Universidad Zaragoza

Academic Year/course: 2022/23

69159 - Advanced SLAM

Syllabus Information

Academic Year: 2022/23
Subject: 69159 - Advanced SLAM
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 aim of the course is to introduce the students to emerging research and innovation topics related to Simultaneous Localization and Mapping (SLAM). For this, state-of-the-art techniques will be detailed in various open SLAM problems, attending to technical but also methodological aspects such as their relationship with the foundations of the study area, their assumptions, limitations and potential, and the critical analysis of available experimental evidence.

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 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
    - Target 8.2 Achieve higher levels of economic productivity through diversification, technological modernization and innovation, including by focusing on high value-added and labor-intensive sectors
- Goal 9: Industry, innovation and infrastructure
    - Target 9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly increase the contribution of industry to employment and gross domestic product, in accordance with national circumstances, and double that contribution in least developed countries

1.2. Context and importance of this course in the degree

SLAM is a technology that is present in most of the sectors covered in this master: it is essential in autonomous robots (including drones and autonomous vehicles) and in virtual and augmented reality applications. If the main sensor is a camera, it makes use of computer vision techniques.

Although the first industrial implementations are beginning to appear, various aspects of SLAM still present significant scientific challenges. Therefore, deepening in advanced and emerging aspects of SLAM is relevant for the professional development of the master's students in the aforementioned fields.

1.3. Recommendations to take this course

The Advanced SLAM course requires basic knowledge of mathematics, statistics and computer programming that are taught in the basic training modules of engineering degrees at the University of Zaragoza.

It is highly recommended to have attended and followed these compulsory courses of the Master Program in Robotics, Graphics and Computer Vision: Computer Vision, Machine Learning and Simultaneous Localization and Mapping. Advanced SLAM will assume as acquired and will use several basic concepts of these subjects (for example, extraction and matching of local visual features, geometry of single and multiple views, deep neural networks (convolutional networks), estimation, fundamentals and terminology of SLAM).

2. Learning goals

2.1. Competences

The student will acquire the following basic and general competences in this course:

- CB6 - Gather and understand the 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 their 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 have the learning skills that allow them to continue studying in a largely self-directed or autonomous manner.
- CG01 - Have acquired 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 Vision by Computer, allowing them to be innovative in a context of research, development and innovation.
- CG05 - Ability to transmit in English, oral and written, 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 - 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.
- CG08 - Have 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 engineering techniques, skills and tools necessary for solving problems in the fields of Robotics, Graphics and / or Computer Vision.
- 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.

The student will also 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 applications.
- CE04 - Ability to conceive, design and develop software, products and systems in the field of Robotics.
- CE09 - Ability to autonomously carry out work of initiation to research and / or development in the field of Robotics, Graphics, or Computer Vision, in which the skills acquired in the degree are synthesized and integrated.

2.2. Learning goals

In order to pass the course, the student must be able to:

- Know the research challenges and specific problems related to current localization and mapping technologies.

- Know and apply the fundamentals and most relevant techniques and methods in RGB-D odometry and SLAM.
- Know and apply advanced and recent techniques in the context of localization and mapping.
- Understand and evaluate the impact of technologies in advanced robotics.
- Identify the research problems for which there are no known solutions in the field of robotics.
- Propose and evaluate the benefits of new algorithms that address unsolved aspects of applications in the field of Robotics.
- Synthetically present the proposed technical and / or scientific results.
- Evaluate relevant bibliographic sources.

2.3. Importance of learning goals

Knowing advanced techniques, research problems and challenges in the areas of localization and mapping is relevant because of 1) the transversality of the technology in multiple applications related to the contents of the master, and 2) the rapid progress of research and the transfer of such technologies. Related to this last point, the competences related to bibliographic analysis, evaluation and analysis of experimental results and potential impact, presentation of results and proposal and evaluation of new algorithms are essential for professionals related to this field.

3. Assessment (1st and 2nd call)

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

The evaluation of the course is continuous and consists of the following components programmed during the course:

E02 - Course assignments related to the two laboratory sessions of the course. The weight in the final grade will be 50%. The understanding of the theoretical foundations, the ability to tackle technical problems, the presentation of the results and critically analyzing them, the scope, the implementation and the methodology will be valued. The test will consist of an oral presentation of the work by the student.

E03 - Oral presentation of scientific articles related to the course. The weight in the final grade will be 50%. The ability to identify the most relevant aspects of the article, its connection with the contents of the subject and the state of the art and the quality of the presentation and the language used will be assessed.

Students will also have the option to pass the course by a global evaluation, on the day designated by the center, having to pass the same evaluation items as in the continuous assessment.

4. Methodology, learning tasks, syllabus and resources

4.1. Methodological overview

The methodology is oriented towards achieving the learning goals. A wide array of teaching and learning tasks are implemented. Students are expected to actively participate in class throughout the semester. Student-lecturer and student-student interactions will be encouraged through tutoring and discussion.

The classroom materials will be available through Moodle. These include a repository of the slides and notes used in the lectures, the course syllabus, as well as other course-specific learning materials, including a discussion forum.

More information about the course will be provided on the first day of class.

4.2. Learning tasks

1. A01 and A02 Theoretical lectures and problems (20 hours)

Expository sessions of theoretical content (15 hours) and problems and brief application examples (5 hours). The main concepts and foundations of the field will be presented. Student participation will be encouraged through questions and short discussions.

2. A03 Laboratory activities (6 hours)

Two laboratory sessions of 3 hours each. They will be oriented to the acquisition of practical skills on the specific topic of RGB-D odometry and SLAM, applying the concepts acquired on the theoretical part of the course.

3. A06 Practical work (16 hours)

Practical work devoted to the acquisition of competences to read and understand recent scientific literature in the topic of SLAM. Each student will be assigned a recent scientific paper, and the tasks will be reading it and understanding it from a critical point of view and in relation to the field, and presenting it to the rest of the class. In each presentation, discussion will be encouraged among the students. The lecturers will assist the students in this task, will participate in the discussions and provide guidance.

4. A07 Study and personal work (30 hours)

The autonomous work of the student in this subject will be devoted to: 1) studying the lecture contents using the suggested bibliography, 2) completing and reviewing the work developed in the laboratory sessions, and 3) completing the course assignments. The lecturers will be available and will promote addressing doubts related to the course contents in tutorship sessions. For this, the student will have a specific schedule that will be communicated by the lecturers at the beginning of the course.

5. A08 Evaluation (3 hours)

Time dedicated to the evaluation tasks of the course.

4.3. Syllabus

PART I: RGB-D Odometry and SLAM

In this first part of the course, the lecturer will provide the fundamentals and main techniques related to RGB-D odometry and SLAM, namely error functions and optimization details, iterative closest point (ICP) approaches, point cloud features and alignment and truncated signed distance functions (TSDF). The laboratory sessions will be devoted to specific implementations involving such concepts using the library Open3D.

PART II: Advanced SLAM topics of high novelty and scientific interest

In this second part, the lecturers will choose a set of technical documents, mainly scientific papers, that contain implementations and developments within SLAM that are very recent and have a high degree of interest. The students will select the papers and will lead the presentations and discussions on these topics, supervised by the lecturers on office hours on their understanding and presentation. The list of papers and the topics will be made available on the first day of the course.

4.4. Course planning and calendar

The lectures and laboratory sessions will be developed according to the schedule established by the Faculty center, that will be published on its website.

The learning activities and their dates and times, along with other related information and documentation on the course, will be published at http://moodle.unizar.es/

4.5. Bibliography and recommended resources

The first part of the course will follow mostly this book chapter:

Javier Civera, Seong Hun Lee. RGB-D Odometry and SLAM. Chapter6, pages 117?144, in Rosin P., Lai YK., Shao L., Liu Y. (eds) RGB-D Image Analysis and Processing. Advances in Computer Vision and Pattern Recognition. Springer, Cham, 2019. An arXiv pre-print is available at https://arxiv.org/pdf/2001.06875.pdf

For the second part of the course, the bibliography will consist on a list of scientific papers that will be made available the first day of the course. As the goal is working on very recent topics of high novelty, the bibliography will be updated very frequently as new papers on the topics of interest appear. For this reason, we do not give specific details in this section.