# 240AR012 - Robotics, Kinematics, Dynamics and Control

<table>
<thead>
<tr>
<th>Coordinating unit:</th>
<th>240 - ETSEIB - Barcelona School of Industrial Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching unit:</td>
<td>707 - ESAII - Department of Automatic Control</td>
</tr>
<tr>
<td>Academic year:</td>
<td>2019</td>
</tr>
<tr>
<td>Degree:</td>
<td>MASTER'S DEGREE IN AUTOMATIC CONTROL AND ROBOTICS (Syllabus 2012). (Teaching unit Compulsory)</td>
</tr>
<tr>
<td>ECTS credits:</td>
<td>6</td>
</tr>
<tr>
<td>Teaching languages:</td>
<td>English</td>
</tr>
</tbody>
</table>

## Teaching staff

- **Coordinator:** Rosell Gratacos, Joan
- **Others:** Rosell Gratacos, Joan
  Lampon Diestre, Cristina

## Prior skills

- Linear Algebra, Differential Calculus, notions of Linear and Non-linear Control Systems

## Requirements

No requisites.

## Degree competences to which the subject contributes

### Specific:

1. The student will be able to analyze and determine the kinematic and dynamic models of robots and control systems design motion and strength.
2. The student will be able to use analysis tools and computer-aided design of control systems in the tasks usual analysis, simulation and controller design.
3. The student will have knowledge to analyze, design and implement advanced robotic applications.

### Generical:

4. 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
5. Ability to reason and act based on the so-called culture of safety and sustainability
6. Have adequate mathematical skills, analytical, scientific, instrumental, technological, and management information.

### Transversal:

7. 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.
8. 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.
240AR012 - Robotics, Kinematics, Dynamics and Control

Teaching methodology

The theoretical contents of the course is developed in sessions of 1.5 h, two sessions per week, where the Professor explains the theory and also solves problems in order to improve the understanding of the units and to train the students in solving practical cases. Moreover, there are laboratory sessions, where the students use simulation packages and experiment with real robots.

The development of the master class sessions follows a methodology similar to that of a seminar, in which the active participation of the assistants is a fundamental aspect. In this sense, the professor's task is, essentially, to direct the session, presenting and setting the topics in a context, and leading the debate and the discussion among the students. To facilitate this debate and to foment the participation, the Professor introduces, at the end of each session, the topics that will be the object of the following one, so that the students can prepare them in advance, in accordance with the bibliographical orientations given by the Professor.

In the presentation of each topic, practical cases are analysed in order to introduce the students in the methodological aspects, and to show them the real difficulties, extent and limitations of the methods and studied techniques in the course.

Learning objectives of the subject

Robotics holds the study of those machines that can replace human beings in the execution of tasks, as regards both physical activity and decision making. In all robot applications, the realization of a task requires the execution of a specific motion prescribed to the robot. The correct execution of such motion is entrusted to the control system which should provide the robot's actuators with the commands consistent with the desired motion. Motion control demands an accurate analysis of the characteristics of the mechanical structure, actuators, and sensors. The goal of such analysis is the derivation of the mathematical (kinematic and dynamic) models describing the input/output relationship characterizing the robot components. Modelling a robot manipulator is therefore a necessary premise to develop motion control strategies.

The objective of the course is to introduce the methodological bases of the robots modelling and control, as well as the main theoretical and practical aspects of these topics. To reach this objective, the course presents the key ideas on robots' morphology, kinematics and dynamics, passing later to analyse the control of movements and force. The course contents are completed with the study of the control guided by vision concluding with practical aspects of the robot control systems architecture and programing.

The expected result of the course is that the students reach the necessary formation to tackle applied and research topics in the field of robot modelling and control.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group: 42h</th>
<th>28.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours small group: 6h</td>
<td>4.00%</td>
</tr>
<tr>
<td></td>
<td>Guided activities: 6h</td>
<td>4.00%</td>
</tr>
<tr>
<td></td>
<td>Self study: 96h</td>
<td>64.00%</td>
</tr>
</tbody>
</table>
# Content

## 1. Foundations

**Learning time:** 6h  
Theory classes: 6h

**Description:**  
1.1. Introduction  
1.2. Basic concepts of linear algebra and feedback control  
1.3. Rigid bodies and homogeneous transformations  
1.4. Robot modelling

## 2. Kinematics

**Learning time:** 18h  
Theory classes: 14h  
Practical classes: 2h  
Laboratory classes: 2h

**Description:**  
2.1. Direct kinematics  
2.2. Inverse kinematics problem  
2.3. Trajectory planning  
2.4. Geometric Jacobian / Analytical Jacobian  
2.5. Singularities and redundancy  
2.6. Inverse kinematics algorithms  
2.7. Statics and manipulability

**Related activities:**  
P1: Kinematic solutions and trajectory planning

## 3. Dynamics

**Learning time:** 12h  
Theory classes: 8h  
Practical classes: 2h  
Laboratory classes: 2h

**Description:**  
3.1. Lagrange formulation  
3.3. Properties of the dynamic model  
3.3. Dynamic model of simple manipulator structures  
3.4. Dynamic parameters identification  
3.5. Operational space dynamics model

**Related activities:**  
P2: Differential kinematics
4. Control

**Description:**
- 4.1. The control problem
- 4.2. Decentralized motion control
- 4.3. Feed-forward compensation
- 4.4. Centralized motion control
- 4.5. Force control
- 4.6. Visual servoing

**Related activities:**
- P3: Force control

**Learning time:** 18h
- Theory classes: 14h
- Practical classes: 2h
- Laboratory classes: 2h

---

**Qualification system**

Lab deliberables 25%; Problem deliverables: 15%; Final work: 25%; Final exam: 35%

**Regulations for carrying out activities**

Practical sessions are mandatory.
Bibliography

Basic:


Complementary:


Others resources:
Universal Robots Simulator - https://www.universal-robots.com/download/?option=38719#section16632
Universal Robots UR3 available at the ESAII robotics lab (second floor ETSEIB).

Hyperlink
On-line tutorial for computer-room sessions
https://sir.upc.edu/projects/kinematics_dynamics_control/