BIOE 484 Statistical Analysis of Biomedical Images

A one-semester course offered at the Grainger College of Engineering by the Department of Bioengineering at the University of Illinois at Urbana-Champaign.

Instructors

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Please email me for meeting appointments

Course Prerequisites

BIOE 485 or permission of the instructor. Students are expected to be familiar with calculus, basic probability & sampling, vector spaces, matrix algebra and constrained optimization. Several NumPy objects and manipulations will be reviewed, and all necessary Sci-kit functions introduced; however, students are expected to have substantial experience with Python programming as the basics of such will not be covered.

Course Description

This course provides a comprehensive understanding of the fundamental concepts and practical applications of traditional and statistical analysis techniques tailored to biomedical images. Students will explore foundational tasks in biomedical image analysis, including image preprocessing, segmentation, feature extraction, and object recognition, while also gaining insights into statistical methods and learning approaches specific to biomedical data. Through hands-on exercises and team-based projects, students will develop the skills necessary to analyze and interpret biomedical images effectively.

Student Learning Objectives (SLOs)

Upon completion of this course, the students will be able to:

- Understand the fundamental principles of biomedical image analysis and apply preprocessing techniques to enhance the quality of biomedical images.
- Understand the concepts, pros and cons, and the differences between traditional and statistical image analysis methods.
- Apply traditional and statistical image analysis techniques for various bio-imaging tasks, including feature extractions, segmentation, and registration.
- Understand the basic principles of machine learning for automated analysis of biomedical images.
- Implement statistical classification methods, including Support Vector Machines (SVM) and decision trees, for categorization of biomedical image data.
- Explore the applications of deep learning, particularly Convolutional Neural Networks (CNNs), for tasks like bio-image classification, denoising, and transfer learning in the biomedical domain.

Optional Resources

- Biomedical Image Analysis : Statistical and Variational Methods, A. Farag, Cambridge University Press, 2014.
- Applied Machine Learning. 1st ed., D. Forsyth, Springer International Publishing, 2019.
- The Image Processing Handbook, J. Russ & F. Neal, Boca Raton, FL: CRC Press, 2016.
- Additional reading material will be assigned from a combination of book chapters, review articles, and primary research papers

Assessment and Grading

Homework: 50%

- Homework projects will be assigned based on lectures and assigned reading material.
- Students may discuss homework problems, but students must complete their own work and write up solutions independently.

Quizzes: 10%

- Two quizzes will be assigned.
- Each will be due within one day since release.

Project: 40% (Final project presentation: 15%; Final project report and code: 25%)

- The course will include a capstone project that involves statistical analysis of real-world biomedical images. Problems with high relevance to the topics covered in this course are strongly encouraged. Students can work in groups that can contain up to three students. A project proposal is due 5 weeks before the last instruction. Towards the end of the course, each team will present their project in a short, roughly ten-minute-long, presentation. Each team will also prepare a final report (between 4 to 8 pages) in the format of a biomedical imaging or machine learning conference paper. The final grade will depend on the rigor of the evaluation studies and quality of the final presentation and report.

Additional Course Polices

In general, homework deadlines are firm. Special circumstances regarding absence or forbearance will be handled on a case-by-case basis at the discretion of the instructor or program director. Please inform the instructor promptly if additional consideration is required.

Academic Integrity

In brief, an infraction of academic integrity is any one of the following:

- Cheating – using or attempting to use unauthorized materials
- Plagiarism – representing the words, work, or ideas of another as your own
- Fabrication – the falsification or invention of any information, including citations
- Facilitation – helping or attempting to help another commit an infraction
- Bribes, Favors, and Threats – actions intended to affect a grade or evaluation
- Academic Interference – tampering, altering or destroying educational material or depriving someone else of access to that material

It is the students' responsibility to refrain from infractions of academic integrity, from conduct that may lead to suspicion of such infractions, and from conduct that aids others in such infractions. "I did not know" is not an excuse. Please ask the instructor for clarification if you are unsure of their expectations.

The complete text of the University of Illinois student code can be found online at http://studentcode.illinois.edu/article1/part4/1-401/. Additional relevant information may be found by searching "academic integrity" at the University of Illinois website (https://illinois.edu).

Students of various Schools, Colleges and Departments within the university may have additional rights, requirements or resources regarding academic integrity so students are encouraged to consult the information specific to their particular program.

Statement of Accessibility & Accommodation

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to the DRES website. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available on campus that can help diagnosis a previously undiagnosed disability by visiting the DRES website and selecting “Sign-Up for an Academic Screening” at the bottom of the page.

Expectations for Students

- Participate throughout each week.
- Consider and respect others' opinions. Complete all assignments on time.
- Discuss concerns privately with the instructor and forum moderators.

Tentative Course Schedule of Topics

Dates	Lectures
Week 1 (01/20)	Introduction to the course **Review of signals and Systems** Signal representation, sampling, and quantization
Week 2 (01/27)	1D Fourier transform and inverse Fourier transform Multi-dimensional signal representation and Fourier transform
Week 3 (02/03)	Linear systems Convolution Basic filtering
Week 4 (02/10)	Image re-sampling and interpolation Image transformation Image relaxation and denoising
Week 5 (02/17)	**Traditional image analysis methods** Edge detection (motivation; image gradients; derivative of Gaussian filters; Canny edge detector; role of edge detection in image understanding)
Week 6 (02/24)	Corner detection (motivation; detection criteria; Harris corner detection criteria; invariance properties of corners)
Week 7 (03/03)	Blob detection Scale invariant detection
Week 8 (03/10)	Image segmentation
Week 9 (03/17)	Spring Break
Week 10 (03/24)	Image alignment
Week 11 (03/31)	Morphology and image matching **Statistical image analysis methods** Review on statistics

Week 12 (04/07)	Decision trees Random forests
Week 13 (04/14)	Support vector machine Image registration
Week 14 (04/21)	Principal component analysis
Week 15 (04/28)	Graph-based methods
Week 16 (05/05)	**Project presentations**
	Final's week