MSCBIO 2027/BIOE 2335

Bioimaging, Analysis and Spatial Biology

Spring 2026

Course Information

Credits:	3
Meeting Time:	Monday and Wednesday, 9:00 AM – 10:30 AM
Location:	814A Murdoch Building
Course Director:	Shikhar Uttam, PhD

Course Description

This course introduces students to micron, nanometer, and sub-nanometer scale imaging-based approaches in experimental, computational, and systems biology and bioengineering. Emphasis will be placed on understanding the fundamentals of image formation, processing, and analysis of different imaging modalities along with spatial transcriptomic and proteomic methods. Applications of these methods in studying biological phenomena in space and time will be discussed.

Prerequisites

- Basic proficiency in Python programming
- Fundamental understanding of linear algebra
- Fundamental understanding of calculus

Course Assessment

Biweekly Homework:	70%
Class Project:	30%
Exams:	None
Grades:	A (90-100); B (80-90); C (70-80); D (60-70); E (40-60); F ($<$ 40)

- Homework assignments will reinforce concepts covered in lectures through hands-on implementation and analysis.
- The class project will involve applying material learned throughout the course to address a quantitative biology or computational pathology problem.

Instructors

- Primary instructor: Shikhar Uttam (Pitt)
- Guest Lecturers: Robin Lee (Pitt), Keisuke Ishihara (Pitt), Min Xu (CMU)

1 Course Topics

1.1 Module 1: Physics and Engineering of Light

- Wave-Particle duality
- Wave and ray optics
- Light microscopy
  - Brightfield microscopy
  - Phase contrast microscopy:
  - Immunofluorescence microscopy
  - Confocal microscopy
  - Light-sheet microscopy
- Super-resolution nanoscopy
  - Breaking the diffraction limit: theoretical foundations
  - Single Molecule Localization Microscopy (SMLM): PALM, STORM, and dSTORM
  - Localization precision and reconstruction algorithms
  - Stimulated Emission Depletion (STED)
  - Structured illumination microscopy (SIM)

1.2 Module 2: Digital Image Processing and Analysis

- Digital image fundamentals
- Image enhancement and filtering
- Morphological operations
- Image segmentation
- Image registration
- Image analysis
  - Object detection
  - Particle and cell tracking

1.3 Module 3: Machine Learning and Deep Learning

- Classical machine learning for bioimage analysis
- Deep Learning for bioimage representation and analysis

1.4 Module 4: Spatial Biology

- Spatial proteomics
  - Highly multiplexed imaging
  - Single-cell spatial protein profiling
  - Neighborhood analysis and cellular microenvironments
  - Spatial statistics and cell-cell interaction analysis
- Spatial transcriptomics
  - Multiplexed error-robust fluorescence in situ hybridization (MERFISH)
  - Spatially-resolved whole transcriptome analysis (Visium)
  - Spatial gene expression patterns and niche identification
  - Integration of spatial transcriptomics with single-cell RNA-seq
  - Trajectory inference and spatial dynamics

1.5 Module 5: Guest lectures

- Live cell imaging and cell signaling
- 3D imaging and organoids
- Cryo electron microscopy

2 Course Policies

2.1 Attendance

Regular attendance is expected as course material builds progressively, and hands-on demonstrations during class are essential for understanding.

2.2 Homework

- Homework assignments will assigned biweekly and will involve theoretical problems and application of Python programming to biological and pathology problems.
- Late submissions will be penalized 10 points per day. (Usually, each homework will be 100 points.)
- Students are encouraged to discuss their approaches with their classmates but must submit individual work.

2.3 Class Project

- Students will work individually or with another classmate. (Maximum group size: 2)
- Project proposal due mid March. (Suggested topics will be provided)
- Instructor approval (latest by end of March). It will involve discussion with each student.
- Final project due date will be decided after discussion with the class.

2.4 Academic Integrity

All students are expected to adhere to the university's academic integrity policies. Plagiarism, or use of unauthorized materials will result in zero credits for the assignment or project.

This syllabus is subject to change. Students will be notified of any modifications.