Medical Image Science: Applications

Medical Physics/Biomedical Engineering 574
1022 WIMR, 9:55-10:45 am, MWF
Spring, 2014

January 22, 2014

Instructor:
Professor Sean B. Fain, 1133 WIMR
Phone (608) 263-0090
Email: sfain@wisc.edu

This course presents the application of medical imaging theory to problems in medical imaging science including: concepts of digital image processing, image reconstruction/compression, point response function analysis, noise characteristics, and measurement.

Prerequisite: MP573 or consent of the instructor. 3 credit hours.

Course Objectives: After completion of this course, the student will be able to apply the tools for the generation, processing, and interpretation of medical images to a range of research problems and applications.

Course structure: This 3 credit course entails over 40 contact hours, 28 with a 50-minute lecture format and approximately 12 with a discussion section, lab or group presentation format. There is an outside homework component that requires solving problems related to various image science applications using Matlab or similar mathematical toolboxes. Approximately two-thirds of the sessions focus on deterministic and stochastic aspects of medical imaging and system performance, while approximately a third focus on some aspect of image interpretation and measurement, including emerging techniques. Topics of spatial resolution and noise characteristics, exact and inexact reconstruction, segmentation and measurement tools, decision theory, and modeling of biological processes are treated. Grading will be based on four application homeworks (40%), in-class contribution to discussion sessions and labs (20% of your grade), one midterm exam (15%), two quizzes (10%), and a final exam (15%).

Printed resources (on reserve):
Recommended:
Kenneth R. Castleman. **Digital Image Processing**, 1996. Prentice-Hall, Englewood Cliffs, New Jersey.

Supplementary:
Bevington and Robinson. **Data Reduction and Error Analysis for the Physical Sciences**. 3rd Edition, 2003. McGraw-Hill. New York.

Electronic resources (on website):
The course website: https://learnuw.wisc.edu/
CAE Accounts: http://www.cae.wisc.edu/newuserhelp
"Numerical Computing with Matlab," by Cleve Moler (http://www.mathworks.com/moler/chapters.html)

In-Class Activity Topics
Discussion Papers:
1. Wiggins et al. Image File Types and Snell and Wilcox on MPEG Image Compression
2. Makhoul, DCT
3. Harris, Spectral Analysis and Windowing

In-Class Lab Activities:
1. ROC curves for a 2 alternative forced choice reader study
2. Image registration and segmentation using Insight Tool Kit (ITK); http://www.itk.org/
3. Visualization Tool Kit (VTK); http://www.vtk.org/

Expectations for the discussions – For the group assigned, read the papers in detail with the expectation that you will present and guide the discussion. 2. For the rest of the class, read the papers to a detail where you are prepared to ask questions and participate with the rest of the class to integrate the ideas in the papers to concepts presented in lecture and on their role in medical imaging. The goal is to improve conceptual understanding by providing concrete examples for the class to discuss.

Expectations for the in-class lab activities – Goal is also to foster better conceptual understanding by engaging in open group discussion to solve a specific problem such as image interpretation/measurement and analysis and registration using concepts from the course. These activities may be held at labs or in conference rooms other than the class room but will be specially announced if so.

Jan. 22	Lecture 1	Course overview and concepts (**Application 1 is assigned**)
Jan. 24	Lecture 2	Computer representation, data classes (**Dr. Andrew Hahn**)
Jan. 27	Lecture 3	Image display concepts and file formats
Jan. 29	Lecture 4	Visualization Tools: Volume Viewer and ImageJ/Fiji (**Prof. Fain/Ms. Laura Bell**)
Jan. 31	Lecture 5	Image Compression
Feb. 3	Discussion	**1st In-Class Discussion**: Wiggins et al., Image File Types *and* Snell and Wilcox, MPEG Encoding Basics. (Group 1)
Feb. 5	Lecture 6	Wavelet Transform and Compression (**Dr. Julia Velikina**)
Feb. 7	Test	**Quiz 1 on digital images, display, and compression concepts**
Feb. 10	Lecture 7	The Discrete Fourier transforms (DFT) and Fast Fourier Transform (FFT)
Feb. 12	Lecture 8	The 2D DFT, separable transforms and vector space concepts (**Application 1 is due; Application 2 assigned**)
Feb. 14	Discussion	**2nd In-Class Discussion**: Makhoul, The Discrete Cosine Transform, IEEE (Group 2)
Feb. 17	Lecture 9	Sampling, restoration, and interpolation; the 2D point response function
Feb. 19	Test	**Quiz 2 on image transform and sampling concepts**
Feb. 21	Lecture 10	Probability and Stochastic Processes
Feb. 24	Lecture 11	Autocovariance and autocorrelation
Feb. 26	Discussion	**3rd In-Class Discussion**: Harris, Spectral Analysis, IEEE (Group 3)
Feb. 28	Lecture 12	Modeling stochastic processes in imaging

Mar. 3	Lecture 13	Modeling stochastic processes in imaging (**continued**)
Mar. 5	In-Class Lab	**In-Class Lab Activity: ROC curves for a 2 alternative forced choice reader study (Application 2 is due; Application 3 assigned)**
Mar. 7	In-Class Lab	Group Presentations of Reader Study results
Mar. 10	Lecture 14	Principal components and multi-spectral classification
Mar. 12	Lecture 15	Bayesian classifiers in breast cancer diagnosis (**Prof. Elizabeth Burnside**)
Mar. 14	Flexible Day	Catch Up/Review/Discussion
	No Class	**Spring break Mar. 15-Mar. 23**
Mar. 24	Lecture 16	Cross-Correlation and Power Spectral Analysis
Mar. 26	Lecture 17	Functional MRI methods in the brain (**Prof. Beth Meyerand**)
Mar. 28	Lecture 18	Image Reconstruction, Part I **(Application 3 is due)**
Mar. 31	Lecture 19	Compressed Sensing (**Dr. Diego Hernando**)
April 2	Lecture 20	Image Reconstruction Part II
April 4	Flexible Day	Catch Up/Review/Discussion
April 7	**Test**	**Midterm**
April 9	Lecture 21	Image Segmentation Concepts (**Application 4 assigned**)
April 11	Lecture 22	Mapping Transformations and Image Registration
April 14	Lecture 23	Image Measurement Approaches
April 16	Lecture 24	Compartmental Modeling: Measurement of Tissue Perfusion and Vascular Leakage
April 18	Lecture 26	Functional Imaging Methods Using Hyperpolarized MRI Contrast Agents
April 21	In-Class Lab	**In-Class Lab Activity: Introduction to Insight Segmentation and Registration Toolkit (ITK) (Dr. Chihwa Song)**
April 23	In-Class Lab	**Application to Image Segmentation and Registration Lab (Dr. Chihwa Song)**
April 25	In-Class Lab	**In-Class Discussion (Dr. Chihwa Song)**
April 28	Lecture 25	Molecular Imaging Concepts (**Prof. Weibo Cai; Application 4 Due**)
April 30	Lecture 27	Microscopy Methods and Applications (**Prof. Paul Campagnola**)
May 2	Lecture 28	Imaging and Modeling of Vascular Flow (**Prof. Oliver Wieben**)
May 5	Lecture 29	1D and 2D Filter Design for Imaging Applications
May 7	Flexible Day	Final Exam Review
May 9	**Test**	**Final Exam**