BME1462 – BIOLOGICAL IMAGE ANALYSIS – Winter 2021

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, segmentation, mathematical morphology and measurements. Students will also have the opportunity to develop solutions to the analysis of images from their own research in a final project.

INSTRUCTOR

Professor Rodrigo Fernandez-Gonzalez
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Office hours: by request (email please).

MATERIALS

Required
During lecture, you will need a computer with Python 3, numpy, scikit-image, and Jupyter notebooks set up.

The easiest way to get both Python 3, numpy, scikit-image and Jupyter ready is to install Anaconda, a free scientific Python distribution that includes all four (and many more!!!). You can download and install Anaconda here:

https://www.anaconda.com/distribution/

IMPORTANT: please, try go **get your computer set up before our organizational meeting on January 11**. At the end of that meeting there will be time to address computer configuration issues. Python installation issues WILL NOT be addressed after January 11.

The reading materials will be largely from:

Digital image processing, by Gonzalez and Woods, Prentice Hall, 3rd edition (the 2nd edition is 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 for download in the authors' website - scroll to the bottom of the page: https://www.bioss.ac.uk/people/chris.html).

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

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

EVALUATION

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

Class participation (20%, throughout the semester)
All students are expected to complete the assigned readings each week. The course will be based on student-led 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 2 or 3)
Teaching a material is the best way to learn it. Every week, two or three students will lead the lecture. The students will prepare a 90-minute, Jupyter notebook-based tutorial to practice the ideas discussed in the readings assigned for that week. The notebook will be submitted to the instructor one week before the presentation date for posting on Quercus. 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.

Project proposal (10%, February 15, groups of 2 or 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).

Progress report (not marked, but mandatory to pass, March 15, groups of 2 or 3)
Two-slide, 5 min presentation with 5 min for questions describing progress so far, challenges and future plans.

Final project presentation (10%, April 12, groups of 2 or 3)
A 10 min presentation with 3 min for questions.

Final project report (30%, April 16, groups of 2 or 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.

CLASS SCHEDULE

LECTURES:

Lectures: Monday, 4-6pm (Bb Collaborate)

LECTURE TOPICS:

Date	Subject
Jan 11	*Organizational meeting*
Jan 18	*Course overview*
Jan 25	NO LECTURE
Feb 1	*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
Feb 8	*Image enhancement I* Gonzalez&Woods 3rd ed. (pp. 120-144) 3.3 Histogram processing
Feb 15	READING WEEK - **Project proposal due**
Feb 22	*Image enhancement II* Gonzalez&Woods 3rd ed. (pp. 144-168) 3.4 Fundamentals of spatial filtering 3.5 Smoothing spatial filters 3.6 Sharpening spatial filters
Mar 1	*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
Mar 8	*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 15	**Progress reports**

Mar 22	*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 29	*Image measurement* Glasbey&Horgan (Chapter 6) 6.1 Measures of size 6.2 Measures of shape 6.3 Boundary statistics
April 5	*Tracking and registration* Gonzalez&Woods 3rd ed. (pp. 87-92) 2.6.5 Spatial operations Chenouard et al., *Nature Methods* 11, 281-289, 2014 Jaqaman and Danuser, *Cold Spring Harbor Protocols* 12, 2009
Apr 12	**Final project presentations**