COURSE DESCRIPTION CARD - SYLLABUS

Course name
Machine Perception [S2SI1E>PMA]

Course

Field of study
Artificial Intelligence

Year/Semester
1/1

Area of study (specialization)
–

Profile of study
general academic

Level of study
second-cycle

Course offered in
english

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
15

Laboratory classes
0

Other (e.g. online)
0

Tutorials
0

Projects/seminars
45

Number of credit points

4,00

Coordinators

prof. dr hab. inż. Piotr Skrzypczyński
piotr.skrzypczynski@put.poznan.pl

Lecturers

mgr inż. Kamil Młodzikowski
kamil.mlodzikowski@put.poznan.pl

prof. dr hab. inż. Piotr Skrzypczyński
piotr.skrzypczynski@put.poznan.pl

Damian Sójka
damian.sojka@doctorate.put.poznan.pl

Prerequisites

Knowledge: a student starting this course should have knowledge of mathematics, probability theory, and basics of machine learning and robotics. Skills: he/she should have the ability to implement algorithms and use selected programming frameworks. He/she should have the ability to obtain information from the indicated sources and cooperate as part of the team, since the course involves group projects.

Course objective

1. Familiarizing the students with the fundamentals and selected advanced topics of machine perception methods, algorithms and applications in the selected areas (robotics, self-driving cars, drones, factory automation, etc.), with emphasis on relations to artificial intelligence and machine learning. 2. Developing skills of implementing machine perception systems using advanced sensors (LiDARs, depth cameras, vision cameras, inertial sensors) and specialized frameworks for 2D and 3D data processing. The application areas covered include but are not limited to localization, simultaneous localization and mapping, scene reconstruction and understanding, semantic segmentation, object detection, object tracking. 3. Developing an ability of working as a team on a software project with data coming from physical sensors data by forming small teams for the projects during laboratories. 4. Upon completing the course, a student should be able to choose an AI algorithm or set of algorithms that make up the task of sensory data processing and implement and test such a system on his/her own.

Course-related learning outcomes

Knowledge Has advanced and in-depth knowledge of widely understood information systems, artificial intelligence systems, theoretical foundations of their construction and methods, tools and programming environments used to implement them [K2st_W1]
Has advanced detailed knowledge regarding selected topics in program synthesis, in particular different types of program specification, using logical reasoning to ensure program correctness and deduce the program satisfying the specification, and understanding how stochastic optimization and machine learning techniques can be used to solve or facilitate solving of the program synthesis problems [K2st_W3].
Has knowledge about development trends and the most important cutting edge achievements in computer science, artificial intelligence, machine perception, and robotics [K2st_W4].
Knows advanced methods, techniques and tools used to solve complex engineering tasks and conduct research in the field of machine perception applying artifical intelligence methods [K2st_W6].
Skills Is able to plan and carry out experiments, including computer measurements and simulations, interpret the obtained results and draw conclusions and formulate and verify hypotheses related to complex engineering problems and simple research problems in machine perception [K2st_U3].
Can use analytical, simulation and experimental methods to formulate and solve engineering problems and simple research problems in machine perception [K2st_U4].
Can - when formulating and solving engineering tasks - integrate knowledge from different areas of computer science (and if necessary also knowledge from other scientific disciplines) and apply a systemic approach, also taking into account non-technical aspects [K2st_U5].
Is able to assess the suitability and the possibility of using new achievements (methods and tools) and new IT products, in particular in the field of machine perception [K2st_U6].
Is able to assess the usefulness of methods and tools for solving an engineering task, consisting in the construction or evaluation of an IT system or its components, including the limitations of these methods and tools; [K2st_U9].
Is able - using among others conceptually new methods - to solve complex tasks involving design and implementation of machine perception systems, including atypical tasks and tasks containing a research component [K2st_U10].
Social competences The student understands that in computer science knowledge and skills very quickly become obsolete [K2st_K1].
The student understands the importance of using the latest knowledge in the field of computer science in solving research and practical problems. [K2st_K2].

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Formative assessment: a) lectures:
asking students questions pertaining to the material presented in previous lectures.
b) project:
assessment of the implementation of assigned tasks,
evaluation of progress in project implementation.
Summary assessment:
a) verification of assumed learning objectives related to lectures:
Evaluation of acquired knowledge in the form of a test on the Moodle platform. To get a passing grade, a student needs to get more than 50% of points from the test.
b) verification of assumed learning objectives related to project:

Evaluation of the implementation of assigned tasks (15 points to score).
Evaluation of the progress in implementing the project during the semester (5 points to score) and the presentation of the project (10 points to score). The grade depends on the total number of scored points. To get a passing grade, a student needs to get at least 50% of points from each part mentioned above.

Programme content

Lectures:
Introduction. Machine perception as the area of AI and ML applications. Recent progress and current challenges. Machine perception in robotics. Autonomous driving. Other practical applications of machine perception. Sensors: classification and definitions, a brief overview of technologies and solutions.
Three-dimensional computer vision. Image formation and image nodels. Projective geometry. Modeling cameras, projection matrix, camera distortions and artifacts. Camera calibration (intrinsic, extrinsic), The geometry of multiple views. Stereo vision, epipolar constraints, disparity, correspondence. Sparse and dense stereo in applications.
Range and depth sensing. Laser range sensors (LiDAR). Depth cameras: structured light, time-of-flight. Image formation, calibration, artifacts. Scene representations: depth images and point clouds. Processing of point clouds: Point Cloud Library, Iterative Closest Points as registration algorithm. Point clouds in machine learning, PointNet/PointNet++, voxel representations.
Scene analysis and understanding. Detection of low and high-level features, semantic segmentation, detection of objects in context, deep learning for object detection and segmentation, segmentation of 3D scenes.
Localization and SLAM. SLAM frameworks revisited, visual odometry with classic and deep learning methods, Structure of a modern visual SLAM system. End-to-end learning for localization and SLAM. Place recognition and topological SLAM.
Multi-sensor systems. The role of multi-sensor systems in machine perception and robotics: the visual-inertial odometry example. Calibration in multi-sensor systems. Factor graph as a tool for integration of multi-sensory data. Applications of multi-sensor systems.
Project:
The project classes (15 x 3 hours) take place in robotics laboratories and are divided into two types: 1. Exercises related to the material covered during lectures (5 x 3 hours) – students will implement selected methods and techniques of sensory data processing according to instructions using dedicated frameworks. They will also learn to use selected physical sensors in the context of collecting data for AI and machine learning tasks.
2. Implementation of smal-scale projects (10 x 3 hours) – students will form project groups (2 or 3 persons) and they will select a project topic from a list provided by the teacher. During the class they will work on the selected projects and consult the progress and encountered issues with the teacher. In the final project class the students will present results of their project.

Teaching methods

Lectures: multimedia presentations.
Projects: practical exercises, problem solving, discussion, teamwork, consultations, presentation of project outcomes.

Bibliography

Basic 1. S. Thrun, D. Fox, W. Burgard, Probabilistic Robotics, MIT Press, Cambridge, 2005.
2. C. M. Bishop, Pattern Recognition and Machine Learning, Springer-Verlag Berlin, Heidelberg, 2006.
3. D. A. Forsyth, J. Ponce, Computer Vision: A Modern Approach, 2nd edition, Pearson, 2011.
4. R. Hartley, A. Zisserman, Multiple View Geometry in Computer Vision. 2nd edition, Cambridge University Press, 2004.
5. S. Ranjan , S. Senthamilarasu, Applied Deep Learning and Computer Vision for Self-Driving Cars, Packt, 2020.
Additional Selected scientific papers related to the course.

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,00
Classes requiring direct contact with the teacher	60	2,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	40	1,50