Artificial Intelligence in Robotics

Module no. or code	8
Module name	Fundamentals of Mobile Robotics
(If applicable) the module's courses	
Module content	1. Introduction – Nomenclature, history, state of the art, module logistics 2. Linear Algebra and Probability Primer – Vectors and operations, matrices and operations, axioms of probability, independent events, Bayes rule 3. Bayes Filter – Recursive Bayesian updating, state transitions, Markov property, derivation 4. Probabilistic Modeling – Odometry- and velocity-based motion models, beam- and scan- based sensor models 5. Localisation with Nonparametric Filters – Discrete Bayes filter, importance sampling, particle filter 6. Localisation with Gaussian Filters – Kalman filter, Extended Kalman filter 7. Mapping with Known Poses – Occupancy maps, reflection probability maps 8. Landmark-based SLAM – SLAM problem, EKF SLAM, loop closing, Rao-Blackwellization, FastSLAM 9. Grid-based SLAM – Scan matching, FastSLAM, improved proposals, selective resampling 10. Motion and Path Planning – Configuration space, combinatorial planning, graph-based search, collision avoidance 11. Markov Decision Processes – MDP definition, utility, value iteration, policy iteration 12. Reinforcement Learning – Temporal-difference learning, exploration vs exploitation, Q- learning, policy search

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<tr><td>Module’s learning outcomes</td><td>By the end of the module students should be able to:

- Apply the Bayes (filter) formula and sample from probability density functions
- Determine and apply probabilistic sensor and motion models
- Discuss the steps and components of realizations of Bayes filters
- Implement realizations of Bayes filters and compute location estimates for robots
- Build and analyze grid maps
- Differentiate between localisation and SLAM systems as well as outline auxiliary techniques for SLAM solutions
- Assess and implement components of landmark- and grid-based solutions to the SLAM problem
- Differentiate between different path planning techniques and discuss the steps of collision avoidance solutions
- Apply and implement graph-search techniques for path planning
- Assess the Markov Decision Process definition as well as the concepts of Utility and Policy
- Apply dynamic programming on Markov Decision Problems to compute of value functions and optimal policies
- Differentiate between different Reinforcement Learning techniques</td></tr>
<tr><td>Semester</td><td>2</td></tr>
<tr><td>Duration of module</td><td>One semester</td></tr>
<tr><td>Frequency</td><td>Winter term only</td></tr>
<tr><td>ECTS-Credits</td><td>5</td></tr>
<tr><td>Workload</td><td><table><tr><td>Workload (Total)</td><td>Attendance time</td><td>Self-Study time (incl. exam preparation)</td></tr><tr><td>150</td><td>60</td><td>90</td></tr></table></td></tr>
<tr><td>Type of module</td><td>Compulsory</td></tr>
<tr><td>Applicability of module</td><td></td></tr>
<tr><td>Conditions for participation</td><td>none</td></tr>
<tr><td>Responsible for module</td><td>Prof. Dr.-Ing. Pascal Meißner</td></tr>
<tr><td>Lecturer</td><td>Prof. Dr.-Ing. Pascal Meißner</td></tr>
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Language of instruction, L. of examination	English
Type of examination; Conditions for the award of CPs	SoP (G) Portfolio
Teaching and learning formats of the module	Seminar-based teaching
Literature	- Probabilistic Robotics, Sebastian Thrun and Wolfram Burgard and Dieter Fox, MIT Press, 978-0262201629, 2005 - Artificial Intelligence: A Modern Approach, Stuart Russell and Peter Norvig, 4th ed. Prentice Hall, 978- 0136042594, 2021