COURSE SYLLABUS

Academic Year: 2020/2021

Identification and characteristics of the course			
Code	401923	ECTS Credits	6
Course title (English)	Optimization and Complexity		
Course title (Spanish)	Optimización y Complejidad		
Degree programs	Master on Simulation in Science and Engineering		
Faculty/ School	Industrial Engineering School		
Semester	2	Course type (compulsory/optional)	Optional
Module	Optional		
Subject matter	Simulation in Science		
Lecturer/s			
Name	Room	E-mail	Web page
Juan Jesús Ruiz Lorenzo	B.202	ruiz@unex.es	www.eweb.unex.es/eweb/fisteor/juan/
Andrés Santos Reyes	B.205	andres@unex.es	www.eweb.unex.es/eweb/fisteor/andres/
Subject Area	Theoretical Physics		
Department	Physics		
Coordinator (Only if there is more than one lecturer)	Juan Jesús Ruiz Lorenzo		

Competencies (see table in https://goo.gl/BJxjVH)*

mpetenciesBasic	Tick if needed	etenciesGeneric	Tick if needed	nciesTransverse	Tick if needed	etenciesSpecific	Tick if needed	SpecificOptional	Tick if needed
CB6	X	CG1	X	CT1	X	CE1		CEO1	X
CB7	X	CG2	X	CT2	X	CE2		CEO2	
CB8	X	CG3	X	CT3	X	CE3		CEO3	
CB9	X	CG4	X	CT4	X	CE4		CEO4	X
CB10	X	CG5	X	CT5	X	CE5		CEO5	
		CG6	X	CT6	X	CE6		CEO6	
		CG7	X	CT7	X	CE7		CEO7	X
				CT8	X	CE8		CEO8	X
				CT9				CEO9	X
				CT10					

Contents

**The sections concerning competencies, course outline, teaching activities, teaching methodology, learning outcomes and assessment methods must conform to those included in the ANECA verified document of the degree program.

Course outline*
Algorithms. Graphs. Theory of Complexity. Algorithms motivated by physical phenomena. The satisfiability problem. Optimization problems in science. Automata. Theory of networks. Scientific applications.
Course contents
Title of unit 1: Algorithms (2 hours) Contents of unit 1: • 1.1 Pidgin algorithm • 1.2 Iterative and recursive algorithms • 1.3 Dynamic programming • 1.4 Backtracking Description of practical activities for unit 1: Programming several optimization problems (2 hours)
Title of unit 2: Graphs (4 hours) Contents of unit 2: • 2.1 Basic concepts and classical problems • 2.2 Basic graph algorithms • 2.3 Random graphs • 2.4. Percolation Description of practical activities for unit 2: Study of tree-search algorithms. Percolation (8 hours)
Title of unit 3: Theory of complexity (4 hours) Contents of unit 3: • 3.1 Turing machines • 3.2 P-class • 3.3 NP-class • 3.4 NP-complete problems: examples
Title of unit 4: Theory of networks (8 hours) Contents of unit 4: • 4.1 Introduction • 4.2 Structure of complex networks • 4.3 Spreading processes. Examples: epidemic spreading and rumor spreading • 4.4. Applications: social networks, internet, metabolic processes and neural networks Description of practical activities for unit 4: Analysis on socioeconomic data in Extremadura (10 hours)
Title of unit 5: Optimization problems in science (10 hours) Contents of unit 5: • 5.1 Algorithms motivated by statistical mechanics: “warning propagation”, “belief propagation” and “survey propagation” • 5.2 Monte Carlo optimization: “Simulated annealing”, cluster algorithms and biased choice • 5.3 Genetic algorithms Description of practical activities for unit 5: Study of the satisfiability problem by means of several algorithms. Study of pairing and spin glasses. Maximum flux in systems in the presence of a random magnetic field (10 hours)

Educational activities *

Student workload (hours per lesson)		Lectures	Practical sessions				Monitoring activity	Homework
Unit	Total	L	HI	LAB	COM	SEM	SGT	PS
1	14	2			2			10
2	22	4			8			10
3	14	4						10
4	33	8			10			15
5	35	10			10			15
Assessment **	32	2						39
TOTAL ECTS	150	30			30			90

L: Lectures (100 students)
HI: Hospital internships (7 students)
LAB: Lab sessions or field practice (15 students)
COM: Computer room or language laboratory practice (30 students)
SEM: Problem-solving classes, seminars or case studies (40 students)
SGT: Scheduled group tutorials (educational monitoring, ECTS type tutorials)
PS: Personal study, individual or group work and reading of bibliography

Note: This course belongs to the internationalization program PALEX_Intermedio. Consequently, 25% of the lectures (final exam excluded) will be given in English. This represents 7 hours.

Teaching Methodology*

Among the different methodologies described in the degree syllabus, the following ones will be used in the course:

Teaching methodologies	Tick as indicated
1. Lectures.	X
2. Workshops with suitable methodology	X
3. Problem solving in the class	X
4. Practical work in environments with specialized equipment (labs, computer rooms, fieldwork).	X
5. Technical visits to installations.	
6. Elaboration and analysis (by groups or individually) of memoirs, exercises, case studies, on the skills and contents (theoretical and practical) related to the course.	X
7. Exams, defense of assignments, etc., oral or written, individually or in groups.	X
8. Student study. Individual preparation and analysis of texts, cases, problems, etc.	X
9. Development of communication skills (oral, written, multimedia).	X
10. Out-of-class learning based on the link between academic education and professional or entrepreneurial experiences.	
11. Tutored and supervised learning in order to detect, by a student-tutor interaction, potential problems in the education process. This will also allow assessing the learning outcome out of class and programming activities such as the master thesis.	

** Insert as many rows as necessary. For instance, you can include one row for a partial exam and another for the final exam.

The theoretical fundamentals of the course concepts will be presented in the **lectures**.
The basic tools for programming the algorithms will be explained in the **computer sessions**.
The **tutored projects** will consist in the solution by means of the course tools of more realistic and relevant problems than those considered in the computer sessions.

Learning outcomes *

Assessment methods *

Assessment criteria

CE1. Command of the theoretical contents of the course.
This is related to the competencies CB6, CB7, CB8, CB10, CG1, CG4, CG5, CT1, CT4, CT7, CEO4, CE08, CE09.

CE2. Ability to apply the acquired theoretical knowledge to the solution of real problems.
This is related to the competencies CB6, CB7, CB8, CG2, CG3, CG4, CG5, CG6, CG7, CT1, CT2, CT4, CT5, CT6, CT7, CT8, CEO4, CEO8, CE09.

CE3. Command of the computational tools related to the course.
This is related to the competencies CG2, CG3, CG6, CG7, CT5, CT6, CEO4, CE07, CE09.

CE4. Ability to communicate knowledge with the appropriate technical language (oral or written) within the field of artificial intelligence.
This is related to the competencies CB8, CB9, CG4, CG5, CT3, CT4, CT5, CT7, CT8.

Assessment activities
Among the assessment activities described in the degree syllabus, the following ones will be used in the course (with the indicated weights):

	Range established in the degree memoir	Ordinary call	Extraordinary call	Global assessment (*)
1. Exams (Final and/or partial).	40%–70%(1) 0%–40%(2) 0%(3)	20 %	20 %	20 %
2. Resolution and delivery of activities (cases, problems, reports, projects, etc.), individually and/or in groups.	0%–40%(1) 40%–80%(2) 0%(3)	70 %	70 %	80 %
3. Attendance and achievement in classes, practices and other face-to-face activities.	0%–20%(1,2) 0%–20%(2) 0%(3)	10	10	---
4. Presentation and defense of projects and reports.	0%(1) 0%(2) 100%(3)			

(*) The student will communicate in the first three weeks of each semester to the instructor, in writing, the type of assessment chosen. The instructor will then inform the Degree Quality Commission. In the absence of communication, it will be understood that the student chooses continuous assessment. Once the type of assessment has been chosen, the student will not be able to change in the ordinary call for that semester and will abide by the evaluation regulations for the extraordinary call.

(1) Courses of the subject *Mathematical foundations* (*Numerical methods, Differential equations*, and *Statistical treatment of data*).
(2) Rest of courses.
(3) Master thesis.

<u>Descripction of the assessment activities</u>

The student will develop program codes in practical classes whose results will be presented in a report. The evaluation of this report will make 30% of the grade of the course (Recoverable 30%).
The student will develop one or more program codes, depending on their length and difficulty, where one or more practical cases will be solved using the techniques studied in the course. A report will be presented with the results obtained. This will represent 40% of the grade for the course (Recoverable 40%).
There will be a theoretical-practical exam at the end of the course, which will represent 20% of the grade for the course (Recoverable 20%).

The global assessment will take place the same day assigned to the final exam of each call by the School of Industrial Engineering. It will consist of the following tests:

- A theoretical-practical exam. This will make 20% of the grade.
- The student must present a report with the results obtained in the resolution of several practical cases similar to those carried out in the practical classes. It will represent 30% of the grade.
- The student must also present a report with the results obtained in solving one or more (depending on their difficulty and length) practical cases using the techniques studied during the course. These practical cases will be similar to those proposed to the rest of students throughout the course. It will represent 50% of the grade.

The practical cases will be assigned to the student when he/she expresses his/her decision to opt for the global assessment.

Note: This subject belongs to the PALEx-intermedio program. Therefore, the students will be able to present the different projects and practices, as well as the exam, in English or in Spanish.

Bibliography (basic and complementary)

Basic

- A. K. Hartmann y M. Weigt, *Phase Transitions in Combinatorial Optimization Problems: Basis, Algorithms and Statistical Mechanics* (Wiley, Weinheim, 2005).
- C. H. Papadimitriou y K. Steiglitz, Combinatorial Optimization. Algorithms and Complexity (Dover, Mineola, 2015).

- G. Chartrand, Introductory Graph Theory (Dover, Mineola, 1977).
- A-L. Barabási, Network Science, (Cambridge University Press, 2016).
- Stefano Boccaletti, Vito Latora, Yamir Moreno, Martin Chavez, D-U Hwang. Complex Networks: Structure and Dynamics. Physics Reports 424, 175-308 (2006).
- W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery, *Numerical Recipes Third Edition* (Cambridge University Press, 2007).
- L. M. Barone, E. Marinari, F. Ricci-tersenghi, *Scientific Programming:C-Language, Algorithms and Models in Science (World Scientific, Singapur, 2013).*

Complementary

- M. Mézard, G. Parisi y M. Virasoro, Spin Glass Theory and Beyond (World Scientific, Singapur, 1987).

Other resources and complementary materials

See
www.unex.es/eweb/fisteor/juan/
www.unex.es/eweb/fisteor/andres/