SPECIAL TOPICS COURSE LISTINGS FOR ACADEMIC YEAR 2024-2025

Deep Learning for Perception (2.0 cr.) — 2024 Fall A Term

This course exposes the students to the mathematical foundations of deep learning applied to images. Perception stacks in state-of-the-art robots are rapidly adapting the latest advancements in deep learning due to their efficacy and high accuracy. These deep learning-based methods are also accelerable using parallelized hardware such as GPUs that can enable low latency operations of complex tasks such as real-time scene segmentation. The students will be trained in formulation, development and implementation of deep learning solutions for common computer vision problems in the context of robot perception. The course will cover advanced and state-of-the-art topics such as sim2real, adversarial attacks on neural networks, vision transformers and diffusion models. Additional topics explored in this course include image formation, linear classifiers, neural networks and backpropagation, Convolutional Neural Networks (CNNs), CNN architectures, data generation for sim2real, black- and white-box attacks on neural networks as applied to build state-of-the-art robotic stack. Students will gain knowledge about the considerations required to enable a robotic system with the state-of-the-art deep learning toolkit. The course is designed to balance theory with applications through projects.

Recommended Background: Proficiency in programming, preferably Python, MA 1024, MA 2071/20772, MA 2621/2631

Robots for Recycling (2.0 cr.) — 2024 Fall B Term

Dive into the cutting edge of robotics and AI technologies to tackle the global waste crisis. This course builds on foundational robotics knowledge to address real-world challenges in sustainable waste management. It provides an opportunity to learn about robotic manipulation and robot vision systems and apply this knowledge for developing waste recycling systems using physical robotic platforms. Specifically, the course will cover computer vision algorithms for developing waste classification methods, robotic grasping and non-prehensile manipulation algorithms for developing waste picking and rearrangement systems, design of various picking mechanisms, and implementation of an end-to-end object picking pipeline. The course includes a term project module on developing prototypes of waste sorting systems.

Pre-requisite: RBE 500
Recommended Background: RBE 549, RBE 4540, CS 541

Socially Assistive Robotics (2.0 cr.) — 2024 Fall B Term

Explore the forefront of robotics and AI technologies designed to enhance human well-being and our society through social interaction rather than physical action. This course covers foundational, interdisciplinary robotics knowledge to address real-world challenges in healthcare, education, and other domains. It introduces the developmental lifecycle for socially intelligent robotics, including design, development, and evaluation. Specifically, the course will cover: 1) Multimodal human-robot interaction, encompassing multimodal sensing and perception, decision-making, and feedback mechanisms; 2) Human-centered AI and embodied AI for personalization and adaptation; and 3) Frontier research applications in socially assistive contexts, such as aging care, dementia care, autism care, and education. The course is intended for students interested in the intersection of social robotics, human-centered computation, healthcare, biomedical engineering, human-computer interaction, and social science, as well as the research frontiers of SAR. Teaching methods include lectures, insights from invited expert speakers, and a term project module where students will design,

Recommended background: RBE/CS 526, RBE 549, RBE 595/4540, CS 541

Fundamentals of Artificial Intelligence and Robotics for Autonomous Vehicle Applications – Online (3.0 cr.) 2024 Fall Semester

Fundamentals of **A**rtificial **I**ntelligence and **R**obotics for **A**utonomous **V**ehicle Applications, short for **FAIR-AV**, is a course to introduce you to the interaction of AI, robotics and autonomous vehicles (AVs). The goal of the course is to introduce you to a variety of systems used to implement AVs. These systems and their associated technologies greatly impact how well-automated driving functions can perform in real-world scenarios. More specifically, they are enabling an AV to detect and predict obstacles/objects, plan its motion, and make intelligent decisions to achieve safe and pleasant driving for occupants inside the vehicle.

While FAIR-AV will discuss the applicability and challenges of AI and robotics used in wheeled vehicles, we will start with the motivation to bring human-like intelligence to ground vehicles which normally involves the shared control between human drivers and electronically controlled systems. The digital driver in the autonomous vehicle aims to replicate human intelligence, hence the need for artificial intelligence (AI). After those introductory discussions, the course will introduce to you the basics of automotive system functions and control systems, the necessary mechatronics components, the software modules, and the system engineering aspects. All those teachings will only touch the rudiment knowledge without deeply diving into individual topics on how those tasks are implemented, which will be taught in follow-up courses.

FAIR-AV will use open-sourced software packages and tools as supplementary material if you would like to dive into how various tasks are realized at the algorithm, coding, and software level. The lectures, handouts, homework assignments, and projects are designed to prepare you to grasp the essence of AV to help you to find your passion on individual topics you would like to pursue or to become a system engineer in the AV industrialization.

Prerequisite: RBE 500

Vision-based Robotic Manipulation (3.0 cr.) 2024 Fall Semester

This course focuses on the role of visual sensing in robotic manipulation. It covers fundamental manipulation concepts such as mathematical grasp formulations, grasp taxonomies, and grasp stability metrics. Various grasp planning strategies in the literature are studied. 2D and 3D vision-based control algorithms are covered. Point cloud processing techniques that allow object detection, segmentation, and feature extraction are studied and implemented. Students will integrate all of these aspects to design the whole vision-based robotic manipulation pipeline.

Recommended background: Knowledge of robot kinematics, wrench spaces, and rigid body transformations as presented in RBE 3001 or RBE 500. Familiarity with robotic simulation software as presented in RBE 3002 or RBE 500.

The course is cross-listed with RBE 4540 in A-term; graduate students will apply material from the course to projects in B-term.

Medical Imaging and Instrumentation (2.0 cr.) 2025 Spring C Term

This course focuses on the role of visual sensing in robotic manipulation. It covers fundamental manipulation concepts such as mathematical grasp formulations, grasp taxonomies, and grasp stability metrics. Various grasp planning strategies in the literature are studied. 2D and 3D vision-based control algorithms are covered. Point cloud processing techniques that allow object detection, segmentation, and feature extraction are studied and implemented. Students will integrate all of these aspects to design the whole vision-based robotic manipulation pipeline.

Recommended background: Knowledge of robot kinematics, wrench spaces, and rigid body transformations as presented in RBE 3001 or RBE 500. Familiarity with robotic simulation software as presented in RBE 3002 or RBE 500.

Advanced Robot Navigation - Online (3.0 cr.) 2025 Spring Semester

The Advanced Robot Navigation course delves into the sophisticated techniques and algorithms used by autonomous robots to navigate complex, real-world environments with precision and efficiency. Building upon fundamental concepts in robotics and navigation, this course equips students with advanced knowledge and practical skills necessary to develop cutting-edge navigation systems for autonomous robots operating in diverse scenarios. The curriculum begins with a review of foundational principles in robot path and motion planning including RRT*, techniques such as probabilistic methods, Simultaneous Localization and Mapping (SLAM), and multi-sensor fusion. Students will deepen their understanding of these concepts through hands-on exercises and simulations.

Prerequisite Courses: RBE 500 or equivalent.
Recommended Background: RBE 549

Reinforcement Learning - Online (3.0 cr.) 2025 Spring Semester

This course will provide a solid introduction to the field of Reinforcement Learning (RL). Students will learn about the core challenges and approaches including Markov decision processes, model based, model free RL, on-policy and off-policy learning, and approximate solution techniques. Through a combination of lectures and coding assignments, students will become well versed in key ideas and techniques in RL and its application in robotic systems. To get students familiarized with the state-of-the-art RL algorithms in robotics, research papers are provided, and students are required to give a presentation about the papers. In addition, an end of the term team project would allow the students to apply mastery of the subject to a real-world robotics application.

Prerequisites: A probability course is required, as well as proficiency in Python. RBE 500/Foundations of Robotics and basic knowledge of neural networks preferred, but not required.