340602 - SIOP-R1O43 - Simulation and Optimization

Coordinating unit: 340 - EPSEVG - Vilanova i la Geltrú School of Engineering
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2017
Degree: MASTER'S DEGREE IN AUTOMATIC SYSTEMS AND INDUSTRIAL ELECTRONICS (Syllabus 2012). (Teaching unit Compulsory)
ECTS credits: 5
Teaching languages: Catalan, Spanish, English

Coordinator: IMMACULADA MASSANA HUGAS
Others: Carles Batlle Arnau

Prior skills

Ability to apply the basic tools of multivariable calculus and differential equations.

Degree competences to which the subject contributes

Specific:
1. CG04- Ability to research, design, develop and implement simulation methods for the control of electronic systems, automatic and robotic
2. CB9 - Students can communicate their conclusions, knowledge and rationale underpinning these, to skilled and unskilled public in a clear and unambiguous way
3. CB7 - Students can apply their knowledge and their ability to solve problems in new or unfamiliar contexts within broader (or multidisciplinary) contexts related to their field of study

Teaching methodology

In the lectures the instructor presents some motivating ideas, the fundamental concepts and some relevant developments, intermingled with key examples and the resolution of representative problems.

In laboratory classes the students learn to use MATLAB to solve different kinds of problems that will be assigned in each session. Every week, the second session will be assessed.

Learning objectives of the subject

1. Calculate the curve (function) that maximizes or minimizes an integral (functional).
2. Know if a system described by ODE (state space) can be controlled by an external input (control function).
3. Compute the optimal control for systems controllable.
4. Know and use MATLAB to solve ODE numerically.
5. Use MATLAB to solve different kind of exercises.
Study load

<table>
<thead>
<tr>
<th></th>
<th>Hours large group:</th>
<th>Hours medium group:</th>
<th>Hours small group:</th>
<th>Guided activities:</th>
<th>Self study:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total learning time:</strong></td>
<td>125h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>22h 30m</td>
<td>0h</td>
<td>22h 30m</td>
<td>0h</td>
<td>80h</td>
</tr>
<tr>
<td></td>
<td>18.00%</td>
<td>0.00%</td>
<td>18.00%</td>
<td>0.00%</td>
<td>64.00%</td>
</tr>
</tbody>
</table>
# 1. Introduction

**Learning time:** 2h  
Theory classes: 1h  
Self study : 1h  

**Description:**  
We introduce with historic examples the several problems that we explain in this subject: optimal function, calculus of variations and optimal control problems.

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# 2. Calculus of variations

**Learning time:** 16h  
Theory classes: 5h  
Self study : 11h  

**Description:**  
2.1 Problem Statement.  
2.2 Basic theory: necessary condition, Euler-Lagrange equation.  
2.3 Particular cases.  
2.4 Generalizations of the Euler-Lagrange equation.  
2.5 Variable endpoints.

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# 3. Lagrange Multipliers

**Learning time:** 6h  
Theory classes: 2h  
Self study : 4h  

**Description:**  
3.1 Constrained maximization or minimization of a function: Lagrange multipliers theory.  
3.2 Constrained calculus of variations.

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# 4. Controllability

**Learning time:** 6h  
Theory classes: 2h  
Self study : 4h  

**Description:**  
4.1 Controllability of control linear systems.  
4.2 Examples.
## 5. Optimal Control

**Description:**
- 5.1 Problem statement.
- 5.2 Hamiltonian.
- 5.3 Pontryagin’s minimum principle (PMP).
- 5.4 Property of the Hamiltonian.

**Learning time:** 8h
- Theory classes: 3h
- Self study: 5h

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## 6. Linear quadratic problem (LQP)

**Description:**
- 6.1 Linear quadratic problems.
- 6.2 Riccati equations.
- 6.3 Examples.

**Learning time:** 6h
- Theory classes: 2h
- Self study: 4h

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## 7. Pontryagin’s Minimum Principle. Piecewise continuous control

**Description:**
- The time-optimal control.

**Learning time:** 8h
- Theory classes: 3h
- Self study: 5h

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## 8. MATLAB Simulation (first part)

**Description:**
- 8.1 Introduction.
- 8.2 MATLAB as advanced calculator.
- 8.3 Scripts and functions.
- 8.4 Vectors and matrices.
- 8.5 The ode45 MATLAB function.
- 8.6 Optimization.

**Learning time:** 24h
- Laboratory classes: 16h
- Self study: 8h
### Planning of activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Hours</th>
<th>Time Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A1:</strong> FIRST LABORATORY EXAM WITH MATLAB (SUBJECT 8 and 9)</td>
<td>9.1 The SIMULINK. 9.2 Simulation of systems and processes.</td>
<td>4h</td>
<td>Guided activities: 2h  Self study: 2h</td>
</tr>
<tr>
<td><strong>A2:</strong> FIRST PARTIAL EXAM (SUBJECTS 2, 3 AND 4)</td>
<td></td>
<td>6h</td>
<td>Guided activities: 2h  Self study: 4h</td>
</tr>
<tr>
<td><strong>A3:</strong> SECOND PARTIAL EXAM (SUBJECTS 5, 6 AND 7)</td>
<td></td>
<td>6h</td>
<td>Guided activities: 2h  Self study: 4h</td>
</tr>
<tr>
<td><strong>A4:</strong> FINAL EXAM (SUBJECTS 2, 3, 4, 5, 6 AND 7)</td>
<td></td>
<td>8h</td>
<td>Guided activities: 2h  Self study: 6h</td>
</tr>
</tbody>
</table>

### Qualification system

Final grade will be obtained from one of the following formulas:

1. 30% A1, 35% A2 and 35% A3.
2. 30% A1 and 70% A4.

A4 is the only re-gradable activity.

### Regulations for carrying out activities

The conditions for carrying out the written exams will be announced in each case in due time. Activities A3 and A4 will be the same day and, therefore, only one of them can be carry out.
Bibliography

Basic: