Introduction to Biomedical Image Analysis

EEL 4930 Section Undergraduate
Class Periods: T 3PM – 455PM, Th 405PM – 455PM
Location: MAEA0327
Academic Term: Spring 2024

Instructor:
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- Office Hour TA: Samuel Border, samuel.border@ufl.edu
- Homework Grader: Nicholas Lucarelli, nicholas.lucarelli@ufl.edu
- Alternative Instructor (as needed): Ahmed Naglah, Ahmed.Naglah@medicine.ufl.edu
- Lab: Fatemeh Afsari, Fatemeh.Afsari@medicine.ufl.edu

Course Description
3 Credit hours
This course focuses on computational quantification of biologically relevant microscopic structures in biomedical images. Students will learn how (i) raw data is acquired before digitization; (ii) to read, display, and interpret various brightfield or fluorescence microscopy image data types using a computer; (iii) to detect, segment, and quantify heterogeneous structures in biomedical images; (iv) to leverage features extracted from biomedical images for classification; (v) to setup experiments in MATLAB via script writing for biomedical image analysis. At the beginning of the course, an overview of the medical imaging will be given. Motivation for conducting quantitative analysis of medical images will be discussed. Forward measurement models describing the microscopic imaging system output will be reviewed. Image analysis problems related to fluorescence and brightfield microscopy systems and corresponding biomedically relevant computational image analysis tools will be discussed. Simulated and real images of these systems will be used for quantitative analysis via MATLAB based script writing.

Course Pre-Requisites
EEL 3135 and EEL 3850

Course Objectives
Learning objectives, and assessment methods are provided below.

	Learning Objectives	Assessment Methods
1	Understand image acquisition pipeline of brightfield and fluorescence microscopy	Midterm, and/or Homework 1 & 2
2	Appreciate the role of heterogeneity in quantitative analysis of biomedical structures in microscopic images	Midterm, Homework 3-10, Final project and Final exam
3	Statistical analysis of data	Midterm, Homework 6, Final project and Final exam
3	Develop algorithms and run MATLAB scripts to quantify structural information in biomedical images	Homework 1-10, Final project and Final exam

4	Learn conducting a project by combining expertise from theoretical image analytic and experimental image acquisition science	Final project

Materials and Supply Fees
NA

Relation to Program Outcomes (ABET):

Outcome	Coverage*
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	High
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	High
3. An ability to communicate effectively with a range of audiences	High
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	Medium
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	Medium
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	High
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	Medium

*Coverage is given as high, medium, or low. An empty box indicates that this outcome is not covered or assessed in the course.

Required Textbooks and Software
- Digital Image Processing using MATLAB, 3rd Ed., Rafael C. Gonzalez, Richard E. Woods, and Steven L. Eddins,
- Digital Image Processing, 4th Ed., Rafael C. Gonzalez and Richard E. Woods, Prentice Hall.

Recommended Materials
- S. Hecht (1930). "The development of Thomas Young's theory of color vision." J. Optical Society of America (JOSA) **20** (5): 231–231.
- Ruifrok, A.C. and D.A. Johnston (2001). "Quantification of histochemical staining of color deconvolution." Anal. Quant. Cytol. Histol. **23** (4): 291 – 299.
- Sarder, P. and A. Nehorai (2006). "Deconvolution methods for 3-D fluorescence microscopy images." Signal Processing Magazine, IEEE **23** (3): 32–45.
- Taha, A.A. and A. Hanbury (2015). "Metrics for evaluating 3D medical image segmentation: Analysis, selection, and tool." BMC Medical Imaging **15** (29): 1–28.

Course Schedule
Lecturer: Pinaki Sarder, Ph.D.

Meeting	Date	Day	Topic	Reading
1	Week 1	Lec	Overview of medical imaging; fluorescence microscopy imaging	FSU Microscopy: http://micro.magnet.fsu.edu/
		Lab	MATLAB basics: Defining variables, sum, subtract, multiplication, for loop, plot, imagesc, imshow, etc.	Note: Familiarity of medical imaging modalities will be assessed during this lecture, and more introductory materials may be added in the following weeks and minor adjustment of the syllabus will be made.
2	Week 2	Lec	Probability and random variables; matrices and vectors; image basics; Homework 1	Materials will be posted via Canvas; Follow class discussion; Gonzalez, Woods, & Eddins Ch 2 & 7
		Lab	Basics of matrix operation (sum, product, inverse, dot product), image basics, random number generation, Gaussian random variable, pdf, cdf, z score	
3	Week 3	Lec & Lab	Convolution, fluorescence microscopy forward model; Homework 2	Materials will be posted via Canvas
4	Week 4	Lec & Lab	Principal component projection; color deconvolution; contrast enhancement of heterogeneous microstructures in brightfield and fluorescence microscopy images; Homework 3	Materials will be posted via Canvas; (Ruifrok & Johnston 2001); Gonzalez, Woods, & Eddins Ch 3
5	Week 5	Lec & Lab	Texture analysis in microscopy; Homework 4	Gonzalez, Woods, & Eddins Ch 4
6	Week 6	Lec & Lab	Color space transformations in microscopy; LAB color space; image restoration; Homework 5	(Hecht 1930); (Sarder & Nehorai 2006); Gonzalez, Woods, & Eddins Ch 5 & 7
7	Week 7	Exam	Mid-term exam; Discussion on the project, expectation on the report & final presentation	Take home on February 20th during class hours
8	Week 8	Lec & Lab	Hypothesis testing, T test, precision, recall, sensitivity, specificity, ROC plot, F1 score; project group selection, and topic presentation next week	Materials will be posted via Canvas; Follow class discussion
9	Week 9	Lec & Lab	Role of heterogeneity in segmenting biomedical structures from microscopy images; segmentation performance analysis; Homework 6	Gonzalez, Woods, & Eddins Ch 11
10	Week 10	Lec & Lab	Feature extraction from digital microscopy images; morphological image processing; Homework 7	Gonzalez, Woods, & Eddins Ch 10 & 13
11	Week 11		Project update	

12	Week 12	Lec & Lab	Classification of microstructures in biomedicine, including SVM, naïve Bayesian classification; Homework 8	Gonzalez, Woods, & Eddins Ch 14
13	Week 13	Lec & Lab	Neural network, forward propagation, back propagation, training; Homework 9	Lab materials will be posted via Canvas; Follow class discussion
14	Week 14	Lec	Overview on convolutional neural network; unsupervised learning; variational autoencoders, generative adversarial network; recursive neural network; application in microscopy images; Homework 10	Lab materials will be posted via Canvas; Follow class discussion
15	Week 15		Project update. Course assessment.	
16	Week 16	Exam	Final exam: Project presentation and group report submission.	05/01/2024, 3-5PM

Attendance Policy, Class Expectations, and Make-Up Policy

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies. Click here to read the university attendance policies: https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/

Evaluation of Grades

This course is co-listed with the undergraduate class. Homework for the graduate section will involve additional work, namely, studying and referring to relevant literature while connecting with the practical image analysis problem of interest. Additional analytical questions will be given to the graduate section of this course on select homework assignments and exams. Programming assignments will also be required to be well annotated and documented for those in the graduate section. The final project will assess students' ability to solve problems, sample relevant literature, understand the challenges involved in the underlying problem of interest, analytically evaluate findings, and propose new directions. Such assessment will be mandatory for the graduate students, while for the undergraduate section, the students will be evaluated solely on their ability to provide a final solution of the underlying problem. The graduate and undergraduate sections will be graded separately.

Assignment	Total Points	Percentage of Final Grade
Class Participation		5%
Homework Sets (10)		25%
Midterm Exam	100	25%
Final Project	100	45%
		100%

- Class participation is evaluated based on active engagement and discussion in the class.
- Homework will involve mixture of theoretical questions and Matlab coding exercises.
- Midterm and Final Exam will consist of a theoretical portion to be given on paper, as well as a practical portion solving problems using Matlab.
- Final project will involve working on a biomedical microscopy image analysis problem, developing a computational pipeline and analyzing performance, and writing a 2-page report, with sections including Background, Methods, Results, and Discussion. Data for the project will be provided by the instructor. Matlab scripts implemented for the project are required to be submitted. Final presentation will involve demonstration of the Matlab program in a test dataset that will only be available on the day of the presentation.

Grading Policy

The following is given as an example only.

Percent	Grade	Grade Points
93.4 - 100	A	4.00
90.0 - 93.3	A-	3.67
86.7 - 89.9	B+	3.33
83.4 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:
https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx

Students Requiring Accommodations
Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation
Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

In-Class Recording
Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by

a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

University Honesty Policy

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://sccr.dso.ufl.edu/process/student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennacc@ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

Campus Resources:

Health and Wellness

U Matter, We Care:

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: https://counseling.ufl.edu, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence
If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Connections Center, Reitz Union, 392-1601. Career assistance and counseling; https://career.ufl.edu.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus*:* https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/;https://care.dso.ufl.edu.

On-Line Students Complaints*: https://distance.ufl.edu/state-authorization-status/#student-complaint*.