Special Topics in Systems and Industrial Engineering SIE 496/596

Spring 2025

Robotic Systems

Syllabus

Course Instructor

Instructor: Prof. Fabio Curti, Department of Systems, and Industrial Engineering (SIE)
Room: ENGR 314
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Ph#: 520-621-3331
Office Hours: Fri 2:00 – 3:00 pm (tentative) or by Appointment
Co-instructors: Dr. Lorenzo Federici (email: lorenzof@arizona.edu)
Dr. Boris Benedikter (email: boris@arizona.edu)

Course Meetings

Mon-Wed-Fri, 1:00-1:50 pm, C E Chavez Building Room 305. The lectures will be videorecorded and posted on d2l.arizona.edu.

Course Objectives and Expected Learning Outcomes

The primary objective of this course is to introduce the fundamentals of robotic systems to senior undergraduate and graduate science and engineering students. The course spans the topics of robot mechanics, perception, planning, and control, including robot simulation testing based on the open-source suite ROS (Robot Operating System).

The course will cover the design and operation of terrestrial and aerial robotic systems such as robotic arms, robotic platforms, rovers, quadcopters. Overview of the underlying algorithms for the implementation of the tasks of a robot will be given for autonomous mission planning and execution.

By taking this course, the **undergraduate** and **graduate** students will possess the capability to:

(i) approach robotics with a system perspective.
(ii) have a solid understanding of the principles behind autonomous robotic systems.
(iii) analyze a robotic system using the state-of-the-art and related software tools.
(iv) identify specific applications of a robotic system.

In addition, the **graduate students** will possess the capability to:
(i) perform a preliminary design of a robotic system.
(ii) specify the requirements for an autonomous system performing a specified task.
(iii) critically evaluate choices of design and architecture.

Semester assignments and final project

The students are required to prepare a design workbook that will be updated with multiple assignments over the course of the semester. The final grade will be computed by evaluating a set of assignments that will be submitted during the semester plus a final report. All Assignments will be submitted to D2L before the due date and time. The project for the **undergraduate students** will be on the basic principles of a robotic system. The project for **graduate** students will concern the design of a robotic system.

Course Breakdown

Week(s)	Topics	Assignments
1-2	***Introduction to Robotic Systems*** ▪ Overview of Robotic Systems ▪ Position and Rotations in Robotics ▪ Dynamics and Stability and Control Design ▪ Lyapunov Stability	Assignment 1
2-4	***Arms-type Robot*** ▪ Direct Kinematics ▪ Inverse Differential Kinematics ▪ Jacobian & Inverse Kinematics ▪ Static Posture & Dynamics	Assignment 2
	▪ Posture Control ▪ Trajectory Tracking: Sliding Mode Control ▪ Contact Control	Assignment 3
5	***Parallel Robot*** ▪ Kinematics & Dynamics ▪ Examples: Stewart Platform, Flight Simulator, Delta Robot	Assignment 4
5-6	***Wheeled Robot*** ▪ Wheeled Robot Models (Bicycle/Unicycle) ▪ Nonlinear Motion Control ▪ Localization ▪ Extended Kalman Filter (EKF) for Localization ▪ Omni-Directional wheel Robot	Assignment 5
7	***Flying Robot*** ▪ Quadrotor systems ▪ Kinematics and Dynamics ▪ Backstepping Control	Assignment 6

8-9	***Path Planning*** ▪ Search Problems ▪ Optimal Search Algorithms ▪ A* Algorithm ▪ Heuristic Search Algorithms	Assignment 7
10-11	***Machine Learning for Robot Control*** ▪ Neural Networks & Supervised Learning ▪ Reinforcement Learning: MDP, Q-Learning ▪ Reinforcement Learning: Policy-Gradient, Actor-Critic ▪ Software Tools: TensorFlow, PyTorch, OpenAI Gym, Stable Baselines	Assignment 8
12-13	***Robot Operating System (ROS)*** ▪ The ROS Graph ▪ Packages ▪ Launch Files ▪ Robot Simulation ▪ Gazebo ▪ Examples ▪ Hands-on	
14-16	**Final Project** In the final project, students will implement ROS-based simulations combined with reinforcement learning techniques to simulate a lunar rover tasked with navigating an obstacle-laden terrain (e.g., rocks and craters), reaching a target location, collecting a sample, and returning to its starting point.	

Course Prerequisites

Advanced standing is required for **undergraduate** students. Please visit the webpage for more information on the advanced standing:
https://engineering.arizona.edu/academic-policies/advanced-standing.

For **graduate** students, knowledge of a programming language is required (e.g., MatLab, Python).

Introductory knowledge of linear algebra, differential equations and mechanics is recommended, but it is not required because the above topics will be reviewed in class.

Reading Materials

Lecture notes, provided and can be downloaded from D2L course website
Robot Operating System (ROS): http://wiki.ros.org/ROS/Tutorials
ROS2 tutorials: https://docs.ros.org/en/foxy/Tutorials.html

Recommended reference books:

- Peter Corke, *Robotics and Control*, Springer 2022, Springer Tracts in Advanced Robotics ISBN 978-3-030-79178-0
- Siciliano B., Sciavicco L., Villani L., Oriolo G., *Robotics: Modelling, Planning and Control*, Springer-Verlag 2010, ISBN 978-1-84628-641-4.
- S. Russel, P. Norvig, *Artificial Intelligence: A Modern Approach*, third edition Prentice Hall Series 2010, ISBN 978-0-13-604259-4.
- S. Sutton, A. G. Barto, *Reinforcement Learning: An Introduction*, second edition The MIT Press 2018, ISBN: 978-0-262-19398-6

Grading Scale and Grade Policy

The grading scheme will follow the distribution below. University policy regarding grades and grading systems is available at http://catalog.arizona.edu/policy/grades-and-grading-system

Points	Percentage	Letter Grade
90-100	90%-100%	**A**
80-89	80%-89%	**B**
70-79	70%-79%	**C**
60-69	60%-69%	**D**
<60	<60%	**E**

Course grades for **undergraduate** section will be determined based on the following criteria:
5 Assignments (max 16 points each): 80
Final project max 20 points: : 20

Course grades for **graduate** section will be determined based on the following criteria:
5 Assignments (max 14 points each): 70
Final project max 30 points: : 30

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal respectively.

Subject to Change Statement

The information contained in the course syllabus, may be subject to change, as deemed appropriate by the instructor, see http://policy.arizona.edu/faculty-affairs-and-academics/course-syllabus-policy-undergraduate-template.