240201 - 240AR065 - Hybrid Systems

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 Optional)
ECTS credits: 4.5  Teaching languages: English

Teaching staff
Coordinator: Ramon Sarrate Estruch

Prior skills
Linear algebra, Modelling and control design of continuous/discrete time linear systems, Optimization and Discrete-event system theory.

Degree competences to which the subject contributes

Specific:
CEAR1. The student will be able to analyze and design linear systems (single and multiple variables, external and internal representation) and nonlinear systems. This includes their stability, controller design and evaluation of closed-loop response.
CEAR4. 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.

General:
CGAR1. Have adequate mathematical skills, analytical, scientific, instrumental, technological, and management information.
CGAR3. 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.

Teaching methodology
The methodology of the course combines face to face instruction such as master classes and practical sessions with self-study through the development of problem assignments. These methodologies are detailed in the activities description section.

Learning objectives of the subject
By the end of the course, students will be able to:
- Enumerate the main hybrid system frameworks, and describe their features.
- Apply hybrid system modelling techniques.
- Analyse hybrid systems to determine their properties and qualities, with special emphasis on stability and verification.
- Design control algorithms for hybrid systems.
- Use software tools for the modelling, simulation, analysis and control of hybrid systems.
# Study load

<table>
<thead>
<tr>
<th></th>
<th>Hours large group:</th>
<th>Hours small group:</th>
<th>Self study:</th>
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<tbody>
<tr>
<td><strong>Total learning time:</strong></td>
<td>112h 30m</td>
<td>30h 30.6m</td>
<td>72h</td>
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<td>9h 59.4m</td>
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<td>64.00%</td>
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- **Total learning time:** 112h 30m
- Hours large group: 30h 30.6m (27.12%)
- Hours small group: 9h 59.4m (8.88%)
- Self study: 72h (64.00%)
## 1. Introduction to hybrid systems

**Learning time:** 7h  
Theory classes: 2h 30m  
Self study: 4h 30m

**Description:**  
1.1. Hybrid system features  
1.2. Examples of hybrid systems  
1.3. Techniques for hybrid systems

**Related activities:**  
Master class, Problem assignment, Final examination

## 2. Modelling of hybrid systems

**Learning time:** 55h 45m  
Theory classes: 14h 45m  
Laboratory classes: 5h  
Self study: 36h

**Description:**  
2.1. Hybrid automata  
2.1.1. Definition and examples  
2.1.2. Properties  
2.1.3. Verification techniques  
2.2. Mixed logical dynamical systems  
2.2.1. Mathematical representation of PWA and MLD systems  
2.2.2. DHA and other formalisms  
2.2.3. Optimization-based reachability analysis

**Related activities:**  
Master class, Practical Session, Problem assignment, Final examination
3. Control of hybrid systems

<table>
<thead>
<tr>
<th>Description:</th>
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<tbody>
<tr>
<td>3.1. Stability analysis</td>
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<td>3.2. Model predictive control</td>
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<td>3.3. Explicit model predictive control</td>
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<td>3.4. Additional applications</td>
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<table>
<thead>
<tr>
<th>Related activities:</th>
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<tbody>
<tr>
<td>Master class, Practical Session, Problem assignment, Final examination</td>
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<table>
<thead>
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<th>Learning time:</th>
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<tbody>
<tr>
<td>49h 45m</td>
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<tr>
<td>Theory classes: 13h 15m</td>
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<tr>
<td>Laboratory classes: 5h</td>
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<tr>
<td>Self study: 31h 30m</td>
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**Planning of activities**

| **MASTER CLASS** | **Hours:** 25h  
Theory classes: 25h |
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<tr>
<td><strong>Description:</strong></td>
<td>The professor will explain the theory and introduce short examples to improve the understanding of the subject. Active participation of the students will be encouraged by the professor. Nine sessions of 3h per week will be scheduled for this activity.</td>
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<td><strong>Support materials:</strong></td>
<td>Slides and bibliography.</td>
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| **PRACTICAL SESSION** | **Hours:** 26h  
Laboratory classes: 10h  
Self study: 16h |
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<td><strong>Description:</strong></td>
<td>Numerical computer tools (such as MATLAB) will be used for the simulation and analysis of hybrid systems and the controller design. Practical assignments will be solved in pairs. Four sessions of 2.5h per week will be scheduled for this activity.</td>
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<td><strong>Support materials:</strong></td>
<td>Practical assignments, software tool user's guides, slides and bibliography.</td>
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<tr>
<td><strong>Descriptions of the assignments due and their relation to the assessment:</strong></td>
<td>Practical assignment reports</td>
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| **PROBLEM ASSIGNMENT** | **Hours:** 14h  
Theory classes: 2h  
Self study: 12h |
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<td><strong>Description:</strong></td>
<td>A problem to be solved individually at home will be proposed every week. The problem will involve theoretical and practical development, and the use of numerical computer tools. A solution will be provided by the professor the following week, in class.</td>
</tr>
<tr>
<td><strong>Support materials:</strong></td>
<td>Problem assignment, software tool user's guides, slides and bibliography.</td>
</tr>
<tr>
<td><strong>Descriptions of the assignments due and their relation to the assessment:</strong></td>
<td>Problem assignment reports</td>
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| **FINAL EXAMINATION** | **Hours:** 47h 30m  
Theory classes: 3h 30m  
Self study: 44h |
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<td><strong>Description:</strong></td>
<td>An exam will be scheduled at the end of the course, that will assess the full course contents. It will be an open book written exam that will be solved individually, possibly with the aid of numerical computer tools.</td>
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The acquired competences and capabilities will be assessed on the basis of three activities:

- practical assignment reports (30% of the course score)
- problem assignment reports (30% of the course score)
- final examination (40% of the course score)

Note: A re-assessment exam will be scheduled. Its score will replace the one of the final examination (40%).

**Bibliography**

**Basic:**


**Complementary:**

