GENERAL INFORMATION

Course information	
Name	Deterministic optimization
Code	MRE-511
Degree	Master's Degree in Research in Engineering Systems Modeling (MRE)
Year	1st
Semester	1st (Fall)
ECTS credits	3
Type	Compulsory
Department	Industrial Organization
Area	Statistics and Operations Research
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DETAILED INFORMATION

Contextualization of the course

Contribution to the professional profile of the degree

This subject introduces the student in simulation and data analysis techniques for supporting decision-making.

Specifically, the contributions of this course to the professional profile are the following:

- Knowing the application of system simulation in real environments, pros and cons of their use.
- Designing and developing simulation models using a simulation language
- Understanding the representation of the uncertainty in input data and analyzing the results for extracting conclusions
- Developing a practical work applied to support decisions in a realistic case study
- Understanding queuing theory applied to open and closed systems and the link with simulation
- Understanding different data analysis techniques to extract information from data available, being either static or dynamic
- Applying these data analysis techniques to some data sets and extracting conclusions about the information

This subject has both theoretical and practical components, based on the exposition and discussion of each topic but also on the application of the simulation and data analysis techniques to realistic case studies.

Prerequisites

Students willing to take this course should be familiar with linear algebra, and undergraduate-level programming. Previous experience with any modeling language is also desired although not strictly required.

CONTENTS

Contents
Theory
Chapter 1. Linear Optimization
1.1 Graphical simplex method. Algebraic simplex. Tabular form 1.2 Revised simplex. Product form of the inverse. Reduced costs. Dual variables 1.3 Primal-dual interior point method
Chapter 2. Modeling of Mixed Integer Linear Programming Problems
2.1. Piecewise linear. Convex and concave regions. Special ordered sets. Reformulation.
Chapter 3. Mixed Integer Linear Optimization
3.1 Branch and bound. Duality. Preprocessing. Branch and cut.
Chapter 4. Nonlinear Optimization
4.1 Unconstrained problem optimality conditions. Unconstrained problem solution methods. Constrained problem optimality conditions. Constrained problem solution methods. Conjugate gradient

Competences and Learning Outcomes

Competences

General Competences

Basic Competences

CB1. To learn advanced scientific knowledge and to demonstrate, in a context of scientific and technological research highly specialized, a detailed understanding of theoretical and application aspects and the methodology of work in one or more study fields.

CB2. To know how to apply and integrate knowledge, the understanding of it, its scientific basis, and problem-solving capabilities in new and loosely defined environments, including multidisciplinary contexts, both for research and highly-specialized professions.

Specific Competences

CE2. To understand the usual optimization techniques and their mathematical principles, and also their potential to be used in different contexts.

CE3. To apply the different existing optimization techniques in the expression of problems and their solution.

Learning outcomes

At the end of the course the student must have the following competences:

RA1. Understand where to use and concepts of deterministic optimization.

RA2. Become familiar within the several topics where deterministic optimization can be applied

RA3. Know how to build an optimization model efficiently

RA4. Achieve mathematical rigorousness

RA5. Understand the mathematical techniques used

RA6. State and solve mockup problems

RA7. Analyze the solutions

RA8. Be prepared to extend their knowledge

RA9. Become familiar with an algebraic language used professionally

TEACHING METHODOLOGY

General methodological aspects	
The objective is improving the learning and incentivizing the autonomous and critical thinking of the students. For that purpose the following teaching resources are used. The teaching resources mentioned require the active participation of the student. It is indispensable that the class activity would be complemented with the personal work of the student and, coherently, it will be taken into account to assess the student performance.	
In-class activities	**Competences**
▪ **Master lectures (20h):** presentation of the contents of the subject.	CB1, CB2, CE2
▪ **Public presentation of the assignments (10h)**	CE3
Out-of-class activities	**Competences**
▪ **Personal work of the student (30h):** study of the contents provided in the master lectures. It requires a deep and critical analysis about modeling aspects of the optimization problems allowing different perspectives and incentivizing creativity and critical thought of the student.	CB1, CE2
▪ **Assignments (30h):** improve knowledge of the techniques presented.	CB2, CE3

ASSESSMENT AND GRADING CRITERIA

Assessment activities	Grading criteria	Weight
Case study	▪ Practical case statement ▪ Model development ▪ Theoretical contribution ▪ Solution analysis ▪ Written communication skill ▪ Teamwork (if done in a team)	80%
Communication skill	▪ Oral presentation of the case study	15%
Classroom participation	▪ Attendance and active participation in class	5%

GRADING AND COURSE RULES

Grading

Regular assessment

- **Case study** will account for the 100%, of which:
  - Written report: 80%
  - Oral presentation: 15%
  - Participation: 5%

In case that the *written report mark* is equal or lower than 3.5, the final grade will be the *written report mark*. Otherwise, the final grade is computed weighting the different marks as the previously shown percentages. In order to pass the course, the final grade should be greater or equal to 5.0.

Retakes

The final grade is computed based only in a new written report about the same or different case study. In order to pass the course, the final grade should be greater or equal to 5.0.

Course rules

- Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Académicas) of the ICAI School of Engineering. Not complying with this requirement may have the following consequences:
  - Students who fail to attend more than 15% of the lectures may be denied the right to take the final exam during the regular assessment period.

Students who commit an irregularity in any graded activity will receive a mark of zero in the activity and disciplinary procedure will follow (cf. Article 168 of the General Regulations (Reglamento General) of Comillas Pontifical University).

WORK PLAN AND SCHEDULE[1]

[1] A detailed work plan of the subject can be found in the course summary sheet (see following page). Nevertheless, this schedule is tentative and may vary to accommodate the pace of the class.

In and out-of-class activities	Date/Periodicity	Deadline
Case study sessions	Every week	
Review and self-study of the concepts covered in the lectures	After each lesson	
Problem-solving	Weekly	
Case study report writing	December	
Case study oral presentation	During the course and, in particular, the last part of the course	

STUDENT WORK-TIME SUMMARY			
IN-CLASS HOURS			
Lectures	Problem-solving	Case sessions	Practices
15	5	5	5
OUT-OF-CLASS HOURS			
Self-study	Problem preparation	Case preparation and evaluation	Final report
25	5	20	10
		ECTS credits:	3 (90 hours)

BIBLIOGRAPHY

Basic bibliography

- Notes prepared by the lecturer (available in Moodle).
- Williams, H.P. (2013) Model Building in Mathematical Programming. 5th Edition. Wiley
- Griva, I., Nash, S.G. and Sofer, A. (2008) Linear and Nonlinear Programming. 2nd Edition. McGraw-Hill.
- Nemhauser, G.L., Wolsey, L.A. (1999) Integer and Combinatorial Optimization. John Wiley and Sons.

Complementary bibliography

	IN-CLASS ACTIVITIES				OUT-OF-CLASS ACTIVITIES				LEARNING OUTCOMES		
Week	h/w	LECTURE & PROBLEM SOLVING	LAB	ASSESMENT	h/w	SELF-STUDY	LAB PREPARATION AND REPORTING	OTHER ACTIVITIES	Learning Outcomes		
1	2	Course presentation and topic 1. Algebraic modeling languages	Problem solving		3	Review, self-study and problem-solving (2h)	Problem preparation (1 h)		RA1, RA9	RA1.	Understand where to use and concepts of deterministic optimization.
2	2	Optimization modeling practices	Problem solving		4	Review, self-study and problem-solving (2h)	Problem preparation (2 h)		RA2, RA3, RA4	RA2.	Become familiar within the several topics where deterministic optimization can be applied
3	2	Topic 1. LINEAR PROGRAMMING. Introduction. Geometry. Properties. Graphical simplex method. Standard form. Basic solution. Partition.	Problem solving		5	Review, self-study and problem-solving (3h)	Problem preparation (2 h)		RA2, RA3, RA4	RA3.	Know how to build an optimization model efficiently
4	2	Topic 1. Reduced cost. Pivoting. Simplex method.	Case study and practice		1	Review, self-study and case-solving (1h)			RA5, RA6, RA7	RA4.	Achieve mathematical rigorousness
5	2	Topic 1. Tabular form. Initial basic feasible solution. Revised simplex.	Case study and practice	Presentation assessment	2	Review, self-study and case-solving (2h)			RA5, RA6, RA7	RA5.	Understand the mathematical techniques used
6	2	Topic 1. Product form of the inverse. Base matrix factorization. Strategies of computing reduced costs. Dual problem. Dual variables. Economic interpretation.	Case study and practice		5	Review, self-study and case-solving (1h)	Work preparation (4h)		RA5, RA6, RA7	RA6.	State and solve mockup problems
7	2	Topic 1. Primal-dual interior point method.	Case study and practice	Presentation assessment	2	Review, self-study and case-solving (2h)			RA5, RA6, RA7	RA7.	Analyze the solutions
8	2	Topic 2. MODELING OF MIXED INTEGER LINEAR PROGRAMMING PROBLEMS. Piecewise linear.	Case study and practice		5	Review, self-study and case-solving (1h)	Work preparation (4h)		RA5, RA6, RA7	RA8.	Be prepared to extend their knowledge
9	2	Topic 2. Convex and concave regions. Special ordered sets. Reformulation.	Case study and practice	Presentation assessment	2	Review, self-study and case-solving (2h)			RA5, RA6, RA7	RA9.	Become familiar with an algebraic language used professionally
10	2	Topic 3. MIXED INTEGER LINEAR PROGRAMMING. Branch and bound. Duality.	Case study and practice		5	Review, self-study and case-solving (1h)	Work preparation (4h)		RA5, RA6, RA7		
11	2	Topic 3. Preprocessing. Branch and cut.	Case study and practice	Presentation assessment	2	Review, self-study and case-solving (2h)			RA5, RA6, RA7		
12	2	Topic 4. NONLINEAR OPTIMIZATION. Unconstrained problem optimality conditions.	Case study and practice		5	Review, self-study and case-solving (1h)	Work preparation (4h)		RA5, RA6, RA7		
13	2	Topic 4. Constrained problem optimality conditions. Unconstrained problem solution methods.	Case study and practice	Presentation assessment	7	Review, self-study and case-solving (2h)	Final report (5)		RA5, RA6, RA7, RA8		
14	2	Topic 4. Constrained problem solution methods.	Case study and practice		5	Review, self-study and case-solving (1h)	Work preparation (4h)		RA5, RA6, RA7		
15	2	Topic 4. Conjugate gradient.	Case study and practice		7	Review, self-study and case-solving (2h)	Final report (5)		RA5, RA6, RA7, RA8		