ECE/BMED 6786
Medical Imaging Systems: Physics, Engineering, and Applications

Instructor(s):

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Office Hours:

TBD

Meeting Times and Locations:

Monday and Wednesday, 3:30 pm - 4:45 pm, MoSE 1201A
HYBRID
See separate course schedule

Catalog Description

Introduce major biomedical and clinical imaging modalities including X-ray radiography, computed tomography (CT), nuclear medicine (SPECT and PET), magnetic resonance imaging (MRI), and ultrasound.

Prerequisites:

BMED 3110

Other Prerequisites:

Desire to learn, common sense, being able to enjoy challenges, ability to work alone and in a team, curiosity, aptitude to modify and control sleep habits, and, finally, some knowledge of digital signal processing and programming in MATLAB.

Course Objectives:

Overall objective:

Introduce underlying physical, mathematical, and engineering principles, approaches and applications of X-ray, computed tomography, nuclear medicine, magnetic resonance imaging and ultrasound imaging.

Specific learning objectives:

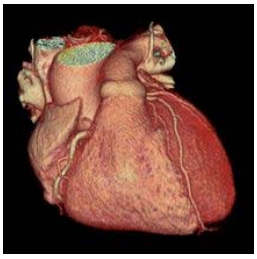
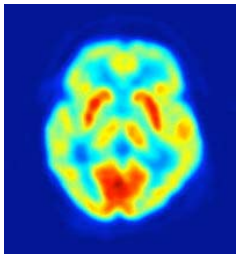
- Apply fundamental mathematical and engineering principles (sampling, Fourier transform, linear systems) in the development of imaging systems and image acquisition.
- Develop understanding of the interactions between electromagnetic, acoustic, or other forms of energy and biological tissues and apply these principles to imaging system design.
- Apply understanding of imaging system physics and instrumentation to design systems or subsystems for specific applications for X-ray, computed tomography, PET/SPECT, MRI, and ultrasound.
- Utilize understanding of imaging physics and imaging systems engineering principles in order to reconstruct acquired data into images.
- Quantitatively compare imaging performance and tradeoffs within and across imaging modalities using criteria including contrast, spatial resolution, contrast-to-noise ratio, and signal-to-noise ratio.

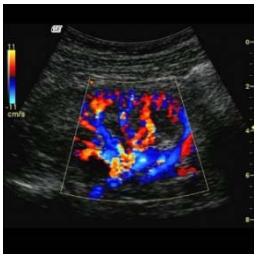
Course Description:

This course is an introduction to imaging systems. The main objective of this course is to expose you to the world of medical and biomedical imaging with emphasis on principles, approaches and applications of each modern imaging modality. For each imaging modality, the following approach is used: 1) describe basic physics; 2) develop a system model of the imaging system; 3) derive imaging equations; 4) describe hardware and software; 5) analyze signal, noise (sources), contrast, and primary artifacts; 6) discuss biomedical and clinical applications.

The course will be divided into three modules. The first module will cover X-ray imaging and Nuclear Medicine including computed tomography (CT), single photon emission computed tomography (SPECT), and positron emission tomography (PET). In the second part of the course, we will focus on nuclear magnetic resonance covering magnetic resonance imaging (MRI) and MR spectroscopy (briefly). In the final part of the course, ultrasound imaging will be introduced. Overall, fundamental similarities between the imaging equations of the different modalities will be stressed, and vital differences between different modalities will be discussed.





Topics Covered:

1. X-ray imaging and computed tomography
2. Nuclear medicine imaging (PET, SPECT)
3. Magnetic resonance imaging (MRI)
4. Ultrasound imaging

Textbooks

Required:

Textbooks: none

Extensive lecture notes, review papers, tutorials, software, and other materials are available on the class web site: http://canvas.gatech.edu/

Supplemental/Optional:

Introduction to Medical Imaging: Physics, Engineering and Clinical Applications, Nadine Barrie Smith and Andrew G. Webb. Hardcover, 264 pages, December 2002, Wiley-IEEE Press

The Essential Physics of Medical Imaging (3rd Edition), J.T. Bushberg, J.A. Seibert , E.M. Leidholdt Jr., J.M. Boone. Hardcover, 1048 pages, December, 2011 ISBN/ISSN: 9780781780575

Medical Imaging Signals and Systems, 2nd Edition, Jerry L. Prince and Jonathan Links ISBN-13: 978-0132145183 ISBN-10: 0132145189 Prentice Hall, 2014

Imaging Systems for Medical Diagnostics Fundamentals, Technical Solutions and Applications for Systems Applying Ionizing Radiation, Nuclear Magnetic Resonance and Ultrasound, Arnulf Oppelt (Ed.) 2006, John Wiley & Sons Inc Magnetic Resonance Imaging-Physical Principles and Sequence Design, E.M. Haacke, R.W. Brown, M.R. Thompson, and R. Venkatesan, Wiley-Liss, New York.

Principles of Magnetic Resonance Imaging, A signal Processing Perspective, Zhi-Pei Liang, Paul C. Lauterbur, IEEE press.

Foundations of Biomedical Ultrasound, Cobbold RSC. New York: Oxford University Press; 2007.

Online resources:

Provided during the class, available at http://canvas.gatech.edu/

Teaching Approach

The students will attend two lectures per week (3 hours). There will be 4 homework assignments and 3 projects covering all imaging modalities. In addition, there will be three midterm exams covering the three modules of the course. Exams will be administered remotely during regular class times using Canvas.

Attendance Policy

Attendance is required for lectures. The first week of courses will be held fully remotely.

This course is designated as a hybrid course, thus for most classes, students may attend lectures remotely or in person if following appropriate campus policies for on-campus activities (e.g. wearing a mask and physical distancing). The latter means the instructor and students will wear masks in the class room (see Current USG Language for Cloth Face Coverings below).

In addition, as part of this hybrid course, specifically designated in-person activities will be held on the dates specified in the schedule. In-person activities may include in-class projects, discussion, presentations, etc. These will be explicitly marked on the schedule. For each in-person activity, the course will be split into two groups and the in person activities will be held on two different dates. Before the first designated date for in-person activities, groups will be formed and further instruction will

be given regarding in-person attendance of lectures and in-person activities with appropriate physical distancing based on the number of students in the course.

Per Georgia Tech policy, if you are experiencing any symptoms, please do not attend class or participate in any in-person class activities. You will still be able to participate remotely.

Current USG Language for Cloth Face Coverings

Effective July 15, 2020, University System of Georgia (USG) institutions will require all faculty, staff, students, and visitors to wear an appropriate face covering while inside campus facilities/buildings where six feet social distancing may not always be possible. All members of the campus community will be provided reusable cloth face coverings.

Face covering use will be in addition to and is not a substitute for social distancing. Anyone not using a face covering when required will be asked to wear one or must leave the area. Refusal to comply with the requirement may result in discipline through the applicable conduct code for faculty, staff or students.

There are a few exemptions. Reasonable accommodations may also be made for those who are unable to wear a face covering for documented health reasons.

For more information about face masks and coverings, review the guidelines from Human Resources.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404) 894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter.

In order to participate fully remotely, Georgia Tech has required that you contact the Office of Disability Services and request accommodations. The Office of Disability Services will then communicate this information to the instructors once approved. This includes COVID accommodations specifically related to pandemic conditions (e.g. high-risk health condition, etc.).

Grading & Evaluation

The course grade will be determined by homework (25%), class projects (30% total, 10% each), and three midterm/final examinations (45% total, 15% each).

Class Web site:

All materials for the class (announcements, schedule/changes, lecture notes, homework assignments, etc.) will be distributed electronically via course web site: http://canvas.gatech.edu/

You will be responsible for checking the course website regularly for class work and announcements. *All assignments and projects are submitted electronically via Canvas.* This is the only way to submit your assignment (no hard copies will be accepted). If you fail to submit before the deadline, the site will lock and you will receive a zero. If there is a technical problem with the site, you need to email the assignment to the instructor *before* the deadline. The time stamp on the email must be prior to the due date/time.

Use of E-mail

In this course, e-mail will be used as a means of communication with students. You will be responsible for checking your e-mail regularly for class work and announcements.

All students should become familiar with the Georgia Tech's official e-mail student notification policy. It is the student's responsibility to keep the Institute informed as to changes in his or her e-mail address. Students are expected to check e-mail on a frequent and regular basis in order to stay current with Institute-related communications, recognizing that certain communications may be time-critical. It is recommended that e-mail be checked daily, but at a minimum, twice per week.

Academic Integrity

Georgia Tech Honor Code: http://www.honor.gatech.edu

Each student must be vigilant of Academic Integrity at all times.

Academic dishonesty will not be tolerated and will be dealt with in as severe a manner as possible.

List of Topics

- Introduction
- Math preliminaries/refresher
- Overview of imaging modalities, differences and similarities, general image characteristics

- X-ray Imaging
  - Physics of X-rays
  - X-ray production, detection, hardware/instrumentation
  - Projection radiography
  - Mammography
  - Fluoroscopy
  - Digital angiography, mammography and fluoroscopy
- Computed tomography (CT)
  - Spiral/helical and multi-slice CT
  - Detectors
  - Image reconstruction
- X-ray Imaging and Computed Tomography
  - Radiation doze
  - Contrast agents
  - Clinical applications
- Nuclear Medicine
  - Radioactivity and radiotracer half-life
  - Generators
  - Gamma camera
  - SPECT and SPECT/CT
  - PET and PET/CT
  - Applications

- Magnetic Resonance Imaging (MRI)
- Spins in a strong magnetic field
  - Radiofrequency pulse, Faraday induction and free induction decay
  - Longitudinal and transverse magnetization relaxation
  - RF pulse excitation and MR signal
  - MR instrumentation
  - Basic imaging sequences
  - The k-space formalism and image reconstruction
  - MRI contrast agents
  - Applications

- Ultrasound Imaging
  - Wave propagation, acoustic impedance, absorption and attenuation
  - Single element ultrasound transducers and ultrasound field
  - Transducer array
  - Imaging modes
  - Doppler ultrasound
  - Ultrasound contrast agents
  - Applications