Syllabus Introduction to Robotics – 5 CP (ECTS)
Counts as an elective for Computer Science students
Instructor: Prof. Dr. Thomas Horsch
Department: Computer Science
Office location: D14 / 208
Office hours: TBD
Phone: +49 6151 16 38457
Email: thomas.horsch@h-da.de
Homepage: https://fbi.h-da.de/personen/horsch-thomas

Teaching assistant: TBD

Recommended Textbook:
Kevin M. Lynch, Frank C. Park: Modern Robotics – Mechanics, Planning and Control (http://modernrobotics.org) available as PDF document.

Course description:
An introduction to the fundamentals of robotics. Students will learn the fundamentals of robotics, including kinematics, inverse kinematics, Jacobian, configuration space, motion planning and path planning algorithms.

The course consist of a lecture (90 minutes per week) and a lab (90 minutes per week).
For the lab the simulation system CoppeliaSim from Coppelia Robotics https://www.coppeliarobotics.com/ is used, which is free for educational use.
The programming is implemented in Python or C++.

Objectives:
At the completion of the course, students will know how to:
- Model the kinematics of robotic systems
- Compute end-effector position and orientation from joint angles of a robotic system
- Compute the joint angles of a robotic system to reach the desired end-effector position and orientation
- Compute the linear and angular velocities of the end-effector of a robotic system from the joint angle velocities
- Convert a robot's workspace to its configuration space and represent obstacles in the configuration space
- Compute valid path in a configuration space with motion planning algorithms
- Apply the generated motion path to the robotic system to generate a proper motion trajectory
- Apply the learned knowledge to several robotic systems including robotic manipulators, mobile systems

Achievement of the above objectives will be measured by a student's ability to:
- Solve questions in assignments and exams on the kinematics of robotic systems
- Write programs and provide solutions to answer questions in assignments and exams to compute end-effector position and orientation from joint angles of a robotic system

- Write programs and provide solutions to answer questions in assignments and exams to compute the joint angles of a robotic system to reach the desired end-effector position and orientation
- Write programs and provide solutions to answer questions in assignments and exams to compute the linear and angular velocities of the end-effector of a robotic system from the joint angle velocities
- Solve questions in assignments and exams on converting a robot's workspace to its configuration space and represent obstacles in the configuration space
- Write programs and provide solutions to answer questions in assignments and exams to compute valid path in a configuration space
- Write programs and provide solutions to answer questions in assignments and exams to generate motion path to the robotic system to generate a proper motion trajectory
- Apply the knowledge to robotic simulation systems in labs

Pre-requisites: Programming, Data Structures and Linear Systems (Algebra).

Course Topics: (at BBU in block format from 28th Sept. to 8th October 2021, 9 days)

Unit	Lecture (90 min) in the morning	Lab (90 min) in the afternoon	Block format at BBU
1	Basics of Robotics and Linear Algebra	CoppeliaSim tutorial part 1	Day 1 / Day 1
2	Representing positions and rotations	CoppeliaSim tutorial part 2	Day 1 / Day 1
3	Rotational transformations and parameterizations of rotations	Interpolating rotational motion	Day 2 / Day 2
4	Homogeneous transformations, kinematic chains	Implementing homogeneous transformations, kinematic chains	Day 2 / Day 3
5	Forward kinematics	Implementing forward kinematics	Day 3 / Day 3
6	Inverse kinematics	Implementing inverse kinematics	Day 4 / Day 4
7	Jacobian	Implementing inverse kinematics via jacobian part 1	Day 4 / Day 5
8	Mid-term self-assessment	Implementing inverse kinematics via jacobian part 2	Day 5 / Day 5
9	Trajectory design, Splines	Measuring coordinate systems	Day 6 / Day 6
10	Configuration space with examples and motion planning introduction	Calibration of a robot tool	Day 6 / Day 7
11	Motion planning: bug algorithms	Calculating configuration space for a simple robot part 1	Day 7 / Day 7
12	Motion planning: potential field and visibility graph	Motion planning with calculated configuration space	Day 8 / Day 8

13	Motion planning: RRT, PRM	Motion planning with potential field	Day 8 / Day 9
14	Mobile robot, sensors and actuators	Motion planning with RRT or PRM	Day 9 / Day 9
15	Exam (?)		(?)