Course Syllabus

Methods in (Bio)Medical Image Analysis (16-725)

Spring 2024

Instructor: **Dr. John Galeotti**
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TA: none assigned

Zoom Link: https://cmu.zoom.us/j/92806645086?pwd=dmZNUXd0ejRmbTBSSGh0N3lqV1pCdz09

Classroom: CMU GHC 4102 (when meeting in person)
Occasionally also at UPMC

Attendance: Primary: Online and/or in-person during class hours (synchronous attendance required unless alternate arrangements have been made)
Secondary: In-person in smaller groups as scheduled

Office Hours: After class on Tuesdays as needed, or by appointment.

Course Description: Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry, statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include deep learning, de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. New since 2022, students may also use the Medical Open Network for Artificial Intelligence (MONAI) PyTorch-based toolkit. In addition to image analysis, the course will include (expected in-person and/or remote) interaction with radiologists and possibly other clinicians such as pathologists.

Regular lectures will use zoom and will be recorded. Remote interaction with clinicians might also use MS Teams. Some or all of the class lectures may eventually be released for public distribution, and students may request to be excluded from distributed video (no reason necessary, just email and ask for a confirmation reply).

Websites: http://www.cs.cmu.edu/~galeotti/methods_course/ will serve as a publicly accessible touch point and provide links to other online resources. Additionally, Canvas and/or Piazza will be used once all students can access it (after any enrollment issues are resolved for both Pitt and CMU students). You should check the course website daily for announcements and handouts.

Prerequisites: Knowledge of vector calculus, basic probability, and basic Python**,** including basic command-line familiarity and how to pass arguments to your own command-line programs. (Students familiar with C++ should be able to quickly and easily learn the required Python.) Extensive expertise with PyTorch, C++, and abstract programming (object oriented with templates) is not necessary, but some students may find it helpful.

Objectives: To gain theoretical and practical skills in biomedical image analysis algorithms.

Zoom and Class Recordings: All synchronous classes will be recorded via Zoom so that students in this course can watch or re-watch past class sessions. I will make the recordings available securely online (typically within 48 hours of class meeting or sooner). Please note that *you are not allowed to share zoom recordings posted on Canvas or Piazza*. This is to protect your FERPA rights and those of your fellow students. Only the instructor can publicly post part of all of the videos, after allowing ample time for students to opt out of each video.

Textbooks are for foundational concepts. More recent content will use academic papers and/or other online resources.
Required Textbook: "Machine Vision", ISBN: 052116981X
Optional Textbook: "Insight to Images", ISBN: 9781568812175

Tentative Course Calendar: A tentative course calendar is listed on the course website(s) **(see above)**. The lecture schedule (and some topics) are subject to change, depending in part on class interest and involvement. Individual items in the calendar will be marked once updated and confirmed for 2024.

Grading Algorithm: Larger assignments/quizzes are weighted more than smaller ones

- Typically implemented with the point system:
- Each question or problem in a quiz or homework is assigned a point value
- Your cumulative grade for quizzes [or homework] is (the sum of points your earned on all quizzes) divided by (the sum of points you could have earned on all quizzes)
- So, your course grade is equally affected whether you miss 1 point on a 3-point quiz, or you miss 1 point on a 10-point quiz. (This is not the case for the more typical "averaged percentages" method.)

Participation/Engagement: 5%

- Multiple ways to earn
- Engage in class discussion during lecture (send me email afterwards to request participation points)
- Engage in class discussion (online message board, e.g. Piazza)
- Go the extra mile on assignments
- Show unusual creativity

Online Quizzes: 15%

- Based on reading material (so you can take them in advance)
- Not taken before deadline = 0

- In case of extenuating circumstances, please talk to me, but I must be fair to the class which means I might be slightly harder on you.

Homework: 30%

- Your Instructor (& TA if applicable) will help you *before* the assignment is due. When grading, they will ***not*** try to figure out a non-working mess of code!
- **Late policy: 0%** for code that does not compile, run, and at least perform some part of the assignment. *However*, if you've made a reasonable effort in advance *and* have been working with the TA/Instructor but still have not been able to get things to work, then we will be much more generous with partial credit and/or extra time, on a case-by-case basis.
- Also, if you using a different coding environment than the TA/Instructor, then you will be given a brief period of time to fix unforeseen cross-platform incompatibilities.

Clinical Shadow/Interaction Program: 10%

- You submit 1 report for each of the (approximately 6) clinical stations. Attendance may be required in person and/or online, typically using MS Teams when online.

Final Project: 40%

- ◦ 15% presentation (see below for "Communication & Presentation Help")
- ◦ 25% code

Final Letter Grade

- While lower cutoffs may be used, the following maximum grade cutoffs are guaranteed:

\>= 93.5 A
\>= 90.0 A-
\>= 87.5 B+
\>= 83.5 B
\>= 80.0 B-

Accommodations for Students with Disabilities:

If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at access@andrew.cmu.edu.

COVID-19 / Flu / RSV / etc.

The previous few years were unlike anything before, and new waves of COVID/Flu/RSV/etc. continue to make people sick for many days (sometimes weeks) at a time. Although things are somewhat back to normal, we can still find ourselves under extra stress and uncertainty. Make sure to move regularly, eat well, and reach out to your support system or me if you need to. We can all benefit from support in times of stress, and this semester is no exception.

Mental Health

Just as you optimized your code and assignments, you will most likely at some point benefit from your own mental optimization. As a student, you may experience a range of challenges that can interfere with learning, such as strained relationships, increased anxiety, substance use, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may diminish your academic performance and/or reduce your ability to participate in daily activities. CMU services are available, and they work. You can learn more about confidential mental health services available on campus at: http://www.cmu.edu/counseling/. Support is always available (24/7) from Counseling and Psychological Services: 412-268-2922.

Respect for Diversity

It is my intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is my intent to present materials, activities, perspectives, and discussions of medical AI (including AI ethics) that are respectful of diversity and applicable to everyone. Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups. In addition, if any of our class meetings conflict with your religious events, please let me know so that we can make arrangements for you. CMU encourages anyone who experiences or observes unfair or hostile treatment on the basis of identity to speak out for justice and support, within the moment of the incident or after the incident has passed. Anyone can share these experiences using the following resources:
Center for Student Diversity and Inclusion: csdi@andrew.cmu.edu, (412) 268-2150
Report-It online anonymous reporting platform: reportit.net username: tartans password: plaid

Academic Integrity and Collaboration

Honesty and transparency are important features of good scholarship. On the flip side, plagiarism and cheating are serious academic offenses with serious consequences. If you are discovered engaging in either behavior in this course, you will earn a failing grade on the assignment in question, and further disciplinary action may be taken.

For a clear description of what counts as plagiarism, cheating, and/or the use of unauthorized sources, please see the University's Policy on Academic Integrity (updated 2020):
https://www.cmu.edu/policies/student-and-student-life/academic-integrity.html

I encourage you to work together (typically using the provided online discussion board) on homework assignments and to make use of campus resources like Academic Development and the Student Academic Success Center, including the Intercultural Communication Center (ICC) to assist you in your pursuit of academic excellence. However, please note that in accord with the university's policy you must acknowledge any collaboration or assistance that you receive on work that is to be graded: so when you turn in a homework assignments, please include a sentence at the end that says either:

1. "I worked alone on this assignment.", or
2. "I worked with __________ on this assignment." and/or
3. "I received assistance from _________ on this assignment."

Note that providing this information will only serve to help me understand you better: I strongly endorse the use of campus resources like Academic Development and the Student Academic Success Center, as well as collaborative learning, when it increases your ability to succeed in this class and when it enhances your education and learning.

If you have questions about my integration of the university's policy into this course, please do not hesitate to ask: my aim is to foster an environment where you can learn and grow, while ensuring that the work we all do is honest and fair. For more information about Carnegie Mellon's standards with respect to academic integrity, you can also check out the following link: http://www.cmu.edu/academic-integrity/

Here are some examples of acceptable collaboration:

- Clarifying ambiguities or vague points in class handouts, textbooks, or lectures.
- Discussing or explaining the general class material.
- Providing assistance with Python/C++, in using the system facilities, or with editing, debugging, and programming tools and libraries.
- Discussing the code that we give out on the assignment.
- Discussing the assignments to better understand them.
- Getting help from anyone concerning programming issues which are clearly more general than the specific assignment (e.g., what does a particular error message mean?).

Now for the dark side. As a general rule, if you do not understand what you are handing in, you are probably cheating. If you have given somebody the answer, you are probably cheating. In order to help you draw the line, here are some examples of clear cases of cheating:

- Copying (program or assignment) files from another person or source, including retyping their files, changing variable names, copying code without explicit citation from previously published works (except the textbook), etc.
- Allowing someone else to copy your code or written assignment, either in draft or final form.
- Getting help from someone whom you do not acknowledge on your solution.
- Copying from another student during an exam, quiz, or midterm. This includes receiving exam-related information from a student who has already taken the exam.
- Writing, using, or submitting a program that attempts to alter or erase grading information or otherwise compromise security.
- Inappropriately obtaining course information from instructors and TAs.
- Looking at someone else's files containing draft solutions, even if the file permissions are incorrectly set to allow it.
- Receiving help from students who have taken the course in previous years.
- Lying to course staff.
- Copying on quizzes or exams.

- Reviewing any code submissions from previous years.
- Reading the current solution (handed out) if you will be handing in the current assignment late.

Education Objectives (Relationship of Course to Program Outcomes)

(a) an ability to apply knowledge of mathematics, science, and engineering: Theoretical and practical lectures are combined with practical and empirical exercises to prepare students for a large-scale science/engineering final project.

(b) an ability to design and conduct experiments, as well as to analyze and interpret data: Class exercises require students to design, build, and run experiments in software to empirically optimize their projects' algorithm architecture and parameter tuning.

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability: The final projects require students to build a working system that address a real need, either by providing new computational tools or by making new discoveries. Required interaction with practicing clinicians and class lectures both expose students to the dominant constraints in the various domains of biomedical image analysis, including matters of usability, patient safety, and legal liability.

(d) an ability to function on multi-disciplinary teams: The entire class is multi-disciplinary, requiring students to interact with clinicians, biologists, and/or engineers. Homework assignments and the final project require engineering approaches to biomedical problems in order to derive clinically/scientifically meaningful results.

(e) an ability to identify, formulate, and solve engineering problems: As a project-based course, students must continually solve engineering problems. The final projects further require students to individually identify relevant biomedical problems, formulate an engineering approach, and then proceed to (at least partially) solve their chosen problems

(f) an understanding of professional and ethical responsibility: Ethical matters of patient safety and legal liability are discussed when relevant to other lecture materials, as part of projects, and when shadowing clinicians.

(g) an ability to communicate effectively: The final projects require individual student presentations, roughly equivalent to an oral conference presentation. Although students are graded primarily on technical content, they are also graded on the clarity, polish, and length of their presentation.

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context: [see item (c) above regarding economic and societal constraints and impact]

(i) a recognition of the need for, and an ability to engage in life-long learning The course repeatedly stresses the need to always consult the latest scientific literature when seeking to build useful systems, and makes use of current papers for some of the lectures. The textbook was chosen in part due to its extensive references which provide an excellent cross-reference starting point from which relevant current literature can be found.

(j) a knowledge of contemporary issues: Biomedical image analysis is a driving factor for many recent developments in the medical and biological communities. Students are instructed and shown that building useful systems requires knowledge of contemporary practice, workflow, and limitations within these communities, so that the students' final systems will be both usable and relevant to current research/medicine.

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice: As a project based course, students are taught and required to use a wide variety of techniques, skills and engineering tools to solve a variety of biomedical image analysis problems.