240AR021 - Non Linear Control 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 Compulsory)
ECTS credits: 6

Teaching languages: English

Prior skills
The student should have basic skills in mathematics (linear algebra, elementary calculus, complex variable and linear differential equations) and automatic control (continuous-time linear systems, time and frequency domain approach).

Degree competences to which the subject contributes

Specific:
3. The student will be able to model, formulate and solve problems of control, taking into account its uncertainty, by Fuzzy logic based controllers.
5. 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.
9. 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).
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.

General:
1. Ability to lead, plan and monitor multidisciplinary teams.
2. Have adequate mathematical skills, analytical, scientific, instrumental, technological, and management information.

Transversal:
6. 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.
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.
Teaching methodology

The teaching methodology will combine lectures together with supervised learning based on problems and autonomous learning. The classes will be organized in regular theoretical teaching.

In addition to the theoretical sessions practical works will be performed, these sessions will take place in the computer room or the laboratory depending on the concrete topics to be addressed.

Learning objectives of the subject

To verify the differences between linear and nonlinear systems; and the difficulties encountered in attempting to justify the stability on the solution of nonlinear systems.

To present some fundamental results of nonlinear control, minimizing the mathematical complexity and showing their applicability.

Provide some general results for the analysis of nonlinear control systems and synthesis of controllers.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group:</th>
<th>36h</th>
<th>24.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours small group:</td>
<td>18h</td>
<td>12.00%</td>
</tr>
<tr>
<td></td>
<td>Self study:</td>
<td>96h</td>
<td>64.00%</td>
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</tbody>
</table>
## 1. Introduction to nonlinear control

**Learning time:** 25h  
Theory classes: 6h  
Practical classes: 4h  
Self study: 15h

### Description:
The main differences between linear and nonlinear systems will be introduced. Standard results of two-dimensional systems based on the phase-plane analysis will be provided.

### Related activities:
Lectures and problem/practice sessions

### Specific objectives:
The student should recognise the main differences between linear and nonlinear systems. He/she should be able to analyse planar nonlinear systems and to know elementary results related to the existence of limit cycles and the planar dynamics that are possible, including the Poincaré-Bendixon theorem.

## Analysis

**Learning time:** 50h  
Theory classes: 10h  
Practical classes: 10h  
Self study: 30h

### Description:
Several tools devoted to the analysis of nonlinear systems will be presented. For instance Lyapunov and LaSalle theorems for autonomous systems, Krasowskii theorem, Popov and the circle criteria for sector bounded nonlinearities. The descriptive function will be introduced as an optimal linear approximation to memoryless nonlinearities.

### Related activities:
Lectures and problem/practice sessions

### Specific objectives:
To learn the concepts of stability, asymptotic stability, exponential stability, local and global, to understand and know how to use the main results on the stability of equilibrium points in autonomous systems (Lyapunov theorems, LaSalle, Krasovskii). To recognise passive systems and their properties. To know the classical results of absolute stability of Lur'e type systems. To be able to analyse systems by descriptive function.
The evaluation will be based on three main elements: Partial Exam, Final Exam and Practical works. The student will get a mark for each of these elements; finally all these marks will be combined to generate the course mark according to:

\[ \text{Mark} = 0.3 \times \text{Partial Exam} + 0.3 \times \text{Final Exam} + 0.4 \times \text{Practical works} \]

Despite the exceptional situation of confinement due to the coronavirus pandemic, the evaluation mechanism will be the same. The only change will be that the assessment exercises will become non-presential.

Those students which do not pass the course will have the chance to be reevaluated, on July, through a reevaluation exam. In this case, the course mark will correspond to the reevaluation exam mark.

### Qualification system

The exams will be performed individually. During the exams only a calculator will be available for the students.

Practical works will be performed in couples.

### Bibliography

- **Controller's synthesis**
  - **Learning time:** 60h
    - Theory classes: 12h
    - Practical classes: 12h
    - Self study: 36h

  **Description:**
  Elementary tools to design nonlinear control systems will be presented. Namely, sliding mode control, passivity based control, control using feedback linearization and change of state variables, and adaptive control. Finally, an analytical introduction to fuzzy control is given.

  **Related activities:**
  Lectures and problems/practice sessions.

  **Specific objectives:**
  The student should be able to synthesize controllers for elementary nonlinear systems in several domains (variable structure systems, passive, static linearization, adaptive, ...) He/she should have sufficient background and tools to gradually be able to learn from the specialized literature.