RBE 595-C01 - ST: Medical Imaging and Instrumentation - Zhang

This course aims to introduce the physical principles behind modern medical imaging, including radiography, X-ray computed tomography, nuclear medicine, ultrasound imaging, and magnetic resonance imaging, and their adaptation for image-guided interventions. In robotics, vision and perception play a crucial role, but the optical camera provides only surface information, which limits its usefulness in medical robotics for surgical guidance and diagnosis. To perceive the structural and functional information inside the body, medical imaging is a critical component. Topics include mathematical and physical foundations of each modality, including their interactions with biological tissue. Additionally, the course will present advanced imaging solutions that combine with robotic instrumentation to enable robotic-assisted imaging and image-guided robotic interventions. In the team project, students will tackle real clinical challenges using novel imaging and instrumentation methods.

Recommended Background: Linear algebra, Basic skills in programming

RBE 595-D01 - ST: Safety and Guarantees for Autonomous Robots – Leahy

Robotic and AI systems have strong potential to directly impact our well-being, from self-driving cars to medical robots. Therefore, it is important to consider strong guarantees on the correctness and safety of their behavior. These guarantees ensure the robot will execute the desired behavior and will not execute undesired behavior. The course will define formal notions of system properties such as safety and liveness, explain how to model and analyze those properties in systems that make decisions and act on them, and understand the specific challenges related to making guarantees on embodied AI systems. This course will cover many topics related to formal guarantees of safety and correctness in robotic and AI systems, including temporal logic-based planning, safe control via invariants and control barrier functions, neural net verification, closed-loop control with machine learning components, safe reinforcement learning, and other state-of-the-art topics at the intersection of safety, guarantees, AI, and robotics.

Prerequisites: RBE 500

Recommended Background: Machine Learning or Intro to AI

RBE 595-S01 - ST: Advanced Robot Navigation

In recent years, robots have become part of our everyday lives. Leaving the research labs to be part of the common tools of a household, tools such as robotic vacuum cleaners (iRobot Roomba, Kalorik), pool cleaners (Polaris, Maytronics), Lawn mowers (Landroid, LawnBott) and more abound. For navigating safely, these robots need the ability to localize themselves autonomously using their onboard sensors. Potential applications of such systems include the automatic 3D reconstruction, 3D reconstruction of buildings, inspection and simple maintenance tasks, metric exploitation, surveillance of public places as well as in search and rescue systems. In this course, we will dive deep into the current techniques for 3D localization, mapping and navigation that are suitable for robotic applications.

Required prerequisites: RBE 501, RBE 502

RBE 595-S02 - ST: Swarm Intelligence – Pinciroli

This course will cover a wide range of topics in swarm intelligence, including mathematical, computational, and biological aspects. The course is organized in four parts. In the first part, the students will learn about complex systems and the basic concepts of self-organization, such as positive and negative feedback, symmetry breaking, and emergence. The second part concerns several types of network models, such as information cascades, epidemics and voting. The instructor will illustrate a diverse collection of self-organized systems in nature, finance, and technology that concretize these concepts. The third part is dedicated to swarm robotics, and will cover common swarm algorithms for task allocation, collective motion, and collective decision-making. The fourth and final part covers optimization algorithms inspired by swarm intelligence, namely ant colony optimization and particle swarm optimization. The course will blend theory and practice, challenging the students to learn by implementing the algorithms discussed in class through a final project in swarm robotics.

Prerequisites: C++/Python/Matlab programming; Linear algebra; Probability and statistics; Calculus.

RBE 595-S04 - ST: Reinforcement Learning - Tehrani

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.

WR 513 – Ethical Impact and Communication in Robotics and AI Research

Engineers and other technologists are increasingly more aware of the ethical, legal, and social impacts of robotics and artificial intelligence. Some of them actively contribute to the creation and communication of new sets of ethical standards, such as the work done by IEEE's Global Initiative on Ethics of Autonomous and Intelligent Systems. What are the ethical principles that underpin these new standards? Since robots and AI systems are designed to work with or alongside humans, do people have a right to understand what autonomous systems are doing and why? How can roboticists and AI designers ensure that these systems are transparent and explainable? This course focuses on the communication of ethical and social impacts of scientific research and technology development. After learning about major debates in robot/AI/data ethics, students will cultivate skills to (1) conceptualize ethical inquiries in technology design and (2) articulate them in writing and other forms of scholarly communication. As part of this course, students will learn to apply the National Science Foundation's (NSF) broader impacts framework to their writing projects (dissertation, thesis, journal publication, grant application, etc.).