BME1462 – BIOLOGICAL IMAGE ANALYSIS – Winter 2025

Image analysis has become a central tool in modern biology. While the human eye can analyze images, its assessments are often qualitative. Computers provide quantitative, unbiased measurements, and enable the automation of the analysis, leading to a larger number of processed samples and a greater power of downstream statistical tests. In this course, we will discuss the main steps in the analysis of digital images. Topics will include image display, filtering, mathematical morphology, segmentation and measurement. Students will also have the opportunity to develop solutions to the analysis of images from their own research in a final project.

INSTRUCTOR

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TEACHING ASSISTANT

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MATERIALS

Required
You will need a computer in which Python 3, numpy, scikit-image, matplotlib and Jupyter lab are set up locally. The easiest way to get Python 3, numpy, scikit-image, matplotlib and Jupyter ready is to install Anaconda, a free scientific Python distribution that includes all of them (and many more!!!). You can download and install Anaconda here:

https://www.anaconda.com/download/

If you would like to run your notebooks using a desktop application, you can check out the JupyterLab Desktop:

https://github.com/jupyterlab/jupyterlab-desktop

IMPORTANT: please, **get your computer set up before our first meeting on January 6**. At the end of that meeting there will be time to address computer configuration issues. Python installation issues WILL NOT be addressed after January 6.

The reading materials will be largely from:

Digital image processing, by Gonzalez and Woods, Prentice Hall, 3rd edition (the 2nd and 4th editions are also OK).

For our discussion on image measurements, we will use the following reference:

Image analysis for the biological sciences, by Glasbey and Horgan, Wiley (out of print, available on the quercus site).

Recommended
It is STRONGLY recommended that, if you do not have previous experience with Python or Jupyter notebooks, you complete the following self-taught course BEFORE the start of the course:

Python for beginners: https://github.com/ChasNelson1990/python-zero-to-hero-beginners-course

Alternative, the Data Sciences Institute at UofT, provides resources for learning Python:

https://github.com/UofT-DSI/python

The following tutorials can also help get you up to speed:

https://scipy-lectures.org/intro/language/python_language.html
https://jupyter-notebook.readthedocs.io/en/stable/index.html (the section on installation and user documentation)

And if you have not used numpy or scikit-image before, you would really benefit from completing these tutorials (at least the appropriate sections) before you prepare your class presentation:

https://scipy-lectures.org/intro/numpy/index.html
https://scipy-lectures.org/packages/scikit-image/index.html

In addition, there are plenty of resources for image processing and analysis, and data visualization in Python here:

https://scipy-lectures.org/index.html

Finally, if you are interested in a good Python book, *Python crash course*, 3rd edition, by Matthes, No Starch Press, is an excellent resource (https://nostarch.com/python-crash-course-3rd-edition).

EVALUATION

BME1462 is a flipped course that uses an active learning approach. That means that theory is covered through assigned, independent readings; and lectures are largely devoted to hands-on exercises that make use of the concepts learned in the readings.

Class participation (20%, throughout the semester)

All students are expected to complete the assigned readings each week. The course will be based on discussion of theoretical and practical problems. Asking questions and contributing to lecture will be a critical component of the final mark.

Presentation (30% once in the semester, groups of 3)

Teaching a material is the best way to learn it. Every week, three students will prepare a 50-minute, Jupyter notebook-based tutorial to practice the ideas discussed in the readings assigned for that week. Please, book a **mandatory** meeting with the teaching assistant **two or more weeks** before your presentation to discuss your choice of presentation topics and the scikit-image functions that you plan to use to illustrate them. The notebook will be submitted to the teaching assistant one week before the presentation date for feedback. During lecture, the students will walk the class through the tutorial and answer questions. At the end of the session we will spend 5 minutes on a class evaluation activity that will contribute to the final mark of the students. Please, keep in mind that depth and clarity of the presentation will be evaluated. Therefore, **choose a small number of topics to present** (e.g. two filters, or one image segmentation method, or one algorithm for object tracking) **and make sure to discuss those topics in depth**. Also, this course is on biological image analysis. Choose images appropriately (e.g. an image of FISH spots in a cell is appropriate to illustrate the effect of a median filter, an image of stars is not).

Project proposal (10%, February 10, groups of 3)

One page (or shorter) final project proposal, including summary, motivation, and methods to be used, pitfalls and alternative approaches. The project should result in the development of a tool that uses quantitative image analysis to answer an original biological question proposed by the students (presumably a SIMPLE question). Remember that answering a biological question requires statistics. Therefore, analyzing a single image is NOT an acceptable project.

Progress report (not marked, but mandatory to pass, March 10, groups of 3)

Two-slide, 5 min presentation with 5 min for questions describing progress so far, challenges and future plans.

Final project presentation (10%, April 7, groups of 3)

A 10 min presentation with 3 min for questions.

Final project report (30%, April 10, groups of 3)

A 5 page (maximum!!) report using the format of a research paper (abstract-introduction-methods-results-discussion-references) + commented source code. Email to the instructor.

COURSE SCHEDULE

LECTURES:

Monday, 3-5pm, MY420.

Date	Subject
Jan 6	*Organizational meeting*
Jan 13	*Getting started with image processing and Python*
Jan 20	*Digital image fundamentals* Gonzalez&Woods 3rd ed. (pp. 52-74) 2.4 Image sampling and quantization 2.5 Some basic relationships between pixels 2.6 An introduction to the mathematical tools used in digital image processing
Jan 27	*Image enhancement I* Gonzalez&Woods 3rd ed. (pp. 144-168) 3.4 Fundamentals of spatial filtering 3.5 Smoothing spatial filters 3.6 Sharpening spatial filters
Feb 3	*Image enhancement II* Gonzalez&Woods 3rd ed. (pp. 120-144) 3.3 Histogram processing
Feb 10	*Morphological image processing I* Gonzalez&Woods 3rd ed. (pp. 628-639, 665-676) 9.1 Preliminaries 9.2 Erosion and dilation 9.3 Opening and closing 9.6 Gray-scale morphology **Project proposals due!!!**
Feb 17	READING WEEK – NO LECTURE
Feb 24	*Morphological image processing II* Gonzalez&Woods 3rd ed. (pp. 640-664) 9.4. The Hit-or-Miss transformation 9.5 Some basic morphological algorithms

Mar 3	*Image segmentation* Gonzalez&Woods 3rd ed. (pp. 690-714, 738-761, 769-778) 10.1 Fundamentals 10.2 Point, line and edge detection 10.3 Thresholding 10.5 Segmentation using morphological watersheds
Mar 10	**Progress reports**
Mar 17	*Image measurement* Glasbey&Horgan (Chapter 6) 6.1 Measures of size 6.2 Measures of shape 6.3 Boundary statistics
Mar 24	*Tracking and registration* Gonzalez&Woods 3rd ed. (pp. 87-92) 2.6.5 Spatial operations Jaqaman and Danuser, *Cold Spring Harbor Protocols* 12, 2009 Vig, Hamby and Wolgemuth, *Biophysical Journal* 110, 1469-1475, 2016
Mar 31	NO LECTURE
Apr 7	**Final project presentations**

ACCOMMODATIONS

The University of Toronto supports accommodations for students with diverse learning needs, which may be associated with mental health conditions, learning disabilities, autism spectrum, ADHD, mobility impairments, functional/fine motor impairments, concussion or head injury, visual impairments, chronic health conditions, addictions, D/deaf, deafened or hard of hearing, communication disorders and/or temporary disabilities, such as fractures and severe sprains, or recovery from an operation.

If you have a learning need requiring an accommodation the University of Toronto recommends that students register with Accessibility Services as soon as possible.

We know that many students may be hesitant to reach out to Accessibility Services for accommodations. The purpose of academic accommodations is to support students in accessing their academics by helping to remove unfair disadvantages. We can assess your situation, develop an accommodation plan with you, and support you in requesting accommodation for your course work. The process of accommodation is private; we will not share details of your needs or condition with any instructor.

If you feel hesitant to register with us, we encourage you to reach out for further information and resources on how we can support. It may feel difficult to ask for help, but it can make all the difference during your time here.

Phone: 416-978-8060
Email: accessibility.services@utoronto.ca

EQUITY, DIVERSTIY AND INCLUSION

Looking for community? Feeling isolated? Not being understood or heard?

You are not alone. You can talk to anyone in the Faculty that you feel comfortable approaching, anytime—professors, instructors, teaching assistants, department academic advisors, student leaders or the Assistant Dean of Diversity, Inclusion and Professionalism.

You belong here. In this class, the participation and perspectives of everyone is invited and encouraged. The broad range of identities and the intersections of those identities are valued and create an inclusive team environment that will help you achieve academic success. You can read the evidence for this approach here.

You have rights. The University Code of Student Conduct and the Ontario Human Rights Code protect you against all forms of harassment or discrimination, including but not limited to acts of racism, sexism, Islamophobia, antisemitism, homophobia, transphobia, ableism, classism and ageism. Engineering denounces unprofessionalism or intolerance in language, actions or interactions, in person or online, on- or off-campus. Engineering takes these concerns extremely seriously and you can confidentially disclose directly to the Assistant Dean for help here.

Resource List:

- Engineering Equity, Diversity & Inclusion Groups, Initiatives & Student Resources
- Engineering Positive Space Resources
- Request a religious-based accommodation here
- Email Marisa Sterling, P.Eng, the Assistant Dean, Diversity, Inclusion &Professionalism here
- Make a confidential disclosure of harassment, discrimination or unprofessionalism here or email disclosure.engineering@utoronto.ca or call 416.946.3986
- Email the Engineering Society Equity & Inclusivity Director here
- U of T Equity Offices & First Nations House Resources

LAND ACKNOWLEDGEMENT & INDIGENOUS STUDENT SUPPORTS

Land Acknowledgement

I wish to acknowledge this land on which the University of Toronto operates. For thousands of years, it has been the traditional land of the Huron-Wendat, the Seneca, and the Mississaugas of the Credit. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.

Learn more about Canada's relationship with Indigenous Peoples here.

Indigenous Students' Supports

If you are an Indigenous engineering student, you are invited to join a private Discord channel to meet other Indigenous students, professors, and staff, chat about scholarships, awards, work opportunities, Indigenous-related events, and receive mentorship. Email Professor Bazylak or Darlee Gerrard if you are interested.

Indigenous students at U of T are also invited to visit Nations House's (FNH) Indigenous Student Services for culturally relevant programs and services. If you want more information on how to apply for Indigenous specific funding opportunities, cultural programs, traditional medicines, academic support, monthly social events or receive the weekly newsletter, go to the FNH website, email or follow FNH on social media: Facebook, Instagram, or TikTok. A full event calendar is on the CLNX platform. Check CLNX often to see what new events are added!