ECE 590/699 Topics in Bioengineering: Medical Imaging
Fall 2009

Credits 3
Thursdays, 7:20 pm – 10:00 pm, Room: East Building, 134

Instructor:
Siddhartha Sikdar, PhD
Assistant Professor
Department of Electrical and Computer Engineering
Office: Engineering, Room 3908
Email: ssikdar@gmu.edu
Phone: 703-993-1539
Office hours: Mondays and Tuesdays 2:00-3:00 pm and by appointment

Course description (ECE 590 and ECE 699):
This course will provide an introduction to the physical, mathematical and engineering foundations of modern medical imaging instruments and image processing methods that enable us to “see” inside the human body to diagnose disease, monitor treatment and perform minimally-invasive interventions. The emphasis will be on diagnostic ultrasound and MRI imaging methods, although several other modalities will also be covered. The course will also provide an overview of recent developments in the field of medical imaging and discuss some of the challenges and controversies. The students will get hands on experience in applying the methods learnt in class to real-world problems and imaging data. There will be broad scope to individually and collaboratively explore current problems in medical imaging.

ECE 699 option:
This course also has an ECE 699 option for students desiring 600-level credits. The course content, homework and exams for ECE 699 would be the same as that for ECE 590. Students taking ECE 699 would be expected to do a more advanced course project demonstrating in-depth understanding and critical assessment of methods from recent research literature and would be required to submit a written project report.

Learning objectives:
At the end of the course the student should be able to:
1. Demonstrate a strong grasp of the basic physical principles underlying several medical imaging modalities.
2. Demonstrate a solid understanding of the concepts of medical image acquisition, image formation, image quality and display methods.
3. Apply the concepts learnt in class to solve real-world problems in medical image reconstruction, image processing and analysis.
4. Demonstrate an appreciation for the strengths and weaknesses of various imaging
modalities and what kind of anatomical and physiological information can be obtained from them.

Prerequisites:
1. University physics (PHYS 262 or equivalent).
2. Familiarity with a programming language (C/C++ or MATLAB)
3. Discrete time signal processing (ECE 410 or equivalent) or permission of instructor.

Resources:
Course home page:
The course material distribution, assignments grading, announcements and discussion boards will be managed using BlackBoard CE6. To access the course home page, log in using your email ID and password on http://courses.gmu.edu. If you have difficulties using this system, please speak with the instructor and appropriate accommodations will be considered.

Required readings:
The lecture slides will be available through the course website. Additional reading and reference material wherever appropriate will be distributed to students periodically. Students are expected to read the assigned material prior to class.

Recommended references:

Course structure:
The course will consist of weekly lectures, homework assignments, two exams and a course project (details below).

Grade:
Midterm exam 25%
Final exam 25%
Homework  25%
Course project  25%

Course Project:
The course will involve a research project. At the end of the semester, all students will be expected to make a 15-min presentation (with slides) on a particular topic in medical imaging. Students should select a topic, discuss with the instructor, and get approval within the first five weeks of class. Students with similar interests can choose to work together and present a joint in-depth project (the contribution of each student should be clearly noted). A list of literature sources should be submitted to the instructor for approval by the ninth week of class. Students enrolled for the ECE 699 option are expected to submit a written report on their project topic in addition to the presentation. Your classmates will grade the final presentation. Grades will be based on: knowledge of the subject and quality of background research, depth of critical analysis, clarity of explanation, and presentation style. For the project, students can select one of the following approaches:

1) Review a specific algorithm or technology for medical image formation, processing or analysis, demonstrate its uses, compare against alternative approaches, discuss the strengths and weaknesses, and suggest avenues for improvement.

2) Explore medical imaging applications for a specific organ or disease by identifying the clinical need, comparing the applicability of various imaging methods, and critically reviewing the latest research directions.

3) Review an emerging medical imaging modality, discuss the physics, instrumentation and image processing involved, describe potential applications, and discuss the strengths and weaknesses compared to existing imaging modalities.

Homework:
There will be assigned homework throughout the semester and will involve processing and analysis of real medical image data, and will involve some programming in C/C++ or MATLAB (depending on the student’s preference). Homework submitted late will be penalized. No homework will be accepted after two weeks. 5 points of the homework grade is reserved for class participation. One student will be assigned each week on a rotating basis to take the lead on compiling a summary of the discussions in class and post it on the class home page. These summaries should be used as a supplement to the lecture slides in preparing for examinations and will be graded as class participation. Students are expected to read the assigned material prior to class.

Exams:
The midterm and final exams will be closed book and notes. They will consist of essay-type and multiple-choice questions and numerical problems. Absence from exams must be notified ahead of time and alternative arrangements made with the instructor.
<table>
<thead>
<tr>
<th>Week</th>
<th>Date</th>
<th>Topics</th>
<th>Readings and other Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9/3</td>
<td><strong>Topics</strong>: Introduction: what is medical imaging? Different imaging modalities. Radiology workflow, image informatics.</td>
<td>Chapter 1 Assigned paper</td>
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<tr>
<td>2</td>
<td>9/10</td>
<td><strong>Topics</strong>: Review of relevant digital signal and image processing concepts: Linear systems, sampling theory, filtering, interpolation, Fourier transforms, point spread functions, probability.</td>
<td>Chapter 11 Handouts</td>
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<tr>
<td>3</td>
<td>9/17</td>
<td><strong>Topics</strong>: Medical imaging systems: Image acquisition, reconstruction, resampling, manipulation, visualization. Patient safety considerations.</td>
<td>Handouts</td>
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<td>5</td>
<td>10/1</td>
<td><strong>Topics</strong>: Principles of ultrasound imaging: acoustic waves, transmission, reflection, attenuation, image formation.</td>
<td>Chapter 19 Paper topic approval due</td>
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<tr>
<td>6</td>
<td>10/8</td>
<td><strong>Topics</strong>: Ultrasound transducers and instrumentation: steering, focusing. Ultrasound signal and image processing. 2D, 3D and 4D imaging.</td>
<td>Chapters 20 and 21</td>
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<td>7</td>
<td>10/15</td>
<td><strong>Topics</strong>: Principles of Doppler ultrasound. Demonstration.</td>
<td>Chapter 22</td>
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<td>8</td>
<td>10/22</td>
<td><strong>Topics</strong>: Mid term exam</td>
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<tr>
<td>9</td>
<td>10/29</td>
<td><strong>Topics</strong>: Structure of matter Principles of magnetic resonance imaging: spin physics</td>
<td>Chapter 2, 23 List of literature sources due</td>
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<tr>
<td>10</td>
<td>11/5</td>
<td><strong>Topics</strong>: MRI signal, data acquisition, image contrast. Image formation and k-space.</td>
<td>Chapters 24 and 25</td>
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<td>11</td>
<td>11/12</td>
<td><strong>Topics</strong>: Principles of X-ray and nuclear imaging: radiation, attenuation, scattering, detection</td>
<td>Chapters 4, 7, 13</td>
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<td>12</td>
<td>11/19</td>
<td><strong>Topics</strong>: Computed Tomography image reconstruction. Fourier slice theorem, filtered backprojection. 2D, 3D and 4D imaging.</td>
<td>Chapter 15 Handouts</td>
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<td>13</td>
<td>11/26</td>
<td><strong>Topics</strong>: Thanksgiving Recess: No class</td>
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<td>14</td>
<td>12/3</td>
<td><strong>Topics</strong>: Introduction to image analysis: enhancement, segmentation, manual and automated image analysis, computer-aided detection. Course wrap up.</td>
<td>Handouts</td>
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<td>15</td>
<td>12/10</td>
<td><strong>Topics</strong>: Final presentations.</td>
<td>Critical review paper due</td>
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<td>16</td>
<td>12/17</td>
<td><strong>Topics</strong>: Final exam.</td>
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Academic Honesty and Collaboration:
The integrity of the University community is affected by the individual choices made by each of us. GMU has an Honor Code with clear guidelines regarding academic integrity. Three fundamental and rather simple principles to follow at all times are that: (1) all work submitted be your own; (2) when using the work or ideas of others, including fellow students, give full credit through accurate citations; and (3) if you are uncertain about the ground rules on a particular assignment, ask for clarification. No grade is important enough to justify academic misconduct.

With collaborative work, names of all the participants should appear on the work. Collaborative projects may be divided up so that individual group members complete portions of the whole, provided that group members take sufficient steps to ensure that the pieces conceptually fit together in the end product. Other projects are designed to be undertaken independently. In the latter case, you may discuss your ideas with others and confer with peers; however, it is not appropriate to give your work to someone else to review. You are responsible for making certain that there is no question that the work you hand in is your own. If only your name appears on an assignment, your professor has the right to expect that you have done the work yourself, fully and independently.

Plagiarism means using the exact words, opinions, or factual information from another person without giving the person credit. Writers give credit through accepted documentation styles, such as parenthetical citation, footnotes, or endnotes. Paraphrased material must also be properly cited. A simple listing of books or articles is not sufficient. Plagiarism is the equivalent of intellectual robbery and cannot be tolerated in the academic setting. If you have any doubts about what constitutes plagiarism, please see the instructor.

Relevant Campus and Academic Resources

Disability Services
Any student with documented learning disabilities or other conditions that may affect academic performance should: 1) make sure this documentation is on file with the Office of Disability Services (SUB I, Rm. 222; 993-2474; www.gmu.edu/student/drc) to determine the accommodations you might need; and 2) talk with the instructor to discuss reasonable accommodations.

Office of Diversity Programs and Services
SUB 1, Rm. 345; 993-2700; www.gmu.edu/student/msaf/index.html

Writing Center
Robinson A116; 993-1200; writingcenter.gmu.edu.