Rensselaer | DEPARTMENT OF BIOMEDICAL ENGINEERING

BMED 4460/6460: Biological Image Analysis
Spring 2014 (Wed 4-7PM)

Course Description:
Automatic analysis of microscope imagery plays an increasingly important role in biosciences research. The system-level analysis of complex biological processes requires methods that enable the quantification of a broad range of phenotypical alterations, the precise localization of signaling events, and the ability to analyze these signaling events in the context of the spatial organization of the biological specimen. Thanks to dramatic technical advances in optics, automation, and microfluidics, microscopes now enable the capture of these biological processes at both high resolution and high throughput. The resulting data sets are so vast in size and complexity that it is no longer feasible to analyze them manually. Hence automated analysis tools play a crucial role in extracting quantitative biologically relevant data.

This course will introduce students to the image analysis methods that can be used to extract biologically relevant measurements. In addition to teaching a core set of image analysis algorithms, the course will highlight some of the application-relevant challenges that need to be addressed. Overall the course balances between introducing theoretical concepts and applying the image analysis tools to actual data sets. By the very nature of the subject matter, this is an interdisciplinary area of research, and the course prepares students for working in this environment.

Topics Covered:
- Survey of image analysis applications in biology, biotechnology, and medicine.
- Introduction to biological microscopy and selected medical imaging systems.
- Image reconstruction and pre-processing.
- Grayscale and geometric corrections.
- Adaptive image segmentation.
- Blob analysis, cell/colony counting, and cell morphometry.
- Vessel and neuron tracing algorithms, with applications to neurobiology and medicine.
- Feature extraction, pattern analysis, cluster analysis and classification.
- Image registration algorithms with applications to mosaicing, spatial referencing, motion estimation, and change detection.

Credits: 3Cr. (Course credits cannot be earned for both BMED 4460 and BMED 6460)

Textbook and Reference Texts:
Publications provided electronically

Course Instructor:
Dr. Dirk Padfield
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www.dirkpadfield.com/BiologicalImageAnalysis

Class Schedule:
Lectures: 3 hrs (Wed 16:00-19:00PM)

Office Hours:
To be announced

Course Contents/Coverage:

Introduction: provides a high-level introduction to the topic of biological imaging and introduces a core set of biological terms that are relevant for the course.

Imaging Methods: discusses the different methods for imaging cells and tissues. Rather than reviewing the technical details of the various imaging methods, we will discuss why certain imaging methods provide challenges for automated image analysis. The unit makes reference to the standard imaging methods for cells and tissues such as automated microscopy.

Image Preprocessing: discusses the acquisition and representation of digital images. In particular, we will focus on acquiring multi-spectral data sets. Algorithms that are used to remove image noise and unmix multi-spectral signals will be presented.

Detection Methods: provides an overview of basic detection methods. Applications to common biological signal detection problems will be discussed.

Image Registration: reviews the most commonly used image registration algorithms. Image registration can play an important part in the image formation process.

Image Segmentation: provides an overview of different segmentation strategies. Automated image segmentation techniques play a central role in the acquisition and analysis of the probe signal.

Algorithm Validation: gives a general overview of validation methods. Algorithm validation plays a major role in medical and biomedical imaging applications. Only if the users have established the validity of an algorithm can it be used for experimental studies. When ground truth is available, it is possible to use established approaches to validate a new algorithm. However, many biological applications pose the challenge that establishing the ground truth is either very difficult or even impossible. The inherent variation of the biological samples posed additional challenges. This unit will highlight general principles and requirements.

Morphological Assessment of Cells: introduces classification methods to identify different cell populations. Changes in cell morphology and tissue structure play an important role in the diagnosis of cancer. This unit will introduce methods for characterizing cellular shape by measuring certain geometrical aspects of cells.

Tubular Structures: introduces some of the specific algorithms that are necessary for extracting tubular structures and assessing their characteristics. In addition to the detection of nuclei, the segmentation of microvasculature (or generalized tubular structures) is highly relevant.

Time-lapse Microscopy: provides an overview on algorithms that enable the detection of changes, visual tracking, and the concept of populations dynamics. Using video microscopy, researchers can capture the dynamical behavior of tagged proteins within the living cell.

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Grading:
The final grade in this course will be based on the student's total score on all components of the course. The total score is broken down into the following components:

- In-class quizzes (5% of grade)
- Extended assignments (40% of grade): 4 to 5 extended assignments (due as assigned) that will include reading assignments with comprehension questions and coding activities.
- Mid-term exam (20% of grade)
- Group project (35% grade): focuses on the application of image analysis methods to an actual problem. Students will be working in small groups, and the project will be organized into various phases. The grade will be based on the results and the final presentation.

Difference between 4000 and 6000 level: At the 6000 level, students define a problem that is related to their area of research in agreement with the instructor. The students are questioned on this problem both at the mid-term and final project. The students are expected to provide a complete solution to the problem. Additional literature is provided to help the student and review is expected to be incorporated in their assignments.

There is no way to make up a missed exam. An unexcused absence from an exam will be assigned a zero grade. An excused absence requires a letter from the Dean's office. An excused absence from a semester exam will receive an EX grade. At the end of the semester, the EX grade will be replaced with the average of the student grades on the other exam and the final project.

Grade disputes will be settled at the discretion of the instructor. The problem in question will be re-graded, making it possible for the student to receive a lower score. To dispute an exam grade, the student must explain his/her dispute in writing and staple this in front of his/her exam.

No wireless devices will be allowed in the classroom.

Academic Integrity
The Biomedical Engineering Department does not tolerate any act of academic dishonesty. As a student in BMED 4460/6460, the departmental code of ethics outlined below will be followed.

"As a member of the Rensselaer Biomedical Engineering Community, I will uphold the ethical conduct befitting a Biomedical Engineer. I will not use knowledge gained from my experiences at Rensselaer for any purpose which may harm society. My actions will reflect positively on the department, university, and profession. I will respect the faculty, staff, and my peers by not misrepresenting myself through acts of deception. I will not participate in any acts of lying, cheating, or stealing in accordance with the Rensselaer Handbook of Student Rights and Responsibilities. I will conduct research with integrity. I will take pride in my work and continue to promote these principles throughout my tenure at Rensselaer and my career as a Biomedical Engineer."

In this class, all assignments that are turned in for grade must represent the student's own work. In cases where help was received, or teamwork was allowed, a notation on the assignment should indicate your collaboration. Submission of any assignment that is in violation of this policy will receive a failing grade for the course and reported to the Dean of Students. If you have any questions concerning this policy before submitting an assignment, please ask for clarification