IE UNIVERSITY

ROBOTICS & AUTOMATION

Bachelor in Computer Science and Artificial Intelligence
BCSAI SEP-2024 RA-CSAI.4.M.A

Area Computer Science and AI
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Number of credits: 6.0
Semester: 2º
Category: COMPULSORY
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Professor: **EDUARDO CASTELLÓ FERRER**

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Prof. Eduardo Castelló Ferrer received his B.Sc. (Hons.) degree in intelligent systems from the University of Portsmouth (U.K.) in 2007, and his M.Eng. and Ph.D. degrees in robotics engineering from Osaka University (Japan) in 2011 and 2016, respectively. Prof. Castelló's experience and interests comprise robotics, cryptography, and complex systems. He was a Marie Curie Fellow at the MIT Media Lab, where he innovated the combination of distributed robotic systems and blockchain technology. In addition to his position as an assistant professor at IE, Prof. Castelló is a research fellow at the MIT Connection Science group where he focuses on implementing new security, behavior, and business models for robotics using novel cryptographic methods.

Office Hours

Office hours will be on request. Please contact at:

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SUBJECT DESCRIPTION

The Czech playwright Karel Capek is credited with coining the word "robot" in his 1920 play, R.U.R. (Rossum's Universal Robots), but the concept of robots as machines with a certain degree of autonomy has been around for centuries. Science fiction aside, a robot is computer that has the physical ability to interact with the world around it. In other words, a goal-oriented machine that can sense, plan, and act. A robot senses its environment using different sensors and uses that information together with a goal to plan an action. In this course, we will cover all the necessary concepts to make a robot sense, plan, and act in simulated environments. During the course, theory-based lectures will be complemented with simulation-based exercises by using ROS (Robot Operating System); the de facto standard software for robotics research. This theory-based course is complemented by an experimental-based course (Robotics & Automation LAB - OACT.M.A_C1_448152), where all the learned concepts will be put into practice with real-robot hardware.

LEARNING OBJECTIVES

By the end of this course, students should be able to:

- Understand the basic concepts behind a modern robotics system: sensing, planning, and actuation
- Program and simulate custom controllers for robotic arms, humanoids, rovers, and drones
- Get acquainted with the latest robotics research and have the ability to analyze a robotics research paper

TEACHING METHODOLOGY

IE University teaching method is defined by its collaborative, active, and applied nature. Students actively participate in the whole process to build their knowledge and sharpen their skills. Professor’s main role is to lead and guide students to achieve the learning objectives of the course. This is done by engaging in a diverse range of teaching techniques and different types of learning activities such as the following:

Learning Activity	Weighting	Estimated time a student should dedicate to prepare for and participate in
Lectures	13.3 %	20.0 hours
Discussions	6.7 %	10.0 hours
Exercises in class, Asynchronous sessions, Field Work	30.0 %	45.0 hours
Group work	20.0 %	30.0 hours
Individual studying	30.0 %	45.0 hours
TOTAL	100.0 %	150.0 hours

AI POLICY

Generative artificial intelligence (GenAI) tools may be used in this course for assignment and code writing with appropriate acknowledgement. GenAI may not be used for presentations, group submissions, and exams. If a student is found to have used AI-generated content inappropriately, it will be considered academic misconduct, and the student might fail the respective assignment or the course.

PROGRAM

SESSION 1 (LIVE IN-PERSON)

We will kick-off the course with an introductory lecture about the robotics field. During the lecture, the instructor will introduce his background in the field. Finally, the class schedule and admin procedures (software installation, opening online accounts, etc.) will be presented to the students. The class will finish, with an overview of the topics covered will during the course.

SESSION 2 (LIVE IN-PERSON)

In this introductory lecture, we will do a quick overview of the GNU/Linux operating system. During the lecture, students will find answers to questions such as: how to navigate through a GNU/Linux filesystem? How to interact with a Linux filesystem? How to manage access to files (permissions)? How to create simple GNU/Linux programs (bash scripts)? How to connect to the remote computer of a robot (ssh)? We will finish the lecture with a programming example that will summarize all covered concepts.

SESSIONS 3 - 4 (LIVE IN-PERSON)

The theorical sessions for this couse will start with an introduction to ROS (Robot Operating System). In this lecture (2 sessions long), we will cover the basic concepts behind ROS, such as: what is ROS? and why do we use it? Then, we will cover the basic technical concepts for ROS operation like: topics, services, and actions. We will finish the lecture with a programming example that will summarize all covered concepts.

SESSIONS 5 - 6 (LIVE IN-PERSON)

In this lecture (2 sessions long), we will introduce URDF (Unified Robot Description Format); an XML-like language that will help us define the structure of a robot and the connections between its parts. During the lecture, students will find answers to questions such as: how to build a visual robot model? How to add physical properties to it (e.g., collision, frictions)? How to use URDF in a ROS ecosystem? We will finish the lecture with a simulated example that will summarize all covered concepts.

SESSIONS 7 - 8 (LIVE IN-PERSON)

In this lecture (2 sessions long), we will introduce the ROS TF (Transformations and Frames) package; a piece of software that lets the robot keep track of multiple coordinate frames over time. During the first part of the lecture, students will fidn answers to questions such as: how to express different coordinate frames? How to describe objects position and location with respect to the robot's point of view? How to understand robot states and joint states? In the second part of the lecture, students will get acquainted with basic robot kinematic models. We will finish the lecture with a simulated example of a robotic arm that will perform manipulation tasks.

SESSIONS 9 - 10 (LIVE IN-PERSON)

In this lecture (2 sessions long), we will introduce the ROS control package; a set of tools that will make robots take actions. During the first part of the lecture, students will deep dive into concepts such as: control loops, PID dynamics, custom controllers, etc. In the second part of the lecture, students will apply the learned concepts in a simulated manipulation task by using the Tiago or Pepper robotic platforms.

SESSIONS 11 - 12 (LIVE IN-PERSON)

In this lecture (2 sessions long), we will introduce the ROS navigation package; a set of tools and mechanisms that make robots explore and navigate an environment. During the first part of the lecture, students will learn how to build a map in a controlled envirommment, how to localize a robot in that map, conduct path planning from an initial positions to the desired destinations. In the second part of the lecture, students will apply the learned concepts in a simulated example by using the Robotnik SUMMIT XL robot.

SESSIONS 13 - 14 (LIVE IN-PERSON)

In this lecture (2 sessions long), we will introduce the ROS navigation package; a set of tools and mechanisms that make robots explore and navigate an environment. During the first part of the lecture, students will learn how to build a map in a controlled envirommment, how to localize a robot in that map, conduct path planning from an initial positions to the desired destinations. In the second part of the lecture, students will apply the learned concepts in a simulated example by using the Robotnik SUMMIT XL robot.

SESSIONS 15 - 16 (LIVE IN-PERSON)

In this lecture (2 session long), we will introduce the ROS OPENCV package; a set of tools and methods that will help a robot see and recognize the environemnt around it. During the lecture, students will learn how to recognize patterns, colors, borders, detection of objects, detection of people, faces in a robotics context. We will finish the lecture with a simulated example that will summarize all covered concepts.

SESSIONS 17 - 18 (LIVE IN-PERSON)

In this last ROS lecture, we will review all important concepts learned during the last 15 theory-based sessions. Moreover, several practical exercises will be reviewed, paying special attention to the control and data acquisition from several robot platform with ROS. We will finish the lecture with a simulated example that will summarize all covered concepts.

SESSION 19 (LIVE IN-PERSON)

MID TERM EXAM

SESSION 20 (LIVE IN-PERSON)

This lecture will start a series of sessions focused on specific state-of-the-art research topics within the robotics field. In this first lecture, students will deep dive into new directions on robotics research. During the session, students will get acquainted with the latests advances in emergent research fields.

SESSION 21 (LIVE IN-PERSON)

This lecture will continue a series of sessions focused on specific state-of-the-art research topics within the robotics field. In this session, students will deep dive into the field of Industry 4.0 and the future of work (AI, IoT, automation). During the session, students will get acquainted with research work where robots improve work-related processes.

SESSION 22 (LIVE IN-PERSON)

This lecture will continue a series of sessions focused on specific state-of-the-art research topics within the robotics field. In this session, students will deep dive into the field of human augmentation and biomechanics. During the session, students will get acquainted with research work where the human body meets the artificial to enhance its capabilities.

SESSION 23 (LIVE IN-PERSON)

This lecture will continue a series of sessions focused on specific state-of-the-art research topics within the robotics field. In this session, students will deep dive into the field of bio-inspired robotics. During the session, students will get acquainted with research work where robot design and function are inspired by biological systems.

SESSION 24 (LIVE IN-PERSON)

This lecture will continue a series of sessions focused on specific state-of-the-art research topics within the robotics field. In this session, students will deep dive into the field of cognitive robotics. During the session, students will get acquanited with research work where robots achieve intelligent behavior, learning, and reasoning in complex environments.

SESSION 25 (LIVE IN-PERSON)

This lecture will continue a series of sessions focused on specific state-of-the-art research topics within the robotics field. In this session, students will deep dive into the field of human-robot interaction and collaborative robotics. During the session, students will get acquaninted with research work where robots share a space with humans and perform direct interactions with them.

SESSION 26 (LIVE IN-PERSON)

Keynote from industry expert

SESSION 27 (LIVE IN-PERSON)

Keynote from industry expert

SESSION 28 (LIVE IN-PERSON)

Keynote from industry expert

SESSIONS 29 - 30 (LIVE IN-PERSON)

FINAL GROUP PRESENTATION

EVALUATION CRITERIA

In session 19, a mid-term exam will be conducted in the form of an individual programming exercise. The idea behind this exam is to demonstrate the student's proficiency by using the ROS programming framework. Complementarily, in session 30, a group (~5 students) presentation will be conducted. In this group presentation, students will pick a robotics research paper (paper candidates will be provided throughout sessions 20 to 29) and conduct a deep scientific analysis. This analysis will include the strengths, weaknesses, opportunities, and threats of the chosen research paper.

criteria	percentage	Learning Objectives	Comments
Intermediate tests	50 %		
Group Presentation	40 %		
Class Participation	10 %		

RE-SIT / RE-TAKE POLICY

Each student has four chances to pass any given course distributed over two consecutive academic years: ordinary call exams and extraordinary call exams (re-sits) in June/July.

Students who do not comply with the 80% attendance rule during the semester will fail both calls for this Academic Year (ordinary and extraordinary) and have to re-take the course (i.e., re-enroll) in the next Academic Year.

Evaluation criteria:

- Students failing the course in the ordinary call (during the semester) will have to re-sit the exam in June / July (except those not complying with the attendance rule, who will not have that opportunity and must directly re-enroll in the course on the next Academic Year).
- The extraordinary call exams in June / July (re-sits) require your physical presence at the campus you are enrolled in (Segovia or Madrid). There is no possibility to change the date, location or format of any exam, under any circumstances. Dates and location of the June / July re-sit exams will be posted in advance. Please take this into consideration when planning your summer.
- The June/July re-sit exam will consist of a comprehensive exam. Your final grade for the course will depend on the performance in this exam only; continuous evaluation over the semester will not be taken into consideration. Students will have to achieve the minimum passing grade of 5 and can obtain a maximum grade of 8.0 (out of 10.0) – i.e., “notable” in the in the re-sit exam.
- Retakers: Students who failed the subject on a previous Academic Year and are now re-enrolled as re-takers in a course will be needed to check the syllabus of the assigned professor, as well as contact the professor individually, regarding the specific evaluation criteria for them as retakers in the course during that semester (ordinary call of that Academic Year). The maximum grade that may be obtained in the retake exam (3rd call) is 10.0.

After ordinary and extraordinary call exams are graded by the professor, you will have a possibility to attend a review session for that exam and course grade. Please be available to attend the session in order to clarify any concerns you might have regarding your exam. Your professor will inform you about the time and place of the review session. Any grade appeals require that the student attended the review session prior to appealing.

Students failing more than 18 ECTS credits in the academic year after the June-July re-sits will be asked to leave the Program. Please, make sure to prepare yourself well for the exams in order to pass your failed subjects.

In case you decide to skip the opportunity to re-sit for an exam during the June/July extraordinary call, you will need to enroll in that course again for the next Academic Year as a re-taker and pay the corresponding extra cost. As you know, students have a total of four allowed calls to pass a given subject or course, in order to remain in the program.

CLASS PARTICIPATION

The rating of the class participation is based on two aspects, the presence and contributions to class discussions. Contributions on class discussions will focus on quality, not quantity of the contribution, so that students who participate often do not necessarily receive a better rating than those who participate less frequently. Therefore, students are encouraged to start contributing to the discussions since the beginning of the course.

INDIVIDUAL AND WORKGROUP ASSIGNMENTS

You are expected to complete several labs exercises individually and present their results. In addition, you will be evaluated based on your contribution to the final group presentation that will take place at the end of course. These practices will give you the opportunity to reflect on what you have learnt in class and apply it to some practical problems. More details of the labs will be provided by the start of the course.

BIBLIOGRAPHY

Recommended

- Bruno Siciliano, Oussama Khatib. (2016). *Springer Handbook of Robotics.* Springer. ISBN 9783319325 (Digital)
- Roland Siegwart, Illah R. Nourbakhsh, Davide Scaramuzza. *Introduction to Autonomous Mobile Robots.* MIT Press. ISBN 978026201535 (Digital)
- Kevin M. Lynch, Frank C. Park. (2017). *Modern Robotics: Mechanics, Planning, and Control.* Cambridge University Press. ISBN 978110715630 (Digital)
- Morgan Quigley, Brian Gerkey, William Smart. (2016). *Programming Robots with ROS: A Practical Introduction to the Robot Operating System.* O'Reilly Media. ISBN 978144932389 (Digital)

BEHAVIOR RULES

Please, check the University's Code of Conduct here. The Program Director may provide further indications.

ATTENDANCE POLICY

Please, check the University's Attendance Policy here. The Program Director may provide further indications.

ETHICAL POLICY

Please, check the University's Ethics Code here. The Program Director may provide further indications.