Universidad Rey Juan Carlos

# TEACHING GUIDE

# ARTIFICIAL INTELLIGENCE AND LEARNING

## GRADO EN INGENIERÍA BIOMÉDICA (INGLÉS) (3º y 4º curso) (2374)

## ACADEMIC YEAR 2026-27

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| I.-Subject Identification | |
|---|---|
| **Type** | OBLIGATORIA |
| **Teaching period** | 3 course, 1Q semester |
| **Nº of credits** | 3 |
| **Language in wich the subject is taught** | English |

## II.-Presentation

Optimization is a branch of mathematics and engineering devoted to the study of methods for improving the performance, design, or decision-making of systems subject to specific constraints. Its aim is to formulate problems in terms of variables, objective functions, and constraints, and to develop tools for finding optimal or sufficiently good solutions in real-world contexts. Although the foundations of differentiable function optimization have a long historical tradition, the field has become increasingly relevant in recent decades. Access to large volumes of data, greater computational power, new algorithmic developments, and the growing prevalence of complex systems arising from the interaction of multiple subsystems have significantly expanded both the scope and applications of optimization.

This shift has had two particularly important consequences. On the one hand, optimization techniques have become essential tools in science and engineering, with applications in areas such as machine learning, data science, planning, system design, signal analysis, and biomedical engineering. On the other hand, the complexity of current problems has driven the development of new models, numerical methods, and computational tools capable of addressing large-scale problems with diverse constraints and, in many cases, continuous, discrete, or integer variables.

This course introduces students to multivariable optimization, with particular emphasis on the modeling and formulation of constrained and unconstrained optimization problems. Throughout the course, students will study the main concepts related to differentiable, convex, linear, and integer optimization, as well as the fundamental differences among these classes of problems. They will also use optimization software tools to solve representative models and analyze their solutions, with attention to their interpretation in engineering contexts.

**Prerequisites and recommendations:** It is highly advisable that students have previously taken the courses **Calculus**, **Algebra**, and **Mathematical Methods in Bioengineering**.

## III.-Learning outcomes

CG01 . Analyze and synthesize problems related to biomedical engineering, solve them and communicate them efficiently.
CG02. Use computational and experimental tools for the analysis and quantification of biomedical engineering problems
CB1. Proven knowledge and understanding of an area of study based on general secondary education and at a level which, although supported by advanced text books, also includes certain aspects that imply knowledge from the forefront of the field of study.
CB5 . That students have developed the learning skills needed to undertake further studies with a considerable degree of autonomy.
CE04. Solve mathematical problems that may arise in biomedical engineering by applying knowledge and concepts related to optimization.

- Key for degrees not adapted to RD 822/21: **CB** - basic competences, **CG** - generic competences, **CE** - specific competences, **CT** - transversal competences.
- Key for degrees adapted to RD 822/21: **CON** - knowledge, **COM** - competences, **HAB** - skills.

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## IV.-Contents

### IV.A.-Syllabus

1. Fundamentals of optimization.
   - Definitions and basic concepts of optimization.
   - Mathematical formulation of optimization problems: variables, objective function, and constraints.
   - Classification of optimization problems.
   - Introduction to methods for solving optimization problems.
2. Unconstrained optimization.
   - Local and global minima. Stationary points for differentiable functions.
   - First- and second-order necessary and sufficient optimality conditions.
   - Gradient descent and variants.
   - Newton's method and modified Newton's method.
3. Convex optimization.
   - Convex sets and convex functions.
   - Basic properties of convex problems.
   - Linear programming and convex quadratic programming.
   - Examples of convex problems in engineering.
4. Constrained optimization and duality.
   - Optimization problems with equality and inequality constraints.
   - Lagrange multipliers.
   - Karush-Kuhn-Tucker (KKT) conditions.
   - Introduction to duality.
   - Dual and primal-dual algorithms.
5. Linear optimization and mixed-integer linear programming.
   - Linear problems with linear constraints: structure and simplex method.
   - Mixed-integer linear programming: structure, relaxations, and basic algorithms.
   - Interpretation of solutions and use of optimization software tools.
6. Applications in biomedical engineering.
   - Optimization models for decision-making in biomedical systems.
   - Applications of optimization in biomedical data analysis, medical signal processing, and the design of computational tools for healthcare engineering.

### IV.B.-Training activities

| Type | Title |
|---|---|
| Experimental and/or technological laboratories | Laboratory practices with specific software. |
| Practical sessions | Problem-solving practices. |
| Theoretical sessions | Classroom lectures. |
| Test and/or exams | Tests and exams. |
| Academic tutorials | Office hours for individual or group Q&A. |

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| V.-Student workload | |
|---|---|
| Theoretical sessions | 14 |
| Resolution of exercises, problems, case studies, etc. | 8 |
| Practical sessions in experimental, technological and clinical laboratories, fieldwork, etc. | 5 |
| Tests and/or exams | 3 |
| Academic tutorials | 7 |
| Related activities: conferences, seminars, etc. | 17 |
| Preparation of theoretical sessions and self-study | 20 |
| Preparation of practical tasks, exercises, case studies, projects, etc. | 5 |
| Preparation for tests and/or exams | 11 |
| Total student workload | 90 |

**VI.-Methodology and academic programme**

| Type | Period | Content |
|---|---|---|
| Theoretical sessions | Week 1 to Week 15 | Lectures |
| Practical sessions | Week 3 to Week 15 | Problem-solving practices. |
| Experimental and/or technological laboratories | Week 3 to Week 15 | Laboratory practices with specific software. |
| Tests and/or exams | Week 16 to Week 18 | Final exam |
| Academic tutorials | Week 2 to Week 16 | Office hours for individual or group Q&A. |

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## VII.-Assessment methods

The general assessment method is continuous as established in the *Regulation for the Assessment of Learning Outcomes* of Rey Juan Carlos University.
All the assessment systems established in the degree report must be employed, except for those that have a minimum weight of 0%, which can be used by professors in the academic years they consider relevant. Each assessment system may be applied through one or more assessment activities, consistent with the system. No assessment activity can exceed individually 60% of the overall grade for the subject.
The sum of non re-evaluable activities cannot exceed 40% of the overall grade for the subject and, in general, should not have an established minimum grade (except for practical activities in which, strictly speaking, the conditions of the ordinary call cannot be reproduced in the extraordinary call).
Those students who do not manage to pass the subject in the ordinary call, or do not attend this first call, may attend the extraordinary call only for failed re-evaluable assessment activities.
The distribution and characteristics of the assessment activities are described below.

### VII.A.-Description and weight of the assessment activities

*The assessment procedure and criteria for students who apply for the early call shall be the same as in the ordinary and extraordinary calls.*

**Ordinary call:**

The ordinary assessment of the course will be carried out according to the following assessment systems and activities:

- A midterm exam, which will account for 25% of the final grade. The exam will include practical, theoretical-practical, and analytical questions.
- A final exam (scheduled in the official examination calendar), which will account for 50% of the final grade. The exam will include practical, theoretical-practical, and analytical questions.
- Submission of code and a laboratory practical exam, which will account for 25% of the final grade. The exam will take place on the date set in the official examination calendar.

The activities listed above do not have a minimum grade requirement and may be reassessed in the extraordinary call. To pass the course in the ordinary call, students must meet the following two conditions:

- Obtain a minimum score of 5 out of 10 in the overall course grade.
- Obtain a minimum grade of 4.7 in the weighted average of the theory exams (such that 33.33%*Midterm Exam Grade + 66.67%*Final Exam Grade >= 4.7).

**Extraordinary call:**

Students who have not passed the ordinary call because they have not met the two conditions above may sit the extraordinary call.
In the extraordinary call, students may sit and be reassessed in any of the three assessment activities they did not pass in the ordinary call (midterm exam, final exam, or practical work).
To pass the course in the extraordinary call, students must meet the following two conditions (the same as in the ordinary call):

- Obtain a minimum score of 5 out of 10 in the overall course grade.
- Obtain a minimum grade of 4.7 in the weighted average of the theory exams (such that 33.33%*Midterm Exam Grade + 66.67%*Final Exam Grade >= 4.7).

### VII.B. Assessment of students with academic exemption from class attendance

Having Academic Exemption from Class Attendance (DAAC) does not imply that students are automatically exempt from participating in the continuous assessment activities or in the training activities of compulsory attendance as established in the teaching guide. Once the exemption has been granted, students must contact the subject's teaching staff, who will propose the adaptations he/she may consider relevant, as long as they guarantee the acquisition and adequate assessment of the learning goals established. Students must maintain adequate communication with the teaching staff so that they may provide information on the dates for training and assessment activities, if these are not established in the programme and available for students at the time of achieving the exemption.
Subject with possibility of academic exemption: Yes.

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**VII.C. Review of assessment activities**

In accordance with the Regulation for the Assessment of Learning Outcomes of Rey Juan Carlos University.

**VII.D.-Students with a disability or special educational needs**

In order to guarantee equal opportunities, non-discrimination, universal accessibility and academic success, students with disabilities or especial education needs may request curricular adaptations to follow their studies. These adaptations will be provided by the Unit of Attention to People with Disabilities of Rey Juan Carlos University, in accordance with the regulation which regulates the service for the Attention of People with Disabilities at the University. This Unit will issue a report for curricular adaptations, so that students with disabilities or special education needs must contact the service (at e-mail discapacidad.programa@urjc.es) in order to provide relevant information for different educational alternatives.

**VII.E.-Academic behaviour, academic integrity and honesty**

Rey Juan Carlos University is fully committed to the highest standards of academic integrity and honesty, so studying at the URJC means assuming and subscribing to the values of integrity and academic honesty set out in the University's Ethical Code. To support this process, the University has Rey Juan Carlos University's Academic Conduct Regulation as well as different tools (anti-plagiarism, supervision...) that offer a collective guarantee for the full development of these essential values.

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| VIII.-Teaching resources and materials |
|---|
| **Basic bibliography** |
| Stephen Boyd and Lieven Vandenberghe, “Convex Optimization”, Cambridge University Press, 2004. |
| **Consultation bibliography** |
| Dimitri P. Bertsekas. "Convex Optimization Theory". Athena Scientific, Belmont, Massachusetts |

| IX.-Professors | |
|---|---|
| **Name and surname** | LUIS MIGUEL LÓPEZ RAMOS |
| **E-mail address** | luismiguel.lopez@urjc.es |
| **Department** | Teoría de la Señal y Comunicaciones y Sistemas Telemáticos y Computación |
| **Campus** | Fuenlabrada |
| **Category** | Profesor/a Ayudante Doctor/a |
| **Academic degree** | Doctor |
| **Person responsible for the subject** | No |
| **Tutorial timetable** | Para consultar las tutorias póngase en contacto con el/la profesor/a a través de correo electrónico |
| **Number of quinquennia** | 0 |
| **Number of sexennia** | 1 |
| **No. of positive evaluations by Docentia** | 0 |
| | |
| **Name and surname** | VÍCTOR MANUEL TENORIO GÓMEZ |
| **E-mail address** | victor.tenorio@urjc.es |
| **Department** | Teoría de la Señal y Comunicaciones y Sistemas Telemáticos y Computación |
| **Campus** | Fuenlabrada |
| **Category** | Profesor/a Ayudante Doctor/a |
| **Academic degree** | Doctor |
| **Person responsible for the subject** | No |
| **Tutorial timetable** | Para consultar las tutorias póngase en contacto con el/la profesor/a a través de correo electrónico |
| **Number of quinquennia** | 0 |

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