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

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.

General:
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.

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 capaç d’aplicar tecnologies noves i avançades i altres progressos rellevants, amb iniciativa i espírit 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’ides, 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 coneeguts dins de contextos més amplis (o multidisciplinars) relacionats amb la seva àrea d’estudi.
CB 8. (ENG) Que els estudiants sàpiguen aplicar els coneixements adquirits i la seva capacitat de resolució de problemes en entorns nous o poc coneeguts dins de contextos més amplis (o multidisciplinars) relacionats amb la seva àrea d’estudi.

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Hours small group</td>
<td>20,3</td>
<td>18.03</td>
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<tr>
<td>Hours large group</td>
<td>20,3</td>
<td>18.03</td>
</tr>
<tr>
<td>Self study</td>
<td>72,0</td>
<td>63.94</td>
</tr>
</tbody>
</table>
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 trajectories**

**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

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**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

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**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

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## 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

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## GRADING SYSTEM

Through the course, the student will have homework to do to solve specific exercises. The professor will evaluate the homework. There will also be 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.

The final note will compound from four partial notes:

- Evaluation of the laboratory exercises of practices: 20% of the note
- Evaluation of the short-projects: 30% of the note
- 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:*

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

BIBLIOGRAPHY

Basic:

Complementary:

RESOURCES

Other resources:
Mobile robots