# 240AR023 - Mobile Robots & Navigation

**Coordinating unit:** 240 - ETSEIB - Barcelona School of Industrial Engineering  
**Teaching unit:** 707 - ESAII - Department of Automatic Control  
**Academic year:** 2019  
**Degree:** MASTER'S DEGREE IN AUTOMATIC CONTROL AND ROBOTICS (Syllabus 2012). (Teaching unit Compulsory)  
MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2014). (Teaching unit Optional)  
**ECTS credits:** 4.5  
**Teaching languages:** English

### Teaching staff

**Coordinator:** ANTONIO-BENITO MARTÍNEZ VELASCO  
**Others:** ALBERTO SANFELIU CORTES  
JUAN ANDRADE CETTO

### 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 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.

Learning objectives of the subject

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.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 112h 30m</th>
<th>Hours large group:</th>
<th>20h 15m</th>
<th>18.00%</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Hours small group:</td>
<td>20h 15m</td>
<td>18.00%</td>
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<tr>
<td></td>
<td>Self study:</td>
<td>72h</td>
<td>64.00%</td>
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</tbody>
</table>
### Content

#### Locomotion

**Description:**
1.1 Introduction
1.2 Locomotion mechanisms. Key issues
1.3 Legged mobile robots
1.4 Wheeled mobile robot

**Learning time:** 4h  
Thyory classes: 1h  
Practical classes: 0h  
Self study: 3h

#### Wheeled mobile robots Kinematics & Dynamics

**Description:**
2.1 Types of wheels
2.2 Kinematics constrains: Forward and inverse kinematics models
2.3 Mobile robot manoeuvrability: Degree of mobility and steereability, robot manoeuvrability.
2.4 Wheeled robots structures
2.5 Dynamic model

**Learning time:** 22h  
Theory classes: 3h  
Practical classes: 4h  
Self study: 15h

#### Perception

**Description:**
3.1 Sensor classification
3.2 Characterizing sensor performance
3.3 Relative and absolute position sensor (GPS and Odometry)
3.4 Range sensing (Sonar, lidar)
3.5 Bearing sensor
3.6 Calibrating vision based sensor (cameras, 3Drange scanners and ToF cameras)

**Learning time:** 12h  
Theory classes: 2h  
Practical classes: 2h  
Self study: 8h
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<table>
<thead>
<tr>
<th>Motion Control of mobile robots</th>
<th>Learning time: 16h</th>
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>4.1 Moving to a point</td>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td>4.2 Moving to a pose (Dubbins curves)</td>
<td>Self study: 10h</td>
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<tr>
<td>4.3 Technics for path following</td>
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<td>4.3 Mission following</td>
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<table>
<thead>
<tr>
<th>Planning and navigation</th>
<th>Learning time: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>5.1 Definition of obstacle avoidance</td>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td>5.2 Reactive Navigation: Braitenberg vehicle and bug algorithms</td>
<td>Self study: 10h</td>
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<tr>
<td>5.3 Map based planning</td>
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<tr>
<td>Distance transform and D*</td>
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<tr>
<td>Voronoi Roadmap Method</td>
<td></td>
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<tr>
<td>Visibility graph</td>
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<td>Cell decomposition</td>
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<tr>
<td>Probabilistic Roadmaps methods, PRM</td>
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<tr>
<td>Rapidly-exploring random tree, RRT</td>
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</table>

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

**Description:**
- 6.1 Landmark-based navigation: Z shape, ceiling sheet
- 6.2 Globally unique localization: US, Signal strength
- 6.3 Positioning beacon systems
- 6.4 Route-based localization: magnetic paint path

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

### Probabilistic localization

**Description:**
- 7.1 Parametric and non-parametric state estimation
  - Kalman filter (EKF, UKF, EIF)
  - Particle filter
- 7.2 Propagation of uncertainty (first order models)
- 7.3 Dead reckoning
- 7.4 Map-based localization
  - Kalman filter localization
  - Markov localization

**Related activities:**
This subject has associated a visit to a mobile robot laboratory to see a real demo.
Simultaneous localization and mapping  Learning time: 18h

<table>
<thead>
<tr>
<th>Description</th>
<th>Learning time</th>
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</thead>
<tbody>
<tr>
<td>8.1 Mapping: feature based and occupancy grid mapping</td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>8.2 Simultaneous localization and mapping: feature based SLAM and pose SLAM</td>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td>8.3 Optimal navigation</td>
<td>Self study: 12h</td>
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<td>8.4 Autonomous exploration</td>
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</table>

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

Qualification 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)

Regulations for carrying out activities

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

Bibliography

Basic:


Complementary: