COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Image Analysis: From Pixels to Insights	

Lecturer (s)	Department (s)
Coordinator: Mohammad Nour Alsamsam (44h) **Co-Lecturer: dr. Marijonas Tutkus (4h)**	Department of Neurobiology and Biophysics, Life Sciences Centre

Cycle	Level of the course unit	Type of the course unit
1st stage (Bachelor's studies) 2nd stage (Master's studies)	-	Facultative

Mode of delivery	Period of delivered	Language(s) of instruction
Lectures/workshops/laboratory	Spring semester	English

Prerequisites and corequisites	
Prerequisites: For undergraduate students in Biology, Chemistry, Physics, Nanoengineering, Health and Medical Sciences, and Life Sciences.	**Corequisites (if any):** - Basic Programming: Familiarity with programming fundamentals such as variables, loops, conditionals, and functions, preferably in Python. - Statistics: Basic knowledge of statistical concepts. - General Higher Mathematics.

Number of credits allocated to the course unit (module)	Total student's workload	Contact hours	Self-directed learning hours
5	148	48	100

Purpose of the course unit (module): programme competencies to be developed

- **Objective of the Course:** The objective of the course is to equip students with the knowledge and skills necessary to proficiently analyze optical microscopy images using computational methods, with a focus on programming in Python and integrating principles from biology, mathematics, and computer science.
- **Knowledge Gained:**
    - Understanding of image processing techniques for biological data analysis.
    - Knowledge of statistical methods and mathematical concepts relevant to image analysis.
    - Familiarity with interdisciplinary principles bridging biology and programming.
- **Skills Gained:**
    - Proficiency in Python programming for manipulating and analyzing biological image data.
    - Proficiency in optical/fluorescence microscopy techniques for biological imaging.
    - Ability to apply quantitative analysis techniques to extract meaningful insights from images.
    - Competence in experimental design, optimization, and interpretation of imaging experiments.

Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment**
1. To provide basic and advanced knowledge of imaging of quantitative fluorescence microscopy of biological samples and processing and analysis of recorded data.	Lectures, Workshops, Self-directed learning.	Workshop Tasks.
2. To learn the methods of fluorescence microscopy data processing and analysis applicable to samples from the cellular level to individual molecules. - Learn how to properly record data using fluorescence microscopes and sample preparation methods for fluorescence microscopy.	Laboratory works, Seminars, Self-directed learning.	Practical exam: Evaluation of lab reports and their oral defense.
3. To develop proficiency in applying image analysis techniques to real-world biological data through individual projects and presentations.	Project-based learning, Presentations, Self-directed learning.	Individual project: Submission of a comprehensive analysis project report applying learned techniques.

Content: breakdown of the topics	**Contact hours**							**Self-study work: time and assignments**	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work placement	**Contact hours**	**Self-study hours**	**Assignments**
1. Introduction to optical imaging systems: basic geometrical optics, conjugated planes, diffraction and imaging, resolution and digital aperture, contrast techniques.	2						**2**	**4**	Reading the literature on the topic
2. Introduction to Microscopy: microscope types, an overview of methods, wide-field, confocal, total internal reflection (TIRF), super-resolution microscopes.	2						**2**	**4**	Reading the literature on the topic
3. Introduction to Detectors: photodiodes, CCD & CMOS cameras, detector noise.	2						**2**	**4**	Reading the literature on the topic

4. Introduction to Fluorophores: molecular fluorescence, dyes, filters and dichroic mirrors, excitation sources, point spread function (PSF), diffraction limit.	2						**2**	**4**	Reading the literature on the topic
5. Introduction to Fluorophores: dyes for monitoring molecular interactions: dye selection, FRET, fluorescence quenching, filter selection.	2						**2**	**4**	Reading the literature on the topic
6. Introduction to Bio-image Analysis with Python: setting up your computer for image analysis, Python basics for image analysis, Jupyter notebooks, best practices.		2					**2**	**4**	Reading the literature on the topic
7. Image Analysis Basics: images are arrays, brightness, and contrast adjustments, cropping and indexing images, multi-dimensional image data.		2					**2**	**4**	Reading the literature on the topic
8. Image File Formats: reading and writing images, formats. Image Visualization.		2					**2**	**4**	Reading the literature on the topic
9. Image Filtering: processing filters, convolution, noise removal, background removal, edge detection.		2					**2**	**4**	Reading the literature on the topic
10. Image Deconvolution: image deconvolution, point-spread-function from bead images. Spatial Transforms: coordinate systems, affine transforms.		2					**2**	**4**	Reading the literature on the topic
11. Image Segmentation Techniques: segmentation basics, blob detection, local maxima detection.		2					**2**	**4**	Reading the literature on the topic
12. Advanced Image Analysis: quantitative analysis.		2					**2**	**4**	Reading the literature on the topic
13. Advanced Image Analysis: classification.		2					**2**	**4**	Reading the literature on the topic
14. Advanced Image Analysis: models and fitting.		2					**2**	**4**	Reading the literature on the topic
15. Individual Projects: brainstorming and consultations.			2				**2**	**4**	Reading the literature on the topic
16. FiJi: an ImageJ distribution for bioimage analysis.		2					**2**	**4**	Reading the literature on the topic
17. Napari: a fast, interactive viewer for multi-dimensional images in Python.		2					**2**	**4**	Reading the literature on the topic

18. The microEye: images analysis with Multi Tiff Viewer.		2					**2**	**4**	Reading the literature on the topic
19. Practical classes: acquaintance with microscopes, their management, the most important details.					3		**3**	**5**	Reading the literature on the topic
20. Quantitative microscopy using the TIRF microscope: measurements of Gatta-PAINT nano rulers for resolution assessment. Using the microEye for analysis.					3		**3**		Reading the literature on the topic
21. Independent study and preparation for the presentation of the description of laboratory work.								**5**	Reading the literature on the topic
22. Independent study and preparation for the individual project report.								**18**	Reading the literature on the topic
23. Presentation of the description of laboratory works and oral presentations.			2				**2**		Reading the literature on the topic
24. Individual Projects: final consultation session.			2				**2**		
25. Presentation of the individual project reports.			2				**2**		
Total							**48**	**100**	

Assessment strategy	**Weight, %**	**Assessment period**	**Assessment criteria**
Workshop tasks.	30 %	During the semester.	The student should participate in workshops and implement desired tasks. (3 points for attendance and tasks)
Implementation of laboratory works lab report and its oral defense.	20 %	During the semester.	The performance of laboratory work is evaluated with 2 points. The maximum evaluation of the laboratory report is 1 point. The maximum grade for oral defense is also 1 point.
Individual Project Report	50%	During the end of semester.	Submission of an individual project report demonstrating proficiency in applying image analysis techniques and concepts covered in the course. Final evaluation based on the quality and completion of the individual project report. Assessment criteria include project design, implementation, analysis, and comprehensive documentation. A student is allowed to proceed with the individual project if laboratory, practical work, and workshop tasks have been completed, and at least 50% of the possible points have been obtained during the semester.

Author	Year of publication	Title	Issue of a periodical or volume of a publication	Publishing place and house or weblink
Compulsory reading				
Douglas B. Murphy, Michael W. Davidson	2013	Fundamentals of Light Microscopy and Electronic Imaging		Wiley-Blackwell
Mohammad Nour Alsamsam, Aurimas Kopūsta, Meda Jurevičiūtė, Marijonas Tutkus.	2022	The miEye: Bench-top super-resolution microscope with cost-effective equipment.		https://doi.org/10.1016/j.ohx.2022.e00368
Jennifer Waters, Torsten Wittmann	2014	Quantitative Imaging in Cell Biology, Volume 123: Methods in Cell Biology		Academic Press
Pete Bankhead	2022-2024	Introduction to Bioimage Analysis		https://bioimagebook.github.io/index.html
Robert Haase, Guillaume Witz, Miguel Fernandes, Marcelo Leomil Zoccoler, Shannon Taylor, Mara Lampert, Till Korten		Bio-image Analysis Notebooks		https://haesleinhuepf.github.io/BioImageAnalysisNotebooks/intro.html
Optional reading				
Andreas Walter, Julia Mannheim, Carmel J. Caruana	2021	Imaging modalities for biological and preclinical research. A compendium Volume 1. Part I, Volume 1.		IOP Publishing
Paul R. Selvin, Taekjip Ha	2008	Single-molecule Techniques: A Laboratory Manual		CSHL Press
Eugene Hecht	2017, 2002	Optics	Fourier transforms chapter	Pearson Higher Education, Addison Wesley
Additional Resources				
Ron Vale, Nico Stuurman, and Kurt Thorn		iBiology: Microscopy Series		https://www.ibiology.org/online-biology-courses/microscopy-series/ https://www.ibiology.org/online-biology-courses/microscopy-series/microscopy-series-table-contents/
Kaggle Inc.		Kaggle: Learn Python		https://www.kaggle.com/learn
Mohammad Nour Alsamsam	-	microEye: a python toolkit for fluorescence microscopy that features hardware control, data analysis and visualization for super-resolution single-molecule localization microscopy and single-particle tracking. [Computer software]		https://github.com/samhitech/microEye

Schindelin, J., Arganda-Carreras, I., Frise, E. et al.	2012	Fiji: an open-source platform for biological-image analysis [Computer software]		https://doi.org/10.1038/nmeth.2019 https://fiji.sc/
Ahlers, J., Althviz Moré, D., Amsalem, O., Anderson, A., Bokota, G., Boone, P., Bragantini, J., Buckley, G., Burt, A., Bussonnier, M., Can Solak, A., Caporal, C., Doncila Pop, D., Evans, K., Freeman, J., Gaifas, L., Gohlke, C., Gunalan, K., Har-Gil, H., Harfouche, M., Harrington, K. I. S., Hilsenstein, V., Hutchings, K., Lambert, T., Lauer, J., Lichtner, G., Liu, Z., Liu, L., Lowe, A., Marconato, L., Martin, S., McGovern, A., Migas, L., Miller, N., Muñoz, H., Müller, J., Nauroth-Kreß, C., Nunez-Iglesias, J., Pape, C., Pevey, K., Peña-Castellanos, G., Pierré, A., Rodríguez-Guerra, J., Ross, D., Royer, L., Russell, C. T., Selzer, G., Smith, P., Sobolewski, P., Sofiiuk, K., Sofroniew, N., Stansby, D., Sweet, A., Vierdag, W., Wadhwa, P., Weber Mendonça, M., Windhager, J., Winston, P., & Yamauchi, K.		napari: a multi-dimensional image viewer for Python [Computer software]		https://doi.org/10.5281/zenodo.3555620 https://napari.org/stable/index.html