Goals of the Course

1. Develop a firm understanding of the fundamentals of medical imaging, including an appreciation for the common principles underlying the various modalities.
2. Gain a basic understanding of the physical principles underlying the major modalities, including X-ray, computed tomography, MRI, and ultrasound.
Basic Imaging

Object → Imaging Device → Measured Data → Reconstruction Algorithm → Image of object

Brief History of Medical Imaging

1895 - Roentgen discovers X-rays
1942 - Dussik demonstrates transmission ultrasound in the brain.
1946 - Bloch and Purcell discover nuclear magnetic resonance (NMR)
1972 - Hounsfield develops the first computed tomography scanner.
1973 - Lauterbur invents magnetic resonance imaging (MRI)
1974 - Ledley develops the first whole body CT scanner.
X-Rays

8 November 1895, Wilhelm Conrad Roentgen discovers X-rays. Receives first Nobel Prize in Physics in 1901.

22 November 1895 X-ray of Mrs. Roentgen’s hand.

X-Ray

An early X-ray imaging system
X-Ray

1917 Johann Radon establishes the mathematical framework for tomography, now called the Radon transform.


1972 Godfrey Hounsfield develops first CT system. Unaware of either Radon or Cormack’s work, develops his own reconstruction method.

1979 Hounsfield and Cormack receive the Nobel Prize in Physiology or Medicine.

Computed Tomography

Computed Tomography

From http://www.sprawls.org/resources/CTIMG/classroom.htm

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From http://www.xray_ct/parallel/Parallel_CT.html

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Computed Tomography

Image from Siemens Siretom CT scanner, circa 1975, 128x128 matrix.

Modern CT image acquired with a Siemens scanner, 512x512 matrix.
Computed Tomography

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History of Ultrasound

1942 Dr. Karl Theodore Dussik
Transmission ultrasound investigation of the brain
First published work on medical ultrasonics.
History of Ultrasound

Holmes and Howry, 1955
Subject submerged in water tank to achieve good acoustic coupling.
Image of normal neck.

History of Ultrasound

Automatic scanner, Glasgow, ca 1959. Image shows twin gestation sacs (s) and bladder (B).
Ultrasound System

Acuson Sequoia

Doppler Ultrasound

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3D Ultrasound

History of MRI

1946: Felix Bloch (Stanford) and Edward Purcell (Harvard) demonstrate nuclear magnetic resonance (NMR)

History of MRI

Late 1970’s: First human MRI images

Early 1980’s: First commercial MRI systems

1993: functional MRI in humans demonstrated

Clinical MRI System
3 Tesla Magnet at UCSD

Magnet Image from http://www.fmrib.ox.ac.uk/~stuart/lectures/lecture1/

MRI System Block Diagram

Image from http://www.fmrib.ox.ac.uk/~stuart/lectures/lecture1/
1D Fourier Transform

2D Fourier Transform
**k-space**

Image space

k-space

- $k_x$
- $k_y$

Fourier Transform

**Image Contrast**

- $T_1$-weighted
- Density-weighted
- $T_2$-weighted

Image from Rick Buxton

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Unfolding the Cortex

MR Angiography
Perfusion Imaging with Contrast

Image from http://irc.chmcc.org/PowerPoint_HTML/pMRI/moyamoya_files/frame.htm

Perfusion Imaging with ASL

Image from E.C. Wong
Cardiac Imaging

Image from http://www.bidmc.harvard.edu/cmr/smash/smash.html

Cardiac Tagging

Image from http://www.mri.jhu.edu/~emcveigh/LabIntro/tagging.html
Functional MRI

Image from http://www.brainvoyager.de/

Diffusion Tensor Imaging

Image from L. Frank
MR Microscopy

Image from http://mouseatlas.caltech.edu/

MR Spectroscopy

PRESS 1H MRSI of the Hippocampal Region in AD and Healthy Elderly

AD

C

MRI

NAA Image

1H MR Spectrum (from left hippocampal body)

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Image from http://www.sf.med.va.gov/mrs/ad/result.htm
Molecular Imaging

EgadMe labels regions positive for beta-gal expression

Fluorescence (GFP)

MRI

Bright field
(fixed and stained)

Image from http://quad.bic.caltech.edu/~meadegroup/smart%20contrast%20agents.htm