Degree competences to which the subject contributes

Specific:
1. The student will be able to identify, obtain models, simulations, analyze and validate simple dynamic systems in adequate representation for the intended purpose (analysis, simulation and design).
2. The student will have knowledge to analyze, design and implement advanced robotic applications.

General:
3. 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.
4. Ability to conduct strategic planning and apply it to both constructive systems of production, quality and optimal resource management.

Learning objectives of the subject

Students attending this course must be able to:

a) Analyze the qualitative properties (logical correctness) and quantitative properties (performance) of robotic systems using Petri nets and discrete-event system simulation.
b) Describe the basic robot motion planning methods, both classic and sampling-based, and propose variants to the basic probabilistic roadmap methods (PRMs) and rapidly-exploring random trees (RRTs).
c) To describe the needs and requirements of software development in robotic applications and to use the Robotic Operating System (ROS) basic communication strategies for the integration of devices.
### Study load

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours medium group:</th>
<th>Hours small group:</th>
<th>Self study:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27h</td>
<td>27h</td>
<td>96h</td>
</tr>
<tr>
<td></td>
<td>18.00%</td>
<td>18.00%</td>
<td>64.00%</td>
</tr>
</tbody>
</table>
# Content

## 1. ROBOTIC SYSTEMS MODELLING USING PETRI NETS

**Description:**
Introduction to Petri nets as a modelling tool for robotic systems, and as a tool for the evaluation of their logical correctness by the analysis of their qualitative properties like boundness, liveness and reversibility.

**Related activities:**
Practical class using the PIPE software for modelling and analysis using Petri nets.

**Specific objectives:**
- To model discrete-event robotic systems using Petri nets.
- To analyze the qualitative properties of robotic systems using Petri nets.

<table>
<thead>
<tr>
<th>Learning time: 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Practical classes: 2h</td>
</tr>
</tbody>
</table>

## 2. DISCRETE-EVENT ROBOTIC SYSTEMS SIMULATION

**Description:**
Introduction to discrete-event system simulation as tool for the performance analysis of robotic systems.

**Related activities:**
Practical classes using the ARENA software for modelling and analysis of discrete-event systems.

**Specific objectives:**
- To explain the mechanisms of discrete-event system simulation.
- To model robotic systems for their performance analysis using a specialized software.
- To perform the output analysis of discrete-event simulations.
- To compare alternative systems designs.

<table>
<thead>
<tr>
<th>Learning time: 14h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 8h</td>
</tr>
<tr>
<td>Practical classes: 6h</td>
</tr>
</tbody>
</table>

## 3. ROBOT MOTION PLANNING: MODELLING ISSUES

**Description:**
Introduction to the geometric modelling of robotic systems and to the configuration space as the space where robot motion planning is to be done. Discussion of collision-check procedures and of sampling issues.

**Related activities:**
Practical classes using The Kautham Project planning environment.

**Specific objectives:**
- To describe the configuration space of a robot.
- To describe sampling sources and sampling bias techniques to explore the configuration space of a robot.

<table>
<thead>
<tr>
<th>Learning time: 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Practical classes: 2h</td>
</tr>
</tbody>
</table>
### 4. ROBOT MOTION PLANNING: CLASSICAL AND SAMPLING-BASED APPROACHES

<table>
<thead>
<tr>
<th>Learning time: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 10h</td>
</tr>
<tr>
<td>Practical classes: 6h</td>
</tr>
</tbody>
</table>

**Description:**

**Related activities:**
Practical classes using The Kautham Project planning environment and the Open MotionPlanning Library. Final work solving a planning problem using alternative planners.

**Specific objectives:**
- To describe the classical methods to robot motion planning and their limitations.
- To explain the core of sampling-based methods.
- To be able to propose improvements to the basic probabilistic roadmap planners and to the basic rapidly-exploring random trees.

### 5. IMPLEMENTATION OF ROBOTIC SYSTEMS

<table>
<thead>
<tr>
<th>Learning time: 12h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Practical classes: 4h</td>
</tr>
<tr>
<td>Laboratory classes: 4h</td>
</tr>
</tbody>
</table>

**Description:**
Introduction to the Robotic Operating System (ROS): a) publisher/subscriber and client/server communication issues; b) basic packages.

**Related activities:**
Practical classes in the computer classroom using the ROS software. Practical classes in the lab using the ROS software and some sensors and actuators.

**Specific objectives:**
- To describe the needs and requirements of software development in robotic applications.
- To use the Robotic Operating System (ROS) basic communication strategies for the integration of devices.
## Planning of activities

<table>
<thead>
<tr>
<th>PRACTICAL</th>
<th>Description</th>
<th>Hours</th>
<th>Support materials</th>
<th>Specific objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>P4</td>
<td>Comparison and evaluation of alternative system designs</td>
<td>2h</td>
<td>ARENA software</td>
<td>To evaluate the capacity to compare alternative robotic systems designs using discrete-event simulation with ARENA software.</td>
</tr>
<tr>
<td>P7</td>
<td>Planning with Probabilistic Roadmaps (PRMs)</td>
<td>2h</td>
<td>The Kautham Project + OMPL</td>
<td>To evaluate the analysis of the parameters of the PRMs in solving motion planning</td>
</tr>
<tr>
<td>P8</td>
<td>Planning with Rapidly-exploring Random Trees (RRTs)</td>
<td>2h</td>
<td>The Kautham Project + OMPL</td>
<td>To evaluate the analysis of the parameters of the RRTs in solving motion planning</td>
</tr>
<tr>
<td>P11</td>
<td></td>
<td>4h</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
240AR032 - Planning and Implementation of Robotic Systems

Description:
Put in practice the communication between devices using ROS

Support materials:
ROS

Descriptions of the assignments due and their relation to the assessment:
Report

Specific objectives:
To evaluate the capacity of establish communications between devices encapsulated as ROS nodes

PARTIAL EXAM

Description:
Written exam - computer room

Support materials:
PIPE - ARENA

Specific objectives:
To evaluate the capabilities of the students in modelling and analyzing discrete-event robotic systems.

FINAL EXAM

Description:
Written exam

Specific objectives:
To evaluate the knowledge acquisition related with the theoretical contents of the course.

FINAL WORK

Description:
Work on analysis of discrete-event robotic systems or on robot motion planning, to be performed in teams of two students.

Descriptions of the assignments due and their relation to the assessment:
Report and oral presentation.

Specific objectives:
To evaluate the capacity to deepen in the theoretical aspects of the course, the initiative and the implementation of solutions

Qualification system

Final assessment = 0.25*Partial Exam + 0.25*Final Exam + 0.25*Practicals reports + 0.25*Final work
Regulations for carrying out activities

The practical sessions are compulsory.
The final work can be done in teams of two students.

Bibliography

Basic:

