Universidad Zaragoza

Academic Year/course: 2021/22

69156 - Simultaneous Localization and Mapping

Syllabus Information

Academic Year: 2021/22
Subject: 69156 - Simultaneous Localization and Mapping
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: 6.0
Year: 1
Semester: Second semester
Subject Type: Compulsory
Module:

1. General information

1.1. Aims of the course

The objective of the course is to study the main techniques of Simultaneous Localization and Map Building (SLAM), understand their mathematical and algorithmic foundations, and be able to apply them in real examples.

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 3: Ensure healthy lives and promote well-being for all at all ages
    - Target: 3.6 By 2020, halve the number of deaths and injuries caused by traffic accidents in the world
- Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
    - Target 8.4 Progressively improve, by 2030, the efficient production and consumption of world resources and seek to decouple economic growth from environmental degradation, in accordance with the Ten-Year Framework of Programs on Sustainable Consumption and Production patterns, starting with the developed countries

1.2. Context and importance of this course in the degree

In this subject we study the concepts and techniques related to SLAM, one of the most important problems and applications of autonomous robots that use sensors to determine their spatial position and build a model of the environment that surrounds them.

1.3. Recommendations to take this course

This subject is compulsory in the second semester. The knowledge and skills acquired in the compulsory subjects of the first semester Autonomous Robots, Computer Vision, Machine Learning, and Programming and Architecture of Computing Systems are very useful. Thus it is advisable to have taken them previously.

2. Learning goals

2.1. Competences

The student will acquire the following basic 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.

- CB8 - That students are able to integrate knowledge and face the complexity of formulating judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
- 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.

The student will acquire the following general competences:

- 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.
- CG02 - Ability to apply and integrate their knowledge, their understanding, their scientific foundation and their problem-solving abilities in new and imprecisely defined environments, including multidisciplinary contexts, as highly specialized researchers and professionals.
- CG03 - Ability to evaluate and select the appropriate scientific theory and the precise methodology of their fields of study to formulate judgments based on incomplete or limited information, including, when necessary and pertinent, considerations on social or ethical responsibility linked to the solution that is proposed in each case.
- CG04 - Ability to predict and control the evolution of complex situations by developing new and innovative work methodologies adapted to the specific scientific / research, technological or professional field, generally multidisciplinary, in which their activity is carried out.
- CG05 - Ability to transmit in English, orally and in writing, in a clear and unambiguous way, to a specialized audience or not, results from scientific and technological research or the most advanced field of innovation, as well as the most relevant foundations on which they are based.
- CG06 ? To have developed sufficient autonomy to participate in research projects and scientific or technological collaborations within their subject area, in interdisciplinary contexts and, where appropriate, with a high component of knowledge transfer.
- CG07 - Ability to take responsibility for your own professional development and specialization in one or more fields of study.
- CG08 ? To possess the aptitudes, skills and method necessary to carry out multidisciplinary research and / or development work in the fields of Robotics, Graphics and / or Computer Vision.
- 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.
- CG12 - Ability to work in a multidisciplinary group and in a multilingual environment.

The student will acquire the following specific competences:

- CE01 - Ability to apply mathematical and artificial intelligence methods to model, design and develop Robotics, Graphics and / or Computer Vision systems and applications.
- CE02 - Ability to design and develop new methods and algorithms applicable to autonomous systems or virtual and augmented reality.
- CE04 - Ability to conceive, design and develop software, products and systems in the field of Robotics.
- CE06 - Ability to conceive, design and develop software, products and systems in the field of Computer Vision.
- CE07 - Ability to develop and evaluate software for Robotics, Graphics and Computer Vision problems that can use general and / or specific purpose architectures.

2.2. Learning goals

The student must be able to:

1. Know the different types of SLAM systems.
2. Understand the main perception algorithms for tracking and recognizing places and their fundamentals.
3. Know, operate and calibrate standard sensors for SLAM.
4. Design and develop SLAM systems for different applications.
5. Evaluate the performance of a SLAM system under realistic operating conditions.
6. Propose and evaluate the benefits of new algorithms that address unresolved aspects of the operation of a SLAM system.

3. Assessment (1st and 2nd call)

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

In accordance with the regulations of the University of Zaragoza, the evaluation of this subject is established as Type continuous or global.

Given the relevance of the acquisition of practical skills in the subject through the use of computer systems, throughout the course the work will also be evaluated, based on (1) a prior study report, (2) the development of the practical work (3) the preparation of a final report and (4) the resolution of the questions raised.

In each call, the evaluation will include the following:

- E01 - Written / laboratory test (30%, T). Graded between 0 and 10 points. It will take place during the exam period.
  The student will be evaluated of the set of learning results from the theoretical point of view and problem resolution.
- E02 - Directed work (60%, L). Graded between 0 and 10 points. The objective of these tests is to evaluate the knowledge and skills that students have acquired in the application of theoretical knowledge. The students attend the laboratory sessions with the previous study of the work done. The sessions will consist in the development in the lab of a series of exercises related to the contents of the subject.
- E03 - Oral presentations and debates (10%, D). Graded between 0 and 10 points. The ability to synthesize, to highlight important concepts, and the dialectical ability to identify different points of view will be considered.

To pass the subject, it is required to obtain a grade in T and L greater than or equal to 5 points over 10. Only in this case, the overall grade of the course will be (0.3T + 0.6L + 0.1D). Otherwise, the overall grade will be the minimum between 4 and the result of applying the above formula. The subject is passed with an overall grade of 5 points out of 10.

Optionally, a student may deliver during the semester, on the dates indicated by the teachers, the solutions implemented for each of the exercises proposed for the directed work sessions. Delivery in date of these solutions will exempt the student from taking the final practical test in the laboratory.

In this case, the grade by continuous assessment of the subject will be (0.9L + 0.1D).

In case of not approving the subject in the first call, in the second call it will be compulsory both to sit for the written test, and presenting the directed works.

4. Methodology, learning tasks, syllabus and resources

4.1. Methodological overview

The learning process includes the following methodologies:

- M01 - Theory Class.
- M02 - Expert talks.

- M04 - Group work.
- M05 - Problem-based learning.
- M07 - Projects.
- M08 - Presentation of group work.
- M09 - Laboratory.
- M10 - Tutoring.
- M11 - Evaluation.
- M12 - Theoretical works.
- M13 - Practical work.
- M14 - Theoretical study.
- M15 - Practical study.
- M16 - Complementary activities.
- M18 - Competitions and hackathons.

4.2. Learning tasks

The course consists of 6 ECTS credits that represent an estimated dedication by the student of 150 hours, divided into the following activities:

- A01 - Master class: 25 hours
- A02 - Troubleshooting and cases: 5 hours
- A03 - Laboratory practices: 20 hoursA05 - Practical research or application work: 25 hours
- A06 - Personalized tutor teacher-student: 5 hours
- A07 - Study: 65 hours
- A08 - Assessment tests: 5 hours

4.3. Syllabus

1. Fundamentals
   Basic concepts, theory and estimation methods
2. Robustness
   Sensors, features
   Data association, tracking, loop detection and closure, relocalisation
   Complex and dynamic environments
3. Accuracy and Scaling
   Non-linearity, computational cost
   Algorithms for large scale SLAM
4. Vision based SLAM systems
   Visual SLAM as an optimization problem. Bundle Adjustment (BA)
   Tracking. Visual odometry (VO). Pose-only BA
   Mapping. Local BA. Lie groups and optimization algorithms
   Relocation and loop closing
5. Advanced Visual SLAM
   Visual-inertial SLAM
   Multi-mapping

4.4. Course planning and calendar

The subject calendar will be defined by the center in the academic calendar of the corresponding course. The detailed calendar of activities will be available in Moodle, and will be presented on the first day of class.

4.5. Bibliography and recommended resources

Robot Manipulators by Paul, Richard. [MIT Press, 1981].

Mobile Robot Localization and Map Building, A Multisensor Fusion Approach by Castellanos, Jose A., Tardós, Juan D. [Springer 1999]

Probabilistic Robotics by Thrun, Sebastian; Burgard, Wolfram; Fox, Dieter. [2005]

Pattern Classification by Duda,Richard O.; Hart,Peter E.; Stork,David G.. [2000,2nd Edition.]

Springer Handbook of Robotics by Siciliano, Bruno; Kathib, Oussama. [2016, 2nd Edition.]

State Estimation for Robotics by Barfoot, Timothy [Cambridge, 2017]

Juan D. Tardós Scholar:

https://scholar.google.es/citations?user=TVf1gw0AAAAJ&hl=en

José A. Castellanos Scholar:

https://scholar.google.es/citations?user=p4dEOQcAAAAJ&hl=en

José Neira Scholar:

https://scholar.google.es/citations?user=scoMbR8AAAAJ&hl=en