasound. Rayleigh diffusion. RF impulse response. Perception and texture analysis. Autocorrelation, power spectrum, decorrelation
Mar 18, 20 Mar 25, 27	Magnetic Resonance Imaging. Image formation model for NMR. Excitation and detection sequence. Image reconstruction. Frequency domain models
Apr 1,3,8	*Project Presentations*
Apr 11	*Project Reports due*

Guest instructor

- *Hail Melouche* will be conducting some of the courses on MRI.
- He is Biomedical Engineer with Hôpital du Gatineau and an expert on MRI.

Site Visit

- I am attempting to organize a visit to any/all of these facilities
  - MRI at Civic
  - CT at Civic
  - PET at Heart Institute
- Preferred time is just after class in February.
  - Tentative Date is Thurs, Feb 27
- Site visit is optional
- How many are interested?