Course guide
240AR023 - 240AR023 - Mobile Robots & Navigation

Last modified: 16/05/2023

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 707 - ESAII - Department of Automatic Control.

Degree: MASTER'S DEGREE IN AUTOMATIC CONTROL AND ROBOTICS (Syllabus 2012). (Compulsory subject).
MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2014). (Optional subject).

Academic year: 2023 **ECTS Credits:** 4.5 **Languages:** English

LECTURER

Coordinating lecturer: Sanfeliu Cortes, Alberto

Others: Garrell Zulueta, Anais

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. The student know selecting appropriate software and hardware elements to implement a solution in a system wardrobe.
2. The student will acquire a set of knowledge and skills to basic and advanced level of mobile robotics, putting special emphasis on probabilistic models applied to mobile robotics.
3. The student will be able to analyze and determine the kinematic and dynamic models of robots and control systems design motion and strength.
4. The student will be able to recognize and represent problems in the area by automatic and robotic techniques optimization, and then apply analytical methods / numerical resolution.
5. The student will have knowledge to analyze, design and implement advanced robotic applications.

Generical:
6. Ability to conduct research, development and innovation in the field of systems engineering, control and robotics, and as to direct the development of engineering solutions in new or unfamiliar environments, linking creativity, innovation and transfer of technology
7. Ability to conduct strategic planning and apply it to both constructive systems of production, quality and optimal resource management.
8. Ability to reason and act based on the so-called culture of safety and sustainability
9. Have adequate mathematical skills, analytical, scientific, instrumental, technological, and management information.

Transversal:
10. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

11. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

12. SUSTAINABILITY AND SOCIAL COMMITMENT: Being aware of and understanding the complexity of the economic and social phenomena typical of a welfare society, and being able to relate social welfare to globalisation and sustainability and to use technique, technology, economics and sustainability in a balanced and compatible manner.

13. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

14. ENTREPRENEURSHIP AND INNOVATION: Being aware of and understanding how companies are organised and the principles that govern their activity, and being able to understand employment regulations and the relationships between planning, industrial and commercial strategies, quality and profit.

CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

CT5. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

CT5. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

CT5. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

CT6. (ENG) Capacitat d'adaptació als canvis, sent capaçd'aplicar tecnologirs noves i avançades i altres progressos rellevants, amb iniciativa i esperit innovador.
CT6. (ENG) Capacitat d'adaptació als canvis, sent capaçd'aplicar tecnologirs noves i avançades i altres progressos rellevants, amb iniciativa i esperit innovador.
CT6. (ENG) Capacitat d'adaptació als canvis, sent capaçd'aplicar tecnologirs noves i avançades i altres progressos rellevants, amb iniciativa i esperit innovador.

Basic:
CB 6. (ENG) Tenir i comprendre coneixements que aportin una base o oportunitat de ser originals en el desenvolupament i/o aplicació d'idees, sovint en un context d'investigació
CB 6. (ENG) Tenir i comprendre coneixements que aportin una base o oportunitat de ser originals en el desenvolupament i/o aplicació d'idees, sovint en un context d'investigació
CB 7. (ENG) Que els estudiants sàpiguen aplicar els coneixements adquirits i la seva capacitat de resolució de problemes en entorns nous o poc coneguts dintre de contextos més amplis (o multidisciplinars) relacionats amb la seva àrea d'estudi.
CB 7. (ENG) Que els estudiants sàpiguen aplicar els coneixements adquirits i la seva capacitat de resolució de problemes en entorns nous o poc coneguts dintre de contextos més amplis (o multidisciplinars) relacionats amb la seva àrea d'estudi.
CB 8. (ENG) Que els estudiants siguin capaços de d'integrar coneixements i enfrentar-se a la complexitat de formular judicis a partir d'una informació que, essent incompleta o limitada, inclogui reflexions sobre les responsabilitats socials i ètiques vinculades a l'aplicació del seus conexicements i judicis.
CB 8. (ENG) Que els estudiants siguin capaços de d'integrar coneixements i enfrentar-se a la complexitat de formular judicis a partir d'una informació que, essent incompleta o limitada, inclogui reflexions sobre les responsabilitats socials i ètiques vinculades a l'aplicació del seus conexicements i judicis.
CB 8. (ENG) Que els estudiants siguin capaços de d'integrar coneixements i enfrentar-se a la complexitat de formular judicis a partir d'una informació que, essent incompleta o limitada, inclogui reflexions sobre les responsabilitats socials i ètiques vinculades a l'aplicació del seus conexicements i judicis.
CB 9. (ENG) Que els estudiants sàpiguen comunicar les seves conclusions i coneixements (i darrers raonaments que els sostentin), a públics especialitzats i no especialitzats de manera clara i sense ambigüitats.
CB 9. (ENG) Que els estudiants sàpiguen comunicar les seves conclusions i coneixements (i darrers raonaments que els sostentin), a públics especialitzats i no especialitzats de manera clara i sense ambigüitats.
CB 9. (ENG) Que els estudiants sàpiguen comunicar les seves conclusions i coneixements (i darrers raonaments que els sostentin), a públics especialitzats i no especialitzats de manera clara i sense ambigüitats.

TEACHING METHODOLOGY

The course is taught carrying out theory/ problem lectures. Moreover, there will be laboratory classes of 2 h/session where the student will be taught to use specific software (Mobile Robot Toolbox) for the realization of the problems and practices.

LEARNING OBJECTIVES OF THE SUBJECT

The objective of this course is to provide students the basic concepts on the technology involved in mobility. "How the mobile robot proposes changes with time as a function of its control inputs?" or "How a mobile robot can move through real-world environments to accomplish its mission?" are some of the main questions in mobile robotics and are objectives of this course. The course also goes into high-level questions of cognition, localization, and navigation that can be performed using standard robot platforms equipped with sensor.
The students will acquire theoretical and practical knowledge in Mobile Robotics techniques by the presentation of real applications that illustrate the interest and needs of the presented techniques.
Learning Outcomes:
- Use techniques for sensor, localization, and maps generation for mobile robots navigation.
- Programming mobile robots.
- Knowing criteria for industrial robots implementation, as well as requirements for applications in service and social robotics.

Mandatory Contents:
- Probabilistic techniques for mobile robotics.
- Stochastic estimation in mobile robotics.
- Localization, maps generation and navigation.

STUDY LOAD

Type	Hours	Percentage
Hours small group	20,3	18.03
Hours large group	20,3	18.03
Self study	72,0	63.94

Total learning time: 112.6 h

CONTENTS

Locomotion

Description:
1.1 Introduction to the course
1.2 General concepts
1.3 Locomotion mechanisms
1.4 Wheeled and caterpillar robots
1.5 Legged mobile robots
1.6 Aerial robots
1.7 Underwater robots

Related activities:
Lab practices

Full-or-part-time: 9h
Theory classes: 2h
Practical classes: 1h
Self study : 6h

Wheeled mobile robots Kinematics & Dynamics

Description:
2.1 Type of wheels
2.2 Kinematics constraints
2.3 The Jacobian
2.4 Kinematics configurations
2.5 Pose estimation
2.6 Probabilistic model of the pose estimation
2.7 Dynamic model

Related activities:
Lab practices

Full-or-part-time: 18h
Theory classes: 4h
Practical classes: 2h
Self study : 12h

Perception

Description:
3.1 Introduction
3.2 Components perception systems
3.3 Type of perception sensors in robotics

Related activities:
Lab practices

Full-or-part-time: 9h
Theory classes: 2h
Practical classes: 1h
Self study : 6h

Planning of trajectoris

Description:
5.1 General concepts in path planning
5.2 Discrete planning
5.3 Motion planning: sampling-based motion planning

Related activities:
This subject has associated a visit to a mobile robot laboratory to see a real demo.

Full-or-part-time: 18h
Theory classes: 4h
Practical classes: 2h
Self study : 12h

Localization systems

Description:
6.1 Introduction
6.2 General concepts
6.3 Global localization
6.4 Local localization
6.5 Precise localization

Related activities:
This subject has associated a visit to a mobile robot laboratory to see a real demo.

Full-or-part-time: 9h
Theory classes: 2h
Practical classes: 1h
Self study : 6h

Probabilistic localization

Description:
7.1 General concepts
7.2 Kalman filter (KF, EKF, SI)
7.3 Probabilistic localization using Kalman filter
7.4 Particle filter
7.5 Probabilistic localization using Monte Carlo Localization

Related activities:
This subject has associated a visit to a mobile robot laboratory to see a real demo.

Full-or-part-time: 18h
Theory classes: 4h
Practical classes: 2h
Self study : 12h

Simultaneous localization and mapping

Description:
8.1 General concepts
8.2 SLAM algorithm using EKF
8.3 Advanced topics in SLAM
8.4 Autonomous exploration

Related activities:
This subject has associated a visit to a mobile robot laboratory to see a real demo.
Short project in autonomous exploration

Full-or-part-time: 24h 15m
Theory classes: 3h 30m
Practical classes: 1h 45m
Guided activities: 4h
Self study : 15h

Navigation

Description:
content english

Specific objectives:
4.1 General concepts in robot navigation
4.2 Control techniques to follow trajectories
4.3 The dynamic window approach (DWA) for navigation
4.4 Local navigation of the Tibi and Dabo robots
4.5 Navigation based on proactive kynodinamic planning using social force model
4.6 Navigation based on radar maps and nearness diagram

Related activities:
Lab practices

Full-or-part-time: 18h
Theory classes: 4h
Practical classes: 2h
Self study : 12h

GRADING SYSTEM

Through the course, the student will have homework to do to solve specific exercises. The professor will evaluate the homework. There will be also a short project that will be selected by the student. This short project will be presented and evaluated in an oral presentation.
Final grade= 20% (homework) + 40% (short project) + 40% (final exam)

For this course 2019-2020, due to the impact of the Convid-19 at the teaching of the subject and his evaluation, the evaluation will modify of the following form.â□¨â□¨

The final note will compound from four partial notes:â□¨â□¨

- Evaluation of the laboratory exercises of practices: 20% of the noteâ□¨
- Evaluation of the short-projects: 30% of the noteâ□¨
- Evaluation of the class exercises: 15% of the note
- Evaluation of the final exam: 35% of the note

EXAMINATION RULES.

The final exam will be individual, using the authorized support material and on the dates established in the academic calendar of the master.

For this course 2020-2021, because of the impact that is having the Convid-19 at the teaching of the subject and his evaluation, the final examination will be of the following form:â□¨â□¨

- The final examination will consist of a combination of conceptual questions and exercises

BIBLIOGRAPHY

Basic:

- LaValle, Steven M. Planning algorithms. New York: Cambridge University Press, 2006. ISBN 9780521862059.
- Corke, Peter I. Robotics, vision and control : fundamental algorithms in Matlab [on line]. 1st ed. New York: Springer, 2011 [Consultation: 05/04/2017]. Available on: http://dx.doi.org/10.1007/978-3-642-20144-8. ISBN 9783642201431.
- Siegwart, R.; Nourbakhsh, I. R.; Scaramuzza, D. Introduction to autonomous mobile robots [on line]. 2nd ed. Cambridge: MIT Press, cop. 2011 [Consultation: 24/03/2023]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=3339191. ISBN 9780262015356.
- Ollero Baturone, Aníbal. Robótica : manipuladores y robots móviles. Barcelona: Marcombo Boixareu, 2007. ISBN 9788426713131.

Complementary:

- Siciliano, B.; Khatib, O. (eds.). Springer handbook of robotics [on line]. 2on ed. Cham: Springer International Publishing, 2016 [Consultation: 29/03/2023]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-319-32552-1. ISBN 3319325523.

RESOURCES

Other resources:

Mobile robots