COURSE SYLLABUS

EEL 4930: Autonomous Robots

Spring 2024

INSTRUCTOR:

Md Jahidul Islam
Email: jahid@ece.ufl.edu **OH**: Fridays 2:00 - 3.00 PM at Mala-5108

CLASS SCHEDULE

T 3:00 - 4:55 PM and **R** 4:05 - 4:55 PM at LAR 0330

TEACHING ASSISTANT:

Adnan Abdullah
Email: adnanabdullah@ufl.edu **OH**: Monday 3:00 - 4:00 PM at PST-206.

COURSE DESCRIPTION

The design, implementation, and operation of autonomous robots, both mobile and stationary. The core computational building blocks of standard robotics systems: perception, planning, and control will be covered. In addition to giving a broader overview of the underlying algorithms, this course includes hands-on practices for the implementation of relevant sensing and estimation pipelines, enabling features for environmental awareness, autonomous mission planning, and execution. (Credits: 3)

COURSE PREREQUISITES

⇒ **At-least one of:** EEL 4744C: Microprocessor Applications or EEL4712C: Digital Design
⇒ Fluent in object-oriented programming (Python and/or C++); basics of linear algebra and calculus

COURSE OBJECTIVES

The primary objective of this course is to learn theoretical and experimental fundamentals involved in the design and operation of autonomous robots and/or intelligent agents. The introductory discussions span over the subtopics of robot perception, planning, and control. Other major topics include robot part design, sensory integration, motion kinematics, simulation testing (ROS/ROS2), unmodeled environmental/social factors, and aspects of field deployment. In addition to the standard terrestrial robotic systems, we will cover analogous topics and design choices for underwater robotics and aerial robotics as well. All the materials and homeworks of this course are developed based on the widely accepted practices of robotics technologies in the modern era. An intended side-effect of this course is to strengthen your expertise toward:

- understanding the past, present, and future of autonomous robotics;
- getting exposed to the current state-of-the-art of scientific literature;
- developing hands-on experience in the relevant engineering aspects; and
- trying out some ideas or extensions of your own through a final project.

This journey will prepare you well for becoming a roboticist - in competitive robotics laboratories at the graduate level (academia) or in industry.

MATERIALS & SUPPLY FEES

N/A

TEXTBOOK

The following textbooks are highly recommended - but not required to purchase.

- ***Introduction to Robotics: Mechanics and Control*** By John Craig.
  ISBN-13: 978-0133489798. Pearson; 4th edition.
- ***Probabilistic Robotics*** By Sebastian Thrun, Wolfram Burgard and Dieter Fox.
  ISBN-13: 978-0262201629, ISBN-10: 0262201623.
  Intelligent Robotics and Autonomous Agents series; 1st Edition.

OTHER MATERIALS

- Robot Operating System (ROS): http://wiki.ros.org/ROS/Tutorials
- ROS2 tutorials: https://docs.ros.org/en/foxy/Tutorials.html
- ***Mastering ROS for Robotics Programming: Best practices and troubleshooting solutions when working with ROS*** By Lentin Joseph and Jonathan Cacace.
  ISBN-13: 978-1801071024, ISBN-10: 1801071020. Packt Publishing; 3rd Edition.
- **Good online resources:**
  - Robotics Specialization by UPenn; AI for Robotics from GTech
  - MIT 18.06 Linear Algebra; SLAM Course by Prof. Cyrill Stachniss
  - TUM Multiple View Geometry by Prof. Daniel Cremers
  - UC Berkeley Artificial Intelligence CS 188 by Prof. Pieter Abbeel

RELATION TO PROGRAM OUTCOMES (ABET):

Outcome	Coverage
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	High
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	High
3. An ability to communicate effectively with a range of audiences	Low
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, & societal contexts	
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	Low
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	High
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	High

LAPTOP & OS

You must have a personal laptop to interface with the devices or sensors to demonstrate your assignment or project progress. We prefer Linux (Ubuntu) distribution; Windows OS is also fine. *Some rare Linux distributions or newer Mac M1/M2 might have some compatibility issues with some sensory interfaces; in such cases, feel free to use virtual OS environments!*

ATTENDANCE, EXCEPTIONS, & MAKE-UP POLICY

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies. Follow this link to read the university attendance policies: https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/**.**

COURSE GRADE BREAKDOWN

Item	Points	% of Final Grade
Hands-on Homework (HH1 - HH4)	4 x 10	40
Analytical Homework (AH1, AH2)	2 x 10	20
Mid-term Exam (Written, in class)	1 x 15	15
Final Project (Demo-1)	1 x 10	10
Final Project (Demo-2)	1 x 15	15
TOTAL		**100**

COURSE MATERIALS & LECTURE PLAN

Week	Topics	Reference
1-2	**Lecture #1** Introduction: Outline and Logistics ● Robotics and AI overview: past, present, and future ● Robot Operating System (ROS / ROS2) overview	* IRMC Chapter 1 * PR Chapter 1
2-3	**Lecture #2** ROS/ROS2 Pipeline for Robotics ● Sensory integration and design choices ● User interface; hardware-software integration ● Middleware: ROS/ROS2 pipeline, OpenCV and other packages	* ROS/ROS2 wiki * Online documentation
3-4	**Lecture #3** Spatial Descriptions and Transformations ● Homogeneous and Euler rotations ● Representation in quaternion space	* IRMC Chapter 2
5-6	**Lecture #4** Kinematics: Manipulators and Mobile Robots ● Forward Kinematics: DH notation (manipulators) ● Adaptation: UGVs (TurtleBot Kinematics)	* IR Chapter 3,4
6-7	**Lecture #5** Locomotion: Mobile Robots ● Motion Gaits: 2-DOF, 3-DOF, and 6-DOF ● Quaternion: Rotation Space and SLERP Interpolation	* IR Chapter 3,4
7-8	**Lecture #6** Robot Perception: UGVs / AUVs / UAVs ● Exteroceptive and interoceptive sensing ● Visual and inertial measurements ○ Gyroscope, accelerometers, IMU, GPS ○ Range sensors, camera vision and LiDAR ● Visual sensing and estimation	* Lecture materials
8-10	**Lecture #7** Visual Perception in Robotics ● Robot vision basics - UGVs / AUVs / UAVs ● Camera model: intrinsic and extrinsic parameters ● Object detection and tracking ● Homography estimation ● Stereo cameras: epipolar geometry	* PR Chapter 3, 4 (partial)
9	Mid-term Exam (written, in class on Tuesday)	
11-12	**Lecture #8** Localization and Odometry ● 2-DOF, 3-DOF, and 6-DOF robots ● Acoustic and optical localization	* PR Chapter 7, 10 (partial)
12-13	**Lecture #9** Planning Algorithms for Mobile Robots ● Map-based planners: Bug0, Bug1 algorithms ● Graph-based algorithms: BFS, DFS, Dijkstra, A* ● Sampling-based algorithms: RRT, RRT* ● Target-centric planners	* PR Chapter 5, 6
13-15	**Lecture #10** Filtering and State Estimation ● Probabilistic filtering concepts ● State estimation and planning under uncertainty ● Kalman Filtering (KF), extended KF (EKF) ● Feedback controllers: PIDs	* PR Chapter 2-7, 10 (partial)
15	Project Showcase: Demo-1	
	Final Project Showcase: Demo-2 Time: 05/01/2024 @ 3:00 PM - 5:00 PM	

HOMEWORK ASSIGNMENTS

[**HH1**] ROS integration and simulation [10 points; out: week 1, due: week 3]
- Part A: ROS/ROS2 installation and setup
- Part B: Interfacing webcam or usb cameras
- Part C: Topic subscription and publishing

[**AH1**] Kinematics [10 points; out: week 2, due: week 5]
- Part A: Spatial descriptions and transformations
- Part B: Manipulator kinematics (DH notation)
- Part C: Fixed and Euler angle rotation

[**HH2**] Kinematics [10 points; out: week 5, due: week 7]
- Part A: RViz setup and world mapping
- Part B: Euler angles and axis of rotation
- Part C: Forward kinematics

[**HH3**] Visual Perception [10 points; out: week 7, due: week 10]
- Part A: Augmented visuals by homography estimation
- Part B: Camera calibration

[**HH4**] Planning Algorithms (ROS/ROS2) [10 points; out: week 10, due: week 13]
- Part A: Dynamic programming with a basic planner
- Part B: Bug0 and Bug1 algorithm implementation in ROS/ROS2

[**AH2**] SLAM [10 points; out: week 13, due: week 15]
- Part A: Basic estimation theory (likelihood and posterior estimators)
- Part B: 2D localization from known landmarks
- Part C: KF and EKF for engineers

GRADING POLICY

Grades are periodically posted online; please check your grades regularly. All grades are final after one week since posting. More information on the general UF grading policy can be found here: https://catalog.ufl.edu/UGRD/academic-regulations/grades-grading-policies/.

Percent	Grade	Grade Points
92 or More	A	4.00
88.0 - 91.9	A-	3.67
84.0 - 87.9	B+	3.33
81.0 - 83.9	B	3.00
78.0 - 80.9	B-	2.67
75.0 - 77.9	C+	2.33
72.0 - 74.9	C	2.00
67.0 - 71.9	C-	1.67
64.0 - 66.9	D+	1.33
60.0 - 63.9	D	1.00
55.0 - 59.9	D-	0.67
Below 55	E	0.00

STUDENTS REQUIRING ACCOMMODATIONS

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center; visit this link for the details: https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

COURSE EVALUATION

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Moreover, the summaries of course evaluation results will be available to students at this link: https://gatorevals.aa.ufl.edu/public-results/.

IN-CLASS RECORDING

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code & Student Conduct Code.

SOFTWARE USE

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

UNIVERSITY HONESTY POLICY

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “In my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Conduct Code listed in this link (https://sccr.dso.ufl.edu/process/student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. If you have any questions or concerns, please consult with the instructor or TAs in this class.

COMMITMENT TO A SAFE & INCLUSIVE LEARNING ENVIRONMENT

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is

expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.
If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennacc@ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

STUDENT PRIVACY

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

CAMPUS RESOURCES

Covid-19 Protocols: UF campus brief, UF health guidelines
U Matter, We Care:
Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: https://counseling.ufl.edu, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS): Student Health Care Center, 392-1161.
University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.
E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Connections Center, Reitz Union, 392-1601. https://career.ufl.edu.
Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. https://teachingcenter.ufl.edu/.
Writing Studio, 302 Tigert Hall*,* 846-1138. https://writing.ufl.edu/writing-studio/.
Student Complaints Campus*:* https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/; https://care.dso.ufl.edu.
On-Line Students Complaints*:* http://www.distance.ufl.edu/student-complaint-process.