Universidad Zaragoza

Academic Year/course: 2021/22

69160 - Multirobot Systems

Syllabus Information

Academic Year: 2021/22
Subject: 69160 - Multirobot Systems
Faculty / School: 110 - Escuela de Ingeniería y Arquitectura
Degree: 615 - Master's in Robotics, Graphics and Computer Vision/ Robótica, Gráficos y Visión por Computador
ECTS: 3.0
Year: 1
Semester: Second semester
Subject Type: Optional
Module:

1. General information

1.1. Aims of the course

The subject and its expected results are associated to the following approaches and objectives:

The objective of the course is to train students in the key aspects related to multi-robot systems and their applications in different contexts. This requires approaching the discipline from different levels:

- The fundamentals related to the classification of the different types of multi-robot systems, the associated problems, and the conceptual framework and tools to work with these systems are studied.
- Techniques and algorithms that allow working with multi-robot systems are presented. The development and implementation of these algorithms requires studying and practicing techniques and programming languages.
- Different case studies and application examples of multi-robot systems are analyzed.
- Finally, the development of applications in the context of multi-robot systems is addressed.

After completing their formation, students are intended to achieve competences related to the analysis, design and programming of multi-robot systems.

These approaches and objectives are aligned with some of the Sustainable Development Goals, SDG, of the 2030 Agenda (https://www.un.org/sustainabledevelopment/es/) and certain specific goals, in such a way that the acquisition of the Learning outcomes of the subject provides training and competence to the student to contribute to a certain extent to their achievement:

- Goal 9. Industry, Innovation and Infrastructures
    - Target 9.4 By 2030, modernize infrastructure and reconvert industries so that they are sustainable, using resources more efficiently and promoting the adoption of clean and environmentally sound industrial technologies and processes, and ensuring that all countries take measures in accordance with their respective capabilities
    - Target 9.5 Increase scientific research and improve the technological capacity of industrial sectors in all countries, particularly developing countries, including by fostering innovation and significantly increasing, by 2030, the number of people working in research and development per million inhabitants and the spending of the public and private sectors in research and development.

1.2. Context and importance of this course in the degree

Multirobot Systems is an optional subject of 3 ECTS credits of the Master's Degree in Robotics, Graphics and Computer Vision from the University of Zaragoza. The contents of this subject are framed within the subject of Advanced Topics in Robotics.

In this subject, general concepts of multi-robot systems are presented, addressing theoretical aspects,

implementation and their practical application. Compulsory subjects of "Autonomous Robots" and "Computer Vision" have been taken in the previous semester, which introduce some of the basic principles used in this subject. In this course, students learn to analyze and design multi-robot systems, understanding the significance and advantages of systems made up of multiple robots in various applications, as well as their potential in different fields.

1.3. Recommendations to take this course

It is advisable to have successfully completed the subjects of Autonomous Robots and Computer Vision, and to have solid skills and knowledge of mathematics and programming.

This course is recommended for students interested in robotics and multi-robot systems. These topics are fundamental and of great importance today, with a wide range of applications related to both industrial automation and research. In this course, a global perspective of the problems associated with multi-robot applications is offered, and the knowledge of modeling, analysis, design and implementation of robotic applications is deepened.

The study and continued work, from the first day of the course, are essential in order to successfully advance and follow the course. It is important to solve any doubts that may arise as soon as possible, by contacting with the teacher, both during classes and during the office hours assigned to it.

2. Learning goals

2.1. Competences

Basic and general competences:

- CB6 ? To possess and understand knowledge that provides a basis or opportunity to be original in the development and / or application of ideas, often in a research context.
- CB7 - That students know how to apply the acquired knowledge and ability to solve problems in new or little-known settings within broader (or multidisciplinary) contexts related to their area of ??study.
- CB9 - That students know how to communicate their conclusions and the latest knowledge and reasons that support them to specialized and non-specialized audiences in a clear and unambiguous way.
- CB10 - That students possess the learning skills that allow them to continue studying in a way that will have to be largely self-directed or autonomous.
- CG01 ? Acquisition of advanced and demonstrated knowledge, in a context of scientific and technological research or highly specialized, a detailed and well-founded understanding of the theoretical and practical aspects and of the working methodology in the fields of Robotics, Graphics and / or Computer Vision, allowing them to be innovative in a context of research, development and innovation.
- CG09 - Ability to use the techniques, skills and tools of Engineering necessary for solving problems of the Robotics, Graphics and / or Computer Vision fields.
- CG10 - Ability to understand, relate to the state of the art and critically evaluate scientific publications in the fields of Robotics, Graphics and / or Computer Vision.
- CG11 - Ability to manage and use bibliography, documentation, databases, software and hardware specific to the fields of Robotics, Graphics and / or Computer Vision.

Specific competences:

- CE04 - Ability to conceive, design and develop software, products and systems in the field of Robotics

2.2. Learning goals

The student must be able to:

- Know the specific challenges and problems in the context of multi-robot systems.
- Know and apply advanced techniques in the context of multi-robot systems.
- Understand and evaluate the impact of applications in advanced robotics.
- Identify the problems under investigation for which there are no known solutions in the field of robotics.
- Have a practical knowledge of the above aspects.
- Present the proposed technical and / or scientific results, synthesizing the main ideas.
- Evaluate relevant bibliographic sources.

2.3. Importance of learning goals

Multi-robot systems have a growing application in a wide range of contexts, including industrial automation, cooperative logistics and transport, cooperative monitoring of environments or facilities, or exploration and rescue, among others. The presence of several robots working in a coordinated way introduces a series of important improvements. Parallel execution allows better use of resources, reducing execution times in tasks that are inherently distributed. The presence of several robots introduces greater robustness to failures due to redundancy. The use of multi-robot systems allows tasks that would not be possible with a single team member to be carried out. On the other hand, having multi-robot systems requires addressing the specific problems related to the assignment of tasks, coordination between robots, communications between them, and cooperative decision-making. The knowledge acquired in this subject is of great importance, since it allows students to have an approach to these type of systems, and to the fundamental tools to work with them and to design applications in these contexts. This subject also allows student to consolidate and get a deeper knowledge of concepts related to perception, robotics and control.

3. Assessment (1st and 2nd call)

3.1. Assessment tasks (description of tasks, marking system and assessment criteria)

Students must demonstrate that they have achieved the expected learning outcomes through the following assessment activities:

In accordance with the regulations of the University of Zaragoza, the evaluation of this subject is established as Global Type. In each call, the evaluation will comprise a single test:

Assessment of Practical Work (100%): Graded between 0 and 10 points. The objective of this test is to evaluate the knowledge and skills acquired during the development of a case study that requires putting all the learning results into play.

4. Methodology, learning tasks, syllabus and resources

4.1. Methodological overview

The teaching-learning process will be carried out through:

- Lectures (explanation of contents)
- Problems and cases (examples and practical cases with active participation of the students, and autonomous practical work of the students, supervised by the teachers)
- Lab sessions (students solve the practical exercises proposed, supervised by the teachers)
- Practical research or application work (learning activities, supervised by teachers, to be carried out throughout the semester).
- Autonomous work (personal study by the students, during the semester).

4.2. Learning tasks

The program offered to the students to help them achieve the expected results includes the following activities ...

1. Lectures (10 hours)
2. Solution of problems and cases (5 hours)
3. Lab sessions (5 hours)
4. Practical research or application work (40 hours, including the necessary tutorials during development)
5. Autonomous work and evaluation (15 hours, including tutorials)

4.3. Syllabus

- Introduction
- Classification of multi-robot systems
- Conceptual framework and classic models
- Fundamentals and applications
- Case studies (related to topics that include: Connectivity maintenance and rendezvous, Search,

Reconnaissance and Mapping in Search and Rescue Scenarios, Deployment, Formation Control, Boundary Estimation and Tracking, Robot Swarms, Mobile Sensor Networks, Cooperative Manipulation and Transport, Task Allocation)

- Examples of recent results

4.4. Course planning and calendar

The lectures will follow the schedule established by the center, and published on its website. Please refer to the EINA website (http://eina.unizar.es).

The detailed description and timetable of the various activities, tutorials, and additional information and documentation on the subject, will be published at http://moodle.unizar.es/

The global schedule is as follows:

- A single two-hour class session is scheduled each week. The content of each session will be devoted to the mentioned activities (lecture, problem solving and cases, lab sessions, practical work or practical research), announcing it in advance.

4.5. Bibliography and recommended resources

Basic bibliography:

1. Siciliano, Bruno, and Oussama Khatib, eds. Springer handbook of robotics. Springer, (ed. 2016). Capítulos 40, y 41. https://www.springer.com/gp/book/9783319325507
2. Ren, Wei, and Randal W. Beard. Distributed consensus in multi-vehicle cooperative control. Vol. 27. No. 2. London: Springer London, 2008. https://www.springer.com/gp/book/9780857291684
3. Mesbahi, Mehran, and Magnus Egerstedt. Graph Theoretic Methods in Multiagent Networks. PRINCETON; OXFORD: Princeton University Press, 2010. www.jstor.org/stable/j.ctt1287k9b Accessed July 10, 2020. doi:10.2307/j.ctt1287k9b.
4. Ren, Wei, and Yongcan Cao. Distributed coordination of multi-agent networks: emergent problems, models, and issues. Springer Science & Business Media, 2010. https://www.springer.com/gp/book/9780857291684
5. Fei Chen and Wei Ren (2019), "On the Control of Multi-Agent Systems: A Survey", Foundations and Trends® in Systems and Control: Vol. 6: No. 4, pp 339-499. http://dx.doi.org/10.1561/2600000019

Supplementary bibliography:

1. Bullo, Francesco, Jorge Cortes, and Sonia Martinez. Distributed control of robotic networks: a mathematical approach to motion coordination algorithms. Vol. 27. Princeton University Press, 2009. Accesible en abierto: http://coordinationbook.info/index.html

Bibliogaphy at UZ:

http://biblos.unizar.es/br/br_citas.php?codigo=69160&year=2020