



Boston University
School of Medicine

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BME website description

Course presents the foundations of modern medical imaging in a systematic program structured as follows: imaging principles, imaging mathematics, imaging physics, and image generation techniques. The medical imaging modalities studied include projectional x-ray imaging, radioactive tracer imaging, ultrasound imaging, computer tomography, and magnetic resonance imaging. Theory and techniques are illustrated in a direct hands-on approach in eight computer laboratory sessions that are topically synchronized with the course lectures. 4 cr.

BE515: INTRODUCTION TO MEDICAL IMAGING

Lectures and labs

Lectures: MO and WE 6-8 pm, PHO-211
Laboratory sessions: MO 9-12 am and TH 9-12 am

Grading system

40% average homework/lab work, 30% midterm, and 30% final

Objectives

The primary goals of the course are to provide biomedical engineering students with exposure to the key topics in mathematics, physics, and computer science that constitute the conceptual core of modern medical imaging. An additional goal of the course is to familiarize the students with the standard clinical and research applications of the several imaging modalities (x-ray, ultrasound, nuclear medicine, CT, and MRI) available in most large hospitals.

Course Description

From a unifying point of view, all medical imaging modalities are based on a set of physical principles to be used in conjunction with a set of mathematical and computational rules, the so-called imaging principles, to produce images containing anatomic and/or functional tissue information. The physical principles describe the interaction (s) of some form of radiation with biologic tissues, the result of which is a measurable signal that contains geometrical and physical information of the tissues that participated in the interaction. The imaging principle(s) refer to: 1) a strategy to partition the measured signal into sub-signals stemming from individual small sub-volumes of tissue (voxels) and 2) to localize these voxel signals within the imaged subject the signal, so a spatially resolved map (image) can be formed and eventually displayed as an

organized array of picture elements (pixels), i.e. the medical image. Altogether, almost every branch of physics, applied mathematics, and engineering is relevant to medical imaging, from electricity and magnetism to quantum theory and relativity, from elementary algebra to advanced image processing computer algorithms, and from material science to the design of very complex and sophisticated machines: the medical imaging systems.

The specific objectives of the course are:

1) To teach the key concepts in physics, mathematics, and computer sciences which are an integral part of the following core topics of medical imaging.

2) To provide an environment of inquiry and scholarship in which biomedical engineering students are invited to: a) participate in the development of new knowledge in the medical environment, b) learn to evaluate findings of scientific research, and c) develop habits of inquiry as a continuing professional responsibility.

Laboratory section objectives:

1. Apply principles taught in class
2. Visualize physical phenomena of medical imaging by computer modeling
3. Develop image processing tools and filters
4. Develop image visualization tools
5. Software platform: Mathcad

Textbooks: required and suggested readings

1. The essential physics of medical imaging. by J.T. Bushberg, J.A. Seibert, E.M. Leidholt, Jr., J.M. Boone. ISBN 0-683-30118-7
2. Principles of magnetic resonance imaging, Z. Liang, P.C. Lauterbur. ISBN 0-7803-4723-4.
3. Foundations of Medical Imaging, Z. H. Cho, Joie P. Jones, Manbir Singh: ISBN: 0-471-54573-2

Syllabus (28 lectures)

A. IMAGING PRINCIPLES (3 LECTURES)

Geometry, physics and mathematics

Imaging methodology fundamentals

Medical imaging modalities

B. MATHEMATICS OF TOMOGRAPHIC IMAGING (5 LECTURES)

Continuous Fourier transforms

Waveform sampling

Discrete Fourier transforms

Image synthesis from geometrical projections: the inverse Radon transform

Image synthesis from spectral projections: the inverse Fourier transform

C. PHYSICS OF TOMOGRAPHIC IMAGING (10 LECTURES)

Electromagnetic radiation

Elements of quantum mechanics

Atomic structure

Interactions of x-rays with tissues

Nuclear structure

Proton nuclear magnetic resonance of biologic tissues

Microscopic NMR physics: quantum mechanical description

Macroscopic NMR physics: isochromat description

D. IMAGE GENERATION (10 LECTURES)

Projection imaging: x-ray radiography, linear radioactive tracer imaging

Reflection imaging: US

Radon transform imaging: CT, SPECT, PET, MRI

Fourier transform imaging: MRI

E. IMAGE POST-PROCESSING

Lab Schedule

[Lab 01](#): Generation of two-dimensional objects using the Mathcad mathematical software environment.

[Lab 02](#): Visualization of Fourier transforms in one dimension.

[Lab 03](#): Computer evaluation of Fourier integrals.

[Lab 04](#): Discrete Fourier transforms and convolution theorem.

[Lab 05](#): Discrete sampling of a continuous function and Fourier transform theory.

[Lab 06](#): Fourier transform based reconstruction of images with incomplete data sets.

[Lab 07](#): Visualization of image artifacts caused by data degradation in k-space.

[Lab 08](#): Simulation of Radon transform based image acquisition and illustration of the uses of the Radon Inversion formula (FBP vs. BP).