Course guide
340602 - SIOP-R1043 - Simulation and Optimization

Unit in charge: Vilanova i la Geltrú School of Engineering
Teaching unit: 707 - ESAII - Department of Automatic Control.

Degree: MASTER'S DEGREE IN AUTOMATIC SYSTEMS AND INDUSTRIAL ELECTRONICS (Syllabus 2012).
(Compulsory subject).

Academic year: 2023  ECTS Credits: 5.0  Languages: Spanish

LECTURER

Coordinating lecturer: FRANCISCO JAVIER RUIZ VEGAS
Others: FRANCISCO JAVIER RUIZ VEGAS

PRIOR SKILLS

Ability to apply the basic tools of multivariable calculus and differential equations. Basic theory of control systems.

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 o SIMULINK to solve different kinds of problems that will be assigned in each session.

LEARNING OBJECTIVES OF THE SUBJECT

1. Know the basics of static optimization with and without constraints.
2. Calculate the curve (function) that maximizes or minimizes an integral (functional).
3. Determine the optimal control for continuous controllable systems.
4. Determine the optimal control for discrete controllable systems.
5. Estimate in an optimal manner the states or the parameters of a system. Kalman filters.
6. Know and use MATLAB and SIMULINK to solve ODE numerically.
7. Use MATLAB and SIMULINK to solve different kind of exercises.
STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours large group</td>
<td>22.5</td>
<td>18.00</td>
</tr>
<tr>
<td>Self study</td>
<td>80.0</td>
<td>64.00</td>
</tr>
<tr>
<td>Hours small group</td>
<td>22.5</td>
<td>18.00</td>
</tr>
</tbody>
</table>

Total learning time: 125 h

CONTENTS

1. Estatic Optimization

Description:
1.1 Unconstrained Optimization in $\mathbb{R}^n$.
1.2 Equality constrained Optimization in $\mathbb{R}^n$. Lagrange Multipliers.
1.3 Equality and inequality constrained Optimization in $\mathbb{R}^n$. Karush-Kuhn-Tucker conditions.
1.4 Convexity.
1.5 Convex optimization problems. Linear programming, quadratic programming.
1.6 Numerical methods.

Specific objectives:
1. To know the basics of optimization of several variables functions, constrained and unconstrained.
2. To solve manually problems of optimization.
3. To know the computer tools for solving optimization problems.

Related activities:
P1, P2, S and R

Full-or-part-time: 16h
Theory classes: 4h
Laboratory classes: 4h
Self study: 8h
2. Calculus of variations

**Description:**
2.2 Basic theory: necessary condition, Euler-Lagrange equation.
2.3 Second order necessary condition.
2.4 Particular cases.
2.5 Generalizations of the Euler-Lagrange equation.
2.6 Variable endpoints. Transversality conditions.
2.7 Optimization of functionals with constraints.

**Specific objectives:**
1. To recognize a calculus of variations problem.
2. To know the Euler-Lagrange equations and the transversality conditions.
3. To solve differential equations.
4. To solve problems of functional optimization, unconstrained and constrained.

**Related activities:**
P1, P2, S and R

**Full-or-part-time:** 16h
- Theory classes: 4h
- Laboratory classes: 4h
- Self study: 8h

3. Optimal Control in continuous systems

**Description:**
3.1 Problem statement.
3.2 Hamiltonian.
3.3 Pontryagin's minimum (or maximum) principle (PMP).
3.4 Sufficient conditions.
3.5 Linear Quadratic Regulator (LQR).

**Specific objectives:**
1. To know relating optimal control problems with calculus of variations.
2. To know solving a problem of optimal continuous problem.
3. To know how to use the computational tools that help to solve problems of continuous optimal control.

**Related activities:**
P1, P2, S and R

**Full-or-part-time:** 16h
- Theory classes: 4h
- Laboratory classes: 4h
- Self study: 8h
4. Optimal control in discrete systems

Description:
4.2. Solution through Lagrange multipliers.
4.3. Solution through Dynamic programming
4.4. Discrete LQR control.

Specific objectives:
1. To know how to pose a discrete optimal control problem. To know the different performance index.
2. To know how to pose and solve a discrete optimal control problem using the Lagrange multipliers method and with the help of MATLAB.
2. To know how to pose and solve a discrete optimal control problem using dynamic programming method and with the help of MATLAB.

Related activities:
P2, S and R

Full-or-part-time: 16h
Theory classes: 4h
Laboratory classes: 4h
Self study: 8h

5. Optimal estimation. Kalman Filter

Description:
5.1 Introduction to Estimation.
5.2 State estimation. Kalman filter.
5.3 Parameter estimation. Least squares estimation.

Specific objectives:
1. To know the concept of State observer.
2. To know how to implement a Kalman filter using MATLAB.
3. To know how to identify the system parameters using least squares method.
4. To apply the Kalman filter for system identification.

Related activities:
P2, S and R

Full-or-part-time: 16h
Theory classes: 4h
Laboratory classes: 4h
Self study: 8h
8. MATLAB and SIMULINK Simulation

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

Specific objectives:
1. To know MATLAB and Simulink enviroment.
2. To use MATLAB as a scientific calculator.
3. To write scripts and function in MATLAB.
4. To use MATLAB for simulating real problems.
5. To know how to represent and interpret results.
6. To use MATLAB to found exact solutions of differential equations.
7. To know different numerical methods implemented in MATLAB and how to implement new numerical methods
8. To know how to use MATLAB to solve exercices proposed in theorical classes.
3. Saber crear scripts y funciones en MATLAB y saber diferenciarlos.
4. Usar MATLAB para simular diferentes problemas físicos o de otro tipo.

Related activities:
S

Full-or-part-time: 40h 40m
Laboratory classes: 14h
Self study : 26h 40m

ACTIVITIES

P1: Midterm of the first three chapters

Description:
Midterm exam of the first three chapters of the course.

Material:
Notes of the course and exam statement.

Full-or-part-time: 2h
Guided activities: 2h

P2: Final exam or second term exam

Description:
The student will be able to choose between doing a second term exam (topics 4 5 6) or a final exam (topics 1 to 6)

Full-or-part-time: 2h
Guided activities: 2h
**R: Retake exam**

**Description:**
Retake exam for students who have not passed the course. Topics 1 to 5. (Following School regulations)

**Full-or-part-time:** 2h
Guided activities: 2h

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**S: Practice of MATLAB-SIMULINK**

**Description:**
Practice of the topics of the course with MATLAB and SIMULINK.

**Delivery:**
Individual report and questionnaire about each practice.

**Full-or-part-time:** 10h
Guided activities: 10h

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**GRADING SYSTEM**

The final grade is:

Grade $= \max(0.7 \times P2, 0.35 \times P1 + 0.35 \times P2) + 0.3 \times S$

The final exam is the only re-gradable exam.

Grade $= 0.7 \times R + 0.3 \times S$ with the limits and constraints included on the School regulations.

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**EXAMINATION RULES.**

The conditions for carrying out the written exams and practice reports will be announced in each case in due time.

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**BIBLIOGRAPHY**

**Basic:**