ENGS 167 - Syllabus

MEDICAL IMAGING

Offered: F08

A comprehensive introduction to the major aspects of standard medical imaging systems used today. Topics include radiation-interaction, radiation damage and risk, x-ray imaging, computed tomography, image reconstruction and analysis, nuclear medicine, MRI, ultrasound and imaging applications in therapy. The fundamental physics and engineering underlying each imaging modality are reviewed and an performance analysis approach to each system is examined. The class involves significant laboratory work to give the student experience in several different imaging systems available at the Medical Center. Evaluation is based upon tests, labs, as well as journal club review of research papers and commercial equipment.

Pre-requisite courses: ENGS 23 or equivalent

Laboratory Exercises

This class has 8 laboratories which will be done outside of class hours. The laboratories are tentatively set to be:

1) <u>Cesium-137 Radiation dosimetry</u> – measuring the irradiator exposure pattern and attenuation through different media.
2) <u>X-ray Imaging and Analysis</u> – imaging breast tissue phantom on a breast biopsy x-ray table.
3) <u>Image Processing</u> – Exercise in using MATLAB image processing tools
4) <u>Image Formation and Analysis</u> – Matlab based exercise to work with the radon transform and image reconstruction, and how to analyze resolution versus contrast resolution.
5) <u>Computed Tomography Laboratory</u> – imaging tissue phantoms with x-ray computed tomography, to test resolution and contrast resolution.
6) <u>Ultrasound Imaging Laboratory</u> – using an imaging system with a water-based tissue phantom to test system resolution.
7) <u>Magnetic Resonance Imaging with a 7T Small Animal Magnet</u> – imaging tissue phantoms and rodents in the MRI, analyzing k-space data and transforming it to real space images.
8) <u>MRI with a 3T whole body human system</u> – Imaging humans with a full body 3T system, examining available pulse sequences and data visualization.

Lecture Schedule **(3 lectures per week of 65 minutes each)**

1. Ionizing Radiation (3 lectures)
    - 1.1 Radiation & interaction with matter
    - 1.2 Radiation dosimetry, risk and protection
    - 1.3 Radiation Biology
2. Radiography (4 lectures)
    - 2.1 X-ray Tubes
    - 2.2 Radiography with film
    - 2.3 Mammography & Fluoroscopy
    - 2.4 Digital Radiography
3. Image Processing (4 lectures)
    - 3.1 Image types and linear processing
    - 3.2 Fourier domain processing
    - 3.3 Image Analysis
    - 3.4 Visualization software
4. Computed Tomography (3 lectures)
    - 4.1 Image reconstruction theory
    - 4.2 Computed Tomography (CT) systems
    - 4.3 System Performance Analysis

Mid term test - Oct 23 (3 hr take home)

5. Magnetic Resonance Imaging (MRI) (4 lectures)
    - 5.1 Principles of NMR
    - 5.2 MR imaging
    - 5.3 MR pulse sequences
    - 5.4 MRS & fMRI
6. Ultrasound Imaging (US) (2 lectures)
    - 6.1 Principles of US
    - 6.2 US Systems
7. Nuclear Medicine Imaging (3 lectures)
    - 7.1 Single Photon Emission Computed Tomography (SPECT)
    - 7.2 Positron Emission Tomography (PET)
    - 7.3 Compartmental Modeling
8. Imaging applications in Therapy (3 lectures)
    - 8.1 Radiation therapy treatment planning
    - 8.2 Conformal therapy / Bracheytherapy

13. Final Exam (in exam period)

Total lectures = 26

Journal article review sessions:

Monthly journal club participation is required. There will be 2 of these sessions total. There will also be two sessions devoted to reviewing companies in medical imaging. The format is that each student reads and summarizes a research paper or literature from a company related to medical imaging, and then presents the summary to the class. Presentation time is restricted to 5-10 minutes, depending upon the class size. Potential journals to select articles are:

- IEEE Transactions in Medical Imaging,
- IEEE Transactions in Biomedical Engineering,
- Physics in Medicine and Biology,
- Medical Physics,
- Radiology,
- Radiation Research,
- Int. J. Radiat. Oncol. Biol. Phys.

Company selections for review will be given out in class, but generally are taken from advertisers in Medical Physics. (links to these are on the course website).

Overall Evaluation:

Labs reports	40%
mid-term test	20%
published paper reviews	15%
Exam	25%

Course Text:

Physics of Radiology, 2nd Edition, (2005) by Anthony Brinton Wolbarst, Medical Physics Publishing, Madison Wisconsin.

Additional Resource Texts:

1) The Essential Physics of Medical Imaging, 2nd Ed., by J. T. Bushberg, J. A. Seibert, E. M. Leidholdt, and J. M. Boone, Lippencott, Williams and Wilkins, Publ. 2002.
2) The Physics of Medical Imaging, S. Webb, Institute of Physics Publishing, 1988.
3) Christensen's Physics of Diagnostic Radiology by Thomas S. Iii Curry, James E. Dowdey, Robert C., Jr Murry, Lea & Febiger Publishing, 4th edition, 1990.
4) Introduction to Radiological Physics and Radiation Dosimetry, F. H. Attix, John Wiley and Sons Publishing, 1986.
5) Medical Physics and Biomedical Engineering, B. H. Brown, R H Smallwood, D C Barber and D R Hose, Institute of Physics Publishing Ltd., 1999.
6) The Modern Technology of Radiation Oncology, J. van Dyk, Medical Physics Publishing, 1999.
7) Radiobiology for the Radiologist, Eric J. Hall, Lippincott Williams & Wilkins, 5th edition, 2000

Learning Objectives:

At the completion of this course, the student will be able to:

1. *describe* the major components of most standard medical imaging systems, including radiography, computed tomography, ultrasound, nuclear scintillation and magnetic resonance imaging systems.

2. *interpret* radiation biology data quantitatively, to estimate effective equivalent doses, compare killing efficiency, calculate average risk of cancer induction, and estimate legal compliance with radiation exposures to personnel.

3. *measure* and *estimate* x-ray and gamma-ray exposures and doses, and how these influence the imaging system usage, and how the system design affects the exposure per exam.

4. *measure* and *calculate* the system resolution from test-phantom objects in Ultrasound, x-ray radiography and x-ray computed tomography (CT), as well as estimate the – contrast-resolution response of each system.

5. *acquire* raw data from a CT scanner such as projection data, or raw k-space data from an magnetic resonance imaging (MRI) scanner and *compute* images the tissue properties, weighted by different filters.