BIM 242: Introduction to Biomedical Imaging

Instructors

Instructor of Record: Wang, Guobao
Email: gbwang@ucdavis.edu; Phone: 916-734-6537;
Office: Room 3158, the ACC building, 4860 Y Street, Sacramento, CA95817.

Instructors: Badawi, Ramsey D. (email: rdbadawi@ucdavis.edu)
Boone, John M. (email: jmboone@ucdavis.edu)
Chaudhari, Abhijit (email: ajchaudhari@ucdavis.edu)
Siebert, J. Tony (email: jaseibert@ucdavis.edu)
Wang, Guobao (email: gbwang@ucdavis.edu)

To schedule an appointment to meet an instructor, please email the instructor directly.

Course Description

Course Goals: To introduce the basic physical principles, instrumentation methods, and imaging algorithms of major biomedical imaging modalities, including x-ray, ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), and optical imaging. Preclinical and clinical aspects are included where possible to provide students with a better understanding of the applications of biomedical imaging.

Course Time: Monday and Wednesday, 8:00-9:50 AM
Classroom: Room 2202, Genome and Biomedical Sciences Facility (GBSF)
Prerequisites: Graduate standing or consent of instructor. Background in engineering with basic knowledge of signals and systems, e.g., Fourier transform and convolution (the text’s Appendix G has a review of Fourier transform and convolution)

Grading

Letter grade: Based on:
Home Work = 40%
Pop Quizzes = 20%
Final Exam = 40%
100%

Pop quizzes will be administered during randomly chosen lectures. The final exam will be take-home.

Late submission: An homework assignment turned in late will receive a 10% penalty if received prior to 5:00 pm of the following day and a 5% penalty for every additional day. No work will be accepted after one week.

Required Text

Reference Texts:
Simon R. Cherry, James A. Sorenson, Michael E. Phelps, “Physics in Nuclear Medicine, Fourth Edition,”
Lihong Wang, “Biomedical Optics: Principles and Imaging,”
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| **Signals, system and image quality** | • Understand and illustrate the concepts of Fourier transform, inverse transform, and convolution  
  • Understand the Shannon sampling theorem  
  • Understand how signal contrast, spatial resolution, image noise are measured  
  • Understand the concepts of point spread function and modulation transfer function | 1        | Bushberg book (Chps 4, Appendix G) |
| **Interaction of Radiation with Matter** | • Particle interactions  
  • X-ray and gamma-ray interactions  
  • Attenuation of photons  
  • Beta particles  
  • Radiation safety | 1        | Bushberg book (Chps 3) |
| **X-ray production and projection imaging** | • Understand the concepts of x-ray production and the construction of x-ray tube components and peripherals  
  • Show how x-ray generators control x-ray beam energy and intensity  
  • Illustrate concepts of x-ray tube output as a function of kVp, waveform, mA, time, and focal spot  
  • Discuss x-ray spectrum concepts related to kVp, HVL, filtration, and radiation dose to the patient  
  • Radiography and fluoroscopy | 1        | Bushberg book (Chps 6-9) |
| **Radiation Dose in X-ray Imaging** | • Dose concepts: absorbed dose, equivalent dose, effective dose  
  • Dose in radiography  
  • Dose in fluoroscopy  
  • Dose in mammography  
  • Dose in computed tomography | 1        | Bushberg book (Chps 11) |
| **X-ray Computed Tomography (CT)** | • The CT generations  
  • Detectors and CT acquisition  
  • Reconstruction  
  • Spatial and contrast resolution  
  • CT dosimetry  
  • Display and formatting  
  • Artifacts  
  • Applications | 2        | Bushberg book (Chps 10) |
| **Ultrasound** | • Review of basic physics of ultrasound (US)  
  • Understand basic US characteristics  
  • Describe US interactions, production, beam properties  
  • Illustrate image acquisition methods and details  
  • Discuss US equipment and special techniques  
  • Show Doppler methods and velocity measurements  
  • Demonstrate ways that artifacts occur  
  • Overview ultrasound intensity issues and bioeffects | 2        | Bushberg book (Chps 14) |
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| Nuclear Magnetic Resonance                                           | • Understand magnetic fields and magnetization  
• Describe characteristics of tissue magnetization  
• Demonstrate stimulation, excitation, emission, and signal capture of proton magnetization | 1 Bushberg book (Chps 12)                     |
| Magnetic Resonance Imaging                                          | • Describe how MR signals are localized  
• Understand factors about image acquisition time and image quality  
• Illustrate image artifacts and causes  
• Discuss MR safety concerns and directives | 2 Bushberg book (Chps 13)                     |
| Optical Imaging                                                      | • Understand the concepts of interaction of light with tissue, including absorption, refractive index, scattering, anisotropy, reduced scattering  
• Understand the objectives of designing optical systems, including performance, configuration and productivity considerations  
• Demonstrate applications of optical imaging | 2 Wang book Lecture slides                    |
| Nuclear Medicine                                                     | • Define functional imaging  
• Understand radiotracers  
• Illustrate the requirements for radionuclide imaging  
• Understand the concept of half-life  
• Understand how detectors detects gamma rays | 1 Bushberg book (Chps 15-18)                   |
| Positron Emission Tomography (PET)                                   | • Understand the concepts of positron emission and annihilation  
• Understand how coincidences are detected  
• Understand different PET radiotracers  
• Understand how PET camera works  
• Illustrate the use of PET for therapy response assessment  
• Understand the corrections needed for quantitative PET imaging, including attenuation correction, scatter correction, randoms correction, dead-time correction, and normalization | 2 Bushberg book (Chps 19) Lecture Slides      |
| Tomographic Image Reconstruction                                     | • Understand the concepts of forward projection, Radon transform and back projection  
• Illustrate how the analytical reconstruction method, filtered backprojection (FBP)  
• Understand the concepts of iterative image reconstruction methods  
• Understand the pros and cons of analytical and iterative methods | 1 Cherry book (chps 16) Lecture slides        |
| Hybrid PET/CT and PET/MR Imaging                                     | • Illustrate the need for hybrid imaging  
• Understand the design of PET/CT  
• Understand the design of PET/MR  
• Understand the challenge of attenuation correction | 1 Cherry paper on multimodality imaging       |
| Tour of Center for Molecular and Genomic Imaging (CMGI)              | • Introduce various imaging modalities at CMGI  
• Understand the differences between different imaging modalities | 1 NA                                          |