GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	3D Vision in Robotics, PG_00068083					
Field of study	Automatic Control, Cybernetics and Robotics					
Date of commencement of studies	October 2026		Academic year of realisation of subject		2028/2029	
Education level	first-cycle studies		Subject group		Optional subject group Subject group related to scientific research in the field of study	
Mode of study	Full-time studies		Mode of delivery		at the university	
Year of study	3		Language of instruction		Polish	
Semester of study	6		ECTS credits		3.0	
Learning profile	general academic profile		Assessment form		exam	
Conducting unit	Department of Decision Systems and Robotics -> Faculty of Electronics Telecommunications and Informatics -> Faculties of Gdańsk University of Technology					
Name and surname of lecturer (lecturers)	Subject supervisor		dr inż. Marek Tatara			
	Teachers		dr inż. Marek Tatara			

Lesson types						
Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	15.0	0.0	15.0	0.0	0.0	30
E-learning hours included: 0.0						

Learning activity and number of study hours				
Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	30	3.0	42.0	75

Subject objectives	Acquire knowledge of three-dimensional data acquisition techniques and processing algorithms, combined with developing the practical skills to design and implement integrated vision systems for mobile robots and manipulators.

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[K6_U08] while identifying and formulating specifications of engineering tasks related to the field of study and solving these tasks, can:n- apply analytical, simulation and experimental methods,n- notice their systemic and non-technical aspects,n- make a preliminary economic assessment of suggested solutions and engineering work n	The student can identify and formulate an engineering task that requires 3D perception, select appropriate methods and tools (sensors, algorithms), and then experimentally verify the proposed solution.	[SU4] Assessment of ability to use methods and tools [SU3] Assessment of ability to use knowledge gained from the subject [SU1] Assessment of task fulfilment
	[K6_W03] knows and understands, to an advanced extent, the construction and operating principles of components and systems related to the field of study, including theories, methods and complex relationships between them and selected specific issues - appropriate for the curriculum	The student knows and understands the principles of operation and limitations of key 3D sensors (e.g., stereo cameras, LiDAR). They understand the fundamental mathematical and algorithmic methods (e.g., epipolar geometry, ICP) used for processing 3D data and can explain the complex relationships within a robot's entire perception system.	[SW1] Assessment of factual knowledge
	[K6_U12] can analyze the operation of components, circuits and systems related to the field of study, as well as measure their parameters and examine technical specifications, and plan and conduct experiments related to the field of study, including computer simulations and measurements, and interpret obtained results and draw conclusions	The student can plan and conduct experiments to investigate the characteristics of 3D vision system components (e.g., calibration accuracy, point cloud registration error). They can analyze and interpret the obtained results and formulate conclusions about the performance and limitations of the tested methods.	[SU5] Assessment of ability to present the results of task [SU2] Assessment of ability to analyse information
	[K6_W01] knows and understands, to an advanced extent, mathematics necessary to formulate and solve simple issues related to the field of study	The student knows and understands advanced mathematical methods, including linear algebra and geometry, necessary for describing spatial transformations, camera modeling, and 3D reconstruction algorithms. They can use this knowledge to formulate problems in the field of machine vision.	[SW1] Assessment of factual knowledge

Subject contents	Course content – lecture **Lecture** 1. Comparison of 2D Imaging with 3D Vision • Limitations of 2D vision and the role of 3D vision in robotics • Camera models, parameters, and distortions 2. Mathematical Foundations of 3D Description • 3D space transformations • Homogeneous coordinates and rotations • Transitions between coordinate systems 3. Passive Stereovision • Epipolar plane and epipoles • Matrix representation • Triangulation and rectification 4. Active Data Acquisition • Structured light • Time-of-Flight • Laser scanners and LiDAR 5. 3D Data Representation and Basic Processing • 3D data structures: point clouds, voxels, meshes • Basic point cloud processing algorithms 6. 3D Data Registration and Matching • Point cloud matching • Introduction to SLAM 7. Machine Learning in 3D Vision • Machine learning tasks on 3D data • Network architectures for 3D data 8. Applications in Robotics and Vision System Calibration • Navigation and planning • Pose estimation • Camera and robot calibration **Laboratory** 1. Camera Calibration: determining intrinsic and extrinsic parameters 2. Stereovision and 3D Reconstruction: distance and dimension measurements 3. Acquisition and Registration of Point Clouds from LiDAR 4. Hand-Eye Calibration 5. Running SLAM on a Mobile Robot
Prerequisites and co-requisites	Knowledge of: • linear algebra, specifically operations on matrices and vectors • image processing • basic Python programming

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Final exam	60.0%	60.0%
Laboratory	60.0%	40.0%

Recommended reading

Basic literature	[1] Hartley, R., & Zisserman, A. (2003). *Multiple view geometry in computer vision (2nd ed.)*. Cambridge University Press. [2] Szeliski, R. (2022). *Computer vision: Algorithms and applications (2nd ed.)*. Springer. https://szeliski.org/Book/ [3] Corke, P. I. (2023). *Robotics, vision and control: Fundamental algorithms in Python (3rd ed.)*. Springer. https://doi.org/10.1007/978-3-031-07262-8
Supplementary literature	[1] Thrun, S., Burgard, W., & Fox, D. (2005). Probabilistic robotics. The MIT Press.
eResources addresses	

Example issues/ example questions/ tasks being completed	**Lecture** 1. Compare 2D and 3D vision in the context of robotics tasks. Discuss the limitations of 2D systems and indicate the new possibilities offered by 3D perception. 2. Discuss the concept of epipolar geometry. Name the key matrices and discuss their role in 3D reconstruction. 3. Compare active 3D data acquisition techniques: structured light, Time-of-Flight, and LiDAR. Discuss their principles of operation, advantages, disadvantages, and typical applications. **Laboratory** 1. Based on a series of images of a calibration board, determine the camera's intrinsic parameter matrix and distortion coefficients. 2. Implement a program to estimate the distance to and dimensions of an object based on a point cloud generated from a stereo camera. 3. For two point clouds acquired from a LiDAR, implement a procedure for their registration (matching) using the ICP algorithm.
Practical activites within the subject	Not applicable

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