03-IMVP-AIR	Athletic Intelligence in Robotics

Lehrform *(teaching format)* / **SWS** *(hours per week)*: 2VL + 2UE

Kreditpunkte *(credit points)*: 6

Turnus *(frequency)*: i.d.R. angeboten in jedem WiSe

Inhaltliche Voraussetzungen *(content-related prior knowledge/skills)*: It is preferable, but not essential, to have a good understanding of mechanics, control theory, linear algebra, advanced calculus, numerical methods and programming.

Sprache *(language)*: English

Lehrende *(teaching staff)*: AG Robotik (Prof. Dr. Frank Kirchner, Dr. Dennis Mronga)

Studiengang *(degree program)*	Module	Semester
Informatik (Master)	IMVP, IMVP-AI	ab 1. Sem.
Systems Engineering I/II (Master)	M07-VT-AuR	ab 1. Sem.
AI and Intelligent Systems (Master)	AI-M-CER	ab 2. Sem.
Elektro- und Informationstechnik (Master)	Vertiegung Automatisierungstechnik	ab 1. Sem.

Lernergebnisse / *Learning Outcome*:

At the end of the course, the student is expected to be able to:

- Have a basic understanding about athletic intelligence in robotics.
- Model underactuated robots as dynamical systems.
- Understand the basics of dynamic programming.
- Apply optimal control methods for robot motion planning.
- Perform hybrid robot planning (planning with contacts).
- Implement trajectory stabilization and control methods.
- Analyze the stability of underactuated robots.
- Have a basic understanding in system identification and state estimation.
- Apply basic reinforcement learning methods for robot motion planning, control and design optimization.
- Assess the strengths and limitations of different control methods presented in the course.
- Identify open challenges in robotics research and current trends in state-of-the-art.
- Communicate confidently using the terminology in the field of robotics.
- Cooperate and work in teams in order to solve tasks.

Inhalte / *Contents*:

Traditional robots (such as the ones used in factories) have a fixed base and perform repetitive tasks in well-known environments, such as pick-and-place, assembly or welding. Moderns robots today, such quadrupeds or humanoids, are not bound to a fixed location, but can move around in a largely unknown environment. Like humans and animals, these robots are capable of performing highly dynamic movements like walking, running, jumping, or even performing a back-flip. These systems are underactuated in essence, which means that we do not have the full control authority over them. Therefore, we need to understand their dynamics and the way they make and break contact with the environment in order to maximize their performance.

This course teaches the fundamentals to achieve athletic intelligence in robotics, that is the skills required to make these robots move in the real world with a similar grace and agility as humans and animals. It starts with modeling underactuated robots, as well as understanding their kinematics and dynamics. After that, the course will dive into behavior generation and control for these systems, including modern control concepts like optimal control, reinforcement learning, as well as methods to analyse and improve their behavior. Students will put the gained knowledge into practice during tutorials and exercises using Python implementations and robot simulations, as well as experiments on real hardware.

- Introduction to Atheletic Intelligence
- Modeling underactuated robots
- Continuous dynamical systems
- Hybrid dynamical systems
- Motion Models
- Dynamic Programming
- Trajectory optimization
- Planning throught contacts
- Instantaneous trajectory stabilization
- Trajectory stabilization over a horizon
- Stability Analysis
- System identification and state estimation
- Reinforcement learning

Hinweise *(remarks)*: The table lists only the primary / most specific modules to which this course is assigned.