240AR012 - Robotics, Kinematics, Dynamics and Control

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 707 - ESAII - Department of Automatic Control
Academic year: 2018
Degree: MASTER'S DEGREE IN AUTOMATIC CONTROL AND ROBOTICS (Syllabus 2012). (Teaching unit Compulsory)
ECTS credits: 6
Teaching languages: English

Teaching staff
Coordinator: RITA MARIA PLANAS DANGLA
Others: Rita M. Planas
Raúl Suárez

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

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.

General:
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.
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.

**Learning objectives of the subject**

- **Total learning time:** 150h
  - Hours large group: 0h (0.00%)
  - Hours medium group: 26h 24m (17.60%)
  - Hours small group: 27h 36m (18.40%)
  - Guided activities: 0h (0.00%)
  - Self study: 96h (64.00%)

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.

**Teaching methodology**

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**Study load**
## Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td><strong>Robot morphology, sensing and actuation</strong></td>
<td>8h</td>
<td><strong>Description:</strong> Robot Structure and Components, Actuating System, Proprioceptive Sensors, Exteroceptive Sensors</td>
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<tr>
<td><strong>Kinematics</strong></td>
<td>42h 30m</td>
<td><strong>Description:</strong> Geometric transformations, Direct Kinematics, Kinematic Calibration, Inverse Kinematics, Differential Kinematics, Singularities</td>
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<tr>
<td><strong>Trajectory design</strong></td>
<td>14h</td>
<td><strong>Description:</strong> Paths and Trajectories, Joint Space Trajectories, Operational Space Trajectories</td>
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# 240AR012 - Robotics, Kinematics, Dynamics and Control

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<thead>
<tr>
<th><strong>Programming</strong></th>
<th><strong>Learning time:</strong> 11h 30m</th>
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<tr>
<td></td>
<td>Theory classes: 2h</td>
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<td></td>
<td>Practical classes: 1h</td>
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<td>Laboratory classes: 3h</td>
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<td>Self study: 5h 30m</td>
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**Description:**
- Programming Environments and languages
- Teaching-by-Showing
- Robot-oriented Programming
- Object-oriented Programming

**Related activities:**
Programming of several robotics tasks

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<th><strong>Dynamics</strong></th>
<th><strong>Learning time:</strong> 28h</th>
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<tr>
<td></td>
<td>Theory classes: 6h</td>
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<tr>
<td></td>
<td>Practical classes: 3h</td>
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<td>Laboratory classes: 3h</td>
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<td>Self study: 16h</td>
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**Description:**
- Lagrange Formulation
- Dynamic Parameter Identification
- Newton\(^2\)Euler Formulation
- Operational Space Dynamic Model

**Related activities:**
Analysis and simulation of the dynamic model of several robots
240AR012 - Robotics, Kinematics, Dynamics and Control

Control

Learning time: 31h
- Theory classes: 7h
- Practical classes: 3h
- Laboratory classes: 3h
- Self study: 18h

Description:
- Joint Space Motion Control
- Operational Space Motion Control
- Force Control
- Visual Servoing (Position-based and Image-based)
- Control Architecture

Related activities:
Simulation of the performance of several robots with various control schemes and verification of their performance.

Qualification system

The acquired competences and abilities will be evaluated on the basis of four evaluations:
- Grade and level of participation along the course in the lectures (contribution to the debate of the topics, formulation and resolution of questions,...) (10% of the mark of the course)
- Grade of resolution of the exercises of the problem classes (20% of the mark of the course)
- Grade of development of the practical works in the laboratory sessions (20% of the mark of the course)
- Grade of the final exam (50%)
Bibliography

Basic:


Complementary:


Others resources:

Peter Corke's Robotics Toolbox for MATLAB
http://petercorke.com/Robotics_Toolbox.html