(1.) Course Title: INFPHD182 Artificial techniques in robotics	**Credits: 6**
Course **Classification: Optional**	
Theoretical or Practical Nature of the Course, *'training character'*[13]: 50-50 (credit%)	
Type of Class: lecture and **number of hours**: **2/week** in the given semester, *(If the course is not (only) taught in Hungarian, then **the language**: **English**)* **Additional** (specific**) methods and characteristics**[2] used in delivering the knowledge *(if any)*: independent material processing, consultation, presentation, discussion, practical testing	
Assessment Method (Exam / Midterm Grade / **Other**[3]): midterm reports **Additional** (specific) **methods**[4] applied in knowledge assessment *(if any)*: case studies, topic elaborations	
Course Placement in Curriculum (Semester Number): -	
Prerequisites (*if any*): -	

Course Description: **A concise yet informative description of the knowledge** to be acquired.

Controlling mobile robots and autonomous vehicles in real-world environments remains a fundamental challenge. Many of these problems can be addressed using artificial intelligence techniques that combine model-based reasoning with data-driven learning.

The objective of this subject is to provide students with AI techniques and methods that help robots to localise themselves, to create a map of their environment, to cooperate with other robots, and to learn efficiently. The course covers both "classical" approaches (probabilistic robotics, SLAM, multi-agent systems, behaviour-based control) and more recent machine learning techniques (deep neural networks, deep reinforcement learning, generative models such as GANs, and large pre-trained models including LLMs) where there is solid empirical evidence of their usefulness in robotics.

The course **does not aim to cover all existing techniques, methods and models** in these areas. Instead, it focuses on a **selected subset** of methods that are both influential and practically relevant for robotics.

A key element of the course is that **students actively choose specific methods** of interest (e.g. a SLAM variant, a deep RL algorithm, a GAN-based approach for data augmentation, or an LLM-based planning or interaction method), **perform a structured literature review**, and then **present and critically discuss** their findings. Whenever feasible, students also **implement and demonstrate the selected methods** in realistic use cases, such as simulated or real robotic platforms, benchmark datasets, or reproducible experiments.

Special emphasis is placed on:

- understanding the assumptions and limitations of each method,
- using AI techniques in a safety-aware way in physical robotic systems, and
- verification, robustness and reproducibility of robot behaviour.

Draft syllabus

- **Overview of AI techniques in robotics**: levels of autonomy, typical AI pipelines; scope of the course and rationale for focusing on a **selected subset** of techniques rather than exhaustive coverage.
- **Probabilistic robotics foundations**: state estimation, Bayes filters, Kalman and particle filters, occupancy grids.
- **Navigation, mapping and SLAM**: graph-based SLAM, pose-graph optimisation, loop-closure detection, scalable mapping approaches.
- **Perception for mobile robots**: feature extraction, visual odometry, deep learning for perception (CNNs for detection/segmentation) and their practical constraints.
- **Learning for decision making and control**: reinforcement learning basics, deep reinforcement learning for navigation and control, sample efficiency, sim-to-real transfer issues.
- **Multi-robot and swarm systems**: coordination, task allocation, consensus, communication constraints; selected case studies.
- **Generative and large models in robotics**: VAEs and GANs for data augmentation, simulation and predictive modelling; visual–language models and LLM-based approaches for planning and human–robot interaction; emphasis on **well-validated, documented use cases and known limitations**.
- **Verification, safety and evaluation**: formal verification concepts, model checking, runtime monitoring, safety constraints, robustness to uncertainty, reproducible benchmarks.
- **Student projects and seminars**: students **select specific methods** (from the above topics), perform a **structured literature review**, and prepare **seminar presentations**. Whenever feasible, they **implement and demonstrate the chosen methods** on realistic use cases (simulated or real robots, benchmark datasets), and critically evaluate results.

2-5 Most Important Required and Recommended Literature

List of required and recommended literature (notes, textbooks) with bibliographic data (author, title, publication details, (possibly pages), ISBN).

Main literature

- **Russell, S.; Norvig, P. (2021).**
  Artificial Intelligence: A Modern Approach, 4th ed. Pearson.
  AIMA site: `https://aima.cs.berkeley.edu`
- **Sutton, R. S.; Barto, A. G. (2018).**
  Reinforcement Learning: An Introduction, 2nd ed. MIT Press.
  MIT Press: `https://mitpress.mit.edu/9780262039246/reinforcement-learning/`
  Author site: `https://incompleteideas.net/book/the-book-2nd.html`
- **Goodfellow, I.; Bengio, Y.; Courville, A. (2016).**
  Deep Learning. MIT Press.
  HTML book: `https://www.deeplearningbook.org`
  MIT Press: `https://mitpress.mit.edu/9780262035613/deep-learning/`
- **Károly, A. I.; Galambos, P.; Kuti, J.; Rudas, I. J. (2021).**
  Deep Learning in Robotics: Survey on Model Structures and Training Strategies.
  IEEE Trans. on Systems, Man, and Cybernetics: Systems, 51(1), 266–279.
  DOI: `https://doi.org/10.1109/TSMC.2020.3018325`
- **Zeng, F.; Gan, W.; Wang, Y.; Liu, N.; Yu, P. S. (2023).**
  Large Language Models for Robotics: A Survey. arXiv:2311.07226.
  arXiv: `https://arxiv.org/abs/2311.07226`

Recommended literature

- **Leonard, J. J.; Durrant-Whyte, H. F. (1991).**
  Simultaneous map building and localization for an autonomous mobile robot. IROS '91.
  DOI: https://doi.org/10.1109/IROS.1991.174711
- **Montemerlo, M. (2003).**
  FastSLAM: A Factored Solution to the Simultaneous Localization and Mapping Problem with Unknown Data Association. PhD thesis, CMU RI.
  CMU RI: https://ri.cmu.edu/publications/fastslam-a-factored-solution-to-the-simultaneous-localization-and-mapping-problem-with-unknown-data-association/
- **Bosse, M.; Newman, P.; Leonard, J.; Soika, M.; Feiten, W.; Teller, S. (2003).**
  An Atlas framework for scalable mapping. ICRA 2003.
  DBLP: https://dblp.org/rec/conf/icra/BosseNLSFT03.html
- **Wooldridge, M. (2009).**
  An Introduction to MultiAgent Systems, 2nd ed. Wiley.
  Wiley: https://wiley.com/en-be/An+Introduction+to+MultiAgent+Systems%2C+2nd+Edition-p-9780470519462
- **Weiss, G. (ed.) (1999).**
  Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence. MIT Press.
  MIT Press: https://mitpress.mit.edu/9780262731317/multiagent-systems/
- **Parker, L. E.; Schneider, F. E.; Schultz, A. C. (eds.) (2005).**
  Multi-Robot Systems: From Swarms to Intelligent Automata, Volume III. Springer.
  Springer: https://link.springer.com/book/10.1007/1-4020-3389-3
- **Trianni, V.; Ampatzis, C.; Christensen, A. L.; Tuci, E.; Dorigo, M.; Nolfi, S. (2007).**
  From Solitary to Collective Behaviours: Decision Making and Cooperation. ECAL 2007.
  Springer: https://link.springer.com/chapter/10.1007/978-3-540-74913-4_58

List of Prescribed Professional Competencies and Competency Elements

(knowledge, skills, etc., KKK Section 8) that the course significantly contributes to developing (highlight the most important ones).

a) Knowledge

- Has a research-level understanding of the general and specific characteristics, major directions, and precisely developed boundaries of the subject area within the discipline, as well as the agreed and debated interrelations.
- Creatively comprehends the interrelations, theories, and conceptual frameworks and terminologies of the given field of study.1
- Possesses research methodology knowledge necessary for independent research in the given discipline/field.

[1] **Section 108**, Article 37 of the National Curriculum Act (Nftv.) 37. lesson: a session (lecture, seminar, exercise, consultation) requiring the personal involvement of the instructor to fulfil the academic requirements specified in the curriculum, the duration of which is at least forty-five minutes and not more than sixty minutes.

[2] e.g. case studies, role play, thematic presentations, etc.

[3] e.g. continuous debriefing, mid-year report

[4] e.g. request for case studies, thematic papers, essays, business, organisational plans, etc.

b) Skills

- Capable of creative analysis of the field, synthesizing comprehensive and specific interrelations with a new perspective, and conducting appropriate evaluative and critical activities.
- Able to apply and further develop the specialized learning and problem-solving methods of the field.
- Can creatively elaborate on the novel, previously unknown practical implications of theoretical issues.
- Capable of planning and executing new projects, conducting research in the field, and developing new techniques and approaches.
- Able to identify unforeseen professional problems and uncover the detailed theoretical and practical background necessary for their resolution at a research level.
- Can construct and communicate new relations relevant to the field, as well as comprehensive interrelations significant for personal and communal existence.

c) Attitudes

- Represents and further develops the relations that contribute to the process of human self-creation based on the field's characteristics.
- Possesses an interest and learning ability that enable identifying and solving currently unpredictable research problems in the field.
- Demonstrates a firm professional commitment, a continuous dedication to exploring new approaches, and an acceptance of the necessity for persistent effort.

d) Autonomy and Responsibility

- Builds and initiates new knowledge areas with creative independence and proposes new practical solutions.
- Participates in formulating theoretical and practical questions with a leadership role and high-level cooperation.
- Engages as an equal discussion partner with professionals in the field.
- Takes responsibility for raising and addressing new ethical questions concerning theoretical and practical aspects of the profession.

Course responsible (name, position, academic degree): **Dr. Zoltán Istenes, Associate Professor, PhD**

Instructor(s) involved in teaching the course (if any) (name, position, academic degree):
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