Introduction

Title: Biological Image Computing (BIOL GU4402)
Fall 2023
Tue/Thu, 11:40 – 12:55
Rm 601, Fairchild (a few lectures will be via zoom)
Course format: Lecture
Credits: 3 pts

Instructor: Asst. Professor Raju Tomer
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Office hours: Thu: 1 – 2pm, additionally a Slack workspace will be created for discussions.

Course description

Imaging based approaches are used in almost all domains of scientific research, particularly in the biological sciences academic research and related industry, with data sizes in multi-Terabytes ranges. Therefore, programmatic data analysis methods are indispensable to extract knowledge out of the large image datasets.

This course is aimed at teaching the fundamentals of automated large image data analysis. The students will be specifically exposed to the fundamentals of Python programming, various scientific Python modules, commonly used image visualization (2D, 3D, 4D) & rendering methods, image segmentation & measurement approaches for extracting knowledge out of raw datasets, and multi-modal image registration for comparisons across samples (e.g., disease vs. control). Finally, students will practically apply these concepts on a self-defined image analysis problem for final project.

Bulletin Description: This is an advanced image data analysis course aimed at advanced undergraduate and graduate students who are interested in learning programmatic analysis of large-scale microscopy datasets in biological sciences research and industry.

Goals: During this course, we will aim for a practical understanding of the fundamentals of Python programming and its use for automated image visualization, segmentation, measurements, and cross-modality registration.

Textbook and materials

Readings from provided notes, jupyter notebooks, web resources and online literature.

Grading rubric

Class participation in discussions and Q&A: 20%
Weekly assignments: 40%
Final project: 40%

Syllabus

Section I: Introduction to images, data types and ImageJ/Fiji tool
Week 1:

- Motivation for automated image analysis
- Basics of images, image data types and formats
- Basics of ImageJ/Fiji tool for inspecting and analyzing images

Section II: Scientific computing with Python
Weeks 2-5

- Introduction to Jupyter notebook ecosystem
- Python programming fundamentals
- Scientific modules including matplotlib, SciPy, NumPy, scikit-image and SimpleITK

Section III: Image visualization and filtering
Week 6

- Visualization methos including orthogonal projections and volume renderings
- Image overlays
- Convolution-based image filtering, including denoising, smoothening and background subtraction

Section IV: Image segmentation & measurements
Weeks 7-9

- Introduction to labelled images and their visualization
- Classic image segmentation approaches including auto-thresholding and watershed
- Machine learning based image segmentation approaches
- Measurements of various shape and intensity parameters from labelled images

Section V: Multi-modal image registration
Weeks 10-11

- Introduction to 2D, 3D image registration approaches
- Rigid, Affine and non-linear registration

Section VI: Case studies
Weeks 12

- analysis of live imaging date of neuronal activity
- segmentation of cell bodies and vasculature in 3D volumes

Section VII: Final projects
Weeks 13-14

- Self-defined (with approval) or Instructor-defined

Faculty Statement on Academic Integrity

The intellectual venture in which we are all engaged requires of faculty and students alike the highest level of personal and academic integrity. As members of an academic community, each one of us bears the responsibility to participate in scholarly discourse and research in a manner characterized by intellectual honesty and scholarly integrity.

Scholarship, by its very nature, is an iterative process, with ideas and insights building one upon the other. Collaborative scholarship requires the study of other scholars' work, the free discussion of such work, and the explicit acknowledgement of those ideas in any work that inform our own. This exchange of ideas relies upon a mutual trust that sources, opinions, facts, and insights will be properly noted and carefully credited.

In practical terms, this means that, as students, you must be responsible for the full citations of others' ideas in all of your research papers and projects; you must be scrupulously honest when taking your examinations; you must always submit your own work and not that of another student, scholar, or internet agent.

Any breach of this intellectual responsibility is a breach of faith with the rest of our academic community. It undermines our shared intellectual culture, and it cannot be tolerated. Students failing to meet these responsibilities should anticipate being asked to leave Columbia.

University Undergraduate Guide to Academic Integrity:
http://www.college.columbia.edu/academics/academicintegrity

Information for students with disabilities

Rights and Responsibilities
Students, instructors, and Disability Services (DS) all have rights and responsibilities in the process of ensuring that students receive the reasonable accommodations necessary for their full participation in their academic program. This page provides a brief oversight of these rights and responsibilities, but for more information you are referred to Disability Services.

Student Rights and Responsibilities
In order to ensure their rights to reasonable accommodations, it is the responsibility of students to report any learning-related disabilities, to do so in a timely fashion, and to do so through the Office of Disability Services. Students who have documented conditions and are determined by DS to need individualized services will be provided an DS-certified 'Accommodation Letter'. It is students' responsibility to provide this letter to all their instructors and in so doing request the stated accommodations.

Disability Services Rights and Responsibilities

DS is responsible for working with students with disabilities to assess their academic needs, for assisting students in communicating with individual instructors regarding reasonable accommodations and, in some cases, for facilitating the implementation of the approved accommodations. DS shares the educational mission of all offices in the University and is therefore also responsible for upholding the academic policies established by the faculty and for the integrity of academic programs. DS therefore has the right to receive current disability documentation and to deny requests for accommodations that are not warranted or are not reasonable.

Instructor Rights and Responsibilities

It is the right of all instructors to establish the academic standards for the courses that they teach and to consult with DS to determine what accommodations are reasonable for a given course. It is therefore the responsibility of an instructor to provide accommodations, as determined by the DS-certified 'Accommodation Letter', as long as they do not undermine the academic integrity of the course. Instructors are also responsible for evaluating the academic work of students with disabilities according to the same criteria of evaluation utilized for all other students in the class.

It is also the responsibility of an instructor to maintain student confidentiality. Instructors are expected to refrain from discussing a student's disability with other students, to file accommodation requests in a secure location, and to provide opportunities for students to discuss privately their accommodation needs.

In order to receive disability-related academic accommodations, students must first be registered with Disability Services (DS). More information on the DS registration process is available online at www.health.columbia.edu/ods. Faculty must be notified of registered students' accommodations before exam or other accommodations will be provided. Students who have, or think they may have, a disability are invited to contact Disability Services for a confidential discussion at (212) 854-2388 (Voice/TTY) or by email at disability@columbia.edu.