Tárgyleírás angol nyelvű képzés tárgya esetén

Tárgy neve: Intelligent Mobile Robots (Intelligens Mobil Robotok)
Tárgyfelelős neve: Dr. Istenes Zoltán
Tárgyfelelős tudományos fokozata: PhD
Tárgyfelelős MAB szerinti akkreditációs státusza: AT

Az oktatás célja angolul / Aim of the subject:

Course Description

This course provides an in-depth understanding of intelligent mobile robots, covering topics such as control systems, robot motion, sensing, mapping, navigation, localization, and estimation. The course combines theoretical foundations with practical applications, ensuring students gain a comprehensive skill set in robotics.

Knowledge

- To provide foundational knowledge in the control, modeling, estimation, and implementation of intelligent mobile robots.
- Students will learn essential concepts in robot kinematics and dynamics, including both linear and nonlinear models.
- The course covers key topics such as PID control, state-space models, model predictive control (MPC), SLAM (Simultaneous Localization and Mapping), sensor fusion, and advanced perception algorithms.
- This foundational knowledge prepares students to tackle complex robotic systems and their applications.

Abilities:

- Equip students with the skills to design and implement feedback, adaptive, and optimal control systems; model and simulate robotic systems using various approaches; estimate system states using advanced filters.
- Students will develop proficiency in modeling and simulating robotic systems using tools like MATLAB, ROS, and Gazebo.
- They will gain hands-on experience in designing control algorithms, including feedback and feedforward control, adaptive control, and optimal control systems.
- The course will also train students in state estimation techniques such as Kalman filtering and particle filtering.
- These abilities will enable students to build and control sophisticated robotic systems effectively.

Attitude:

- Foster a proactive and innovative approach towards solving complex robotic problems.
- The course encourages curiosity and continuous learning, promoting an innovative mindset for tackling robotic challenges.

- Students will engage in creative problem-solving and experimentation with new technologies and methodologies.
- Emphasis will be placed on collaboration and teamwork, as students work together on projects and group activities.
- This attitude aims to develop not just technical skills, but also a resilient and forward-thinking approach to robotics.

Autonomy, responsibility:

- Encourage students to develop independent projects that apply theoretical concepts to practical scenarios in robotics.
- Students will undertake independent research projects, applying theoretical knowledge to real-world problems and developing practical solutions.
- The course emphasizes the importance of responsibility and professionalism in the development and deployment of robotic systems.
- Students will be encouraged to utilize online resources, engage in self-learning, and adapt to new tools and technologies.
- This approach fosters autonomy, critical thinking, and a sense of accountability in their work.

Az oktatás tartalma angolul / Major topics:

1. Introduction to Intelligent Mobile Robots

- **History and Evolution**: Overview of the development of mobile robots.
- **Definitions and Classifications**: Types of mobile robots and their applications.
- **Autonomous Systems Overview**: Evolution from teleoperated to autonomous robots.

2. Robot Motion

- **Kinematics and Dynamics**: Understanding how robots move, including forward and inverse kinematics.
- **Linear and Nonlinear Models**: Modeling the motion of robots accurately.

3. Control Systems

- **Feedback and Feedforward Control**: Maintaining desired performance using real-time and predictive adjustments.
- **PID Control**: Proportional, Integral, and Derivative control strategies.
- **Advanced Control Strategies**: Robust, adaptive, optimal, and model predictive control (MPC).
- **State Feedback and LQR**: Using state vectors for feedback and optimizing control performance.
- **Nonlinear Control and Gain Scheduling**: Handling complex and varying conditions.
- **Control Strategies for Autonomous Systems**: Adaptive and learning-based control methods.

4. Sensing

- **Types of Sensors**: LiDAR, cameras, IMUs, sonar, and more.
- **Sensor Fusion**: Combining data from multiple sensors for improved accuracy.
- **Perception Algorithms**: Techniques for processing sensor data, including image processing and object recognition.

- **Sensing for Autonomous Discovery**: Role of sensing in exploring and understanding environments.

5. Mapping

- **SLAM (Simultaneous Localization and Mapping)**: Building and using maps in real-time.
- **Environmental Mapping**: Techniques for creating accurate maps of the robot's surroundings.
- **Autonomous Discovery**: Techniques for autonomous exploration and mapping of unknown environments.
- **Dynamic Environment Mapping**: Real-time updates and handling dynamic obstacles.

6. Navigation

- **Path Planning**: Algorithms for determining optimal routes.
- **Obstacle Avoidance**: Ensuring safe navigation in dynamic environments.
- **Behavior-Based Navigation**: Reactive navigation strategies.
- **Task Execution and Planning**:
    - **High-Level Task Planning**: Methods for planning complex tasks and missions.
    - **Hierarchical Planning**: Combining high-level task planning with low-level motion planning.
    - **Execution Monitoring**: Techniques for monitoring and adjusting plans during execution.

7. Localization

- **Position Estimation**: Techniques for accurately determining the robot’s location.
- **Localization Algorithms**: Methods such as Kalman filtering and particle filtering.

8. Estimation

- **Kalman Filtering and Particle Filtering**: Improving state estimation accuracy.
- **Probabilistic Methods**: Handling uncertainties in perception and control.
- **Autonomous Systems Estimation**: Real-time state estimation for autonomous systems.

9. Other Topics

- **Machine Learning and AI in Robotics**: Autonomous decision-making and learning from interactions. Advanced perception and control tasks.
- **Multi-Robot Systems**: Coordination and control, swarm robotics.
- **Human-Robot Interaction**
- **Ethics, Safety, and Social Considerations**
- **Practical Applications and Case Studies**

A számonkérés és értékelés rendszere angolul / Requirements and evaluation:

XPG – Lecture + Practice with practical grade

1. **Continuous and Regular Assessment of the Lectures:** Short tests to assess understanding of theoretical notions. Multiple-choice questions, short answers, problem-solving exercises, homeworks.
2. **Practical Exercises:** Hands-on exercises to apply theoretical knowledge in practical scenarios. Implementing algorithms, programming tasks, simulation projects using tools.
3. **Course Participation:** Active involvement in discussions and group activities during lectures and labs. Contributions to discussions, engagement in collaborative tasks.

Weights of the evaluation components:

1. **Continuous and Regular Assessment of the Lectures**: 40%
2. **Practical Assignments**: 40%
3. **Class Participation**: 20%

Ajánlott irodalom / Recommended literature:

- Siegwart, R., Nourbakhsh, I. R., & Scaramuzza, D. (2011). *Introduction to Autonomous Mobile Robots*. MIT Press. Available at: https://mitpress.mit.edu/9780262015356/introduction-to-autonomous-mobile-robots/

- Spong, M. W., Hutchinson, S., & Vidyasagar, M. (2006). *Robot Modeling and Control*. Wiley. Available at: https://www.wiley.com/en-us/Robot+Modeling+and+Control%2C+2nd+Edition-p-9781119524045

- Thrun, S., Burgard, W., & Fox, D. (2005). *Probabilistic Robotics*. MIT Press. Available at: https://mitpress.mit.edu/9780262201629/probabilistic-robotics/

- LaValle, S. M. (2006). *Planning Algorithms*. Cambridge University Press. Available at: http://lavalle.pl/planning/

- Choset, H., Lynch, K. M., Hutchinson, S., Kantor, G., Burgard, W., Kavraki, L. E., & Thrun, S. (2005). *Principles of Robot Motion: Theory, Algorithms, and Implementations*. MIT Press. Available at: https://mitpress.mit.edu/9780262033275/principles-of-robot-motion/