Advanced Computation Theory

Academic Year: (2023 / 2024)   **Review date: 09-02-2024**

Department assigned to the subject: Computer Science and Engineering Department

Coordinating teacher: ALONSO WEBER, JUAN MANUEL

Type: Electives ECTS Credits : 6.0

Year : 4 Semester :

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Discrete Mathematics (Course 1 - Semester 2)
Theory of Automata and Formal Languages (Course 2 - Semester 1)

SKILLS AND LEARNING OUTCOMES

CB1. Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2. Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CB3. Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4. Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CB5. Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.
CG1. Students are able to demonstrate knowledge and understanding of concepts in mathematics, statistics and computation and to apply them to solve problems in science and engineering with an ability for analysis and synthesis.
CG3. Students can solve computationally with the help of the most advanced computing tools mathematical models coming from applications in science, engineering, economy and other social sciences.
CG4. Students are able to show that they can analyze and interpret, with help of computer science, the solutions obtained from problems associated to real world mathematical models, discriminating the most relevant behaviours for each application.
CG6. Students can search and use bibliographic resources, in physical or digital support, as they are needed to state and solve mathematically and computationally applied problems arising in new or unknown environments or with insufficient information.
CE12. Students have shown that they know the main data structures, being able to use, design, and implement them determining its computational and storage complexity.

RA1. Students must have acquired advanced cutting-edge knowledge and demonstrated indepth understanding of the theoretical and practical aspects of working methodology in the area of applied mathematics and computing.
RA2. Through sustained and well prepared argument and procedures, students will be able to apply their knowledge, their understanding and the capabilities to resolve problems in complex specialized professional and work areas requiring the use of creative and innovative ideas.
RA3. Students must have the capacity to gather and interpret data and information on which they base their conclusions, including where relevant and necessary, reflections on matters of a social, scientific, and ethical nature in their field of study.
RA4. Students must be able to perform in complex situations that require developing novel solutions in the academic as well as in the professional realm, within their field of study.
RA5. Students must know how to communication with all types of audiences (specialized or not) their knowledge, methodology, ideas, problems and solutions in the area of their field of study in a clear and precise way.
RA6. Students must be capable of identifying their own education and training needs in their field of study and the work or professional environment and organize their own learning with a high degree of autonomy in all types of contexts (structured or not).

RA7. Students must possess the professional maturity necessary to choose and evaluate their work objectives in a reflexive, creative, self-determined and responsible way, for the betterment of society.

DESCRIPTION OF CONTENTS: PROGRAMME

Relevant contents:
1.- Cost of computational processes
2.- Recursive algorithms complexity
3.- Introduction to computability theory
4.- Introduction to computational complexity theory
5.- Spatial complexity
6.- Kolmogorov complexity
7.- Computation models
8.- Probabilistic algorithms

Programme:
1. Computational Cost of Algorithms.
  1.1 Computational Complexity and Computational Cost.
  1.2 Computational Cost of Structured Programs
  1.3 Computational Cost of Recursive Programs
  1.4 Probabilistic Analysis

2. Introduction to Computability Theory
  2.1 Definition of Problem. Decision Problems
  2.2 Turing Machines and Decidability
  2.3 Computability and Decidability

3. Introduction to Complexity Theory
  3.1 Problem Reduction
  3.2 Classes P, NP and NP-Complete.
  3.3 Classes PSpace, NPSpace.
  3.3 Classes NP-Hard, Exp, CoP, CoNP

4. Models of Computation
  4.1 Turing Machines (Multi-tape, Non deterministic)
  4.2 Cellular Automata
  4.3 Lindenmayer Systems

LEARNING ACTIVITIES AND METHODOLOGY

THEORETICAL-PRACTICAL CLASSES. [44 hours with 100% classroom instruction, 1.67 ECTS]
Knowledge and concepts students must acquire. Student receive course notes and
will have basic reference texts to facilitate following the classes and carrying
out follow up work. Students partake in exercises to resolve practical problems
and participate in workshops and evaluation tests, all geared towards
acquiring the necessary capabilities.

TUTORING SESSIONS. [4 hours of tutoring with 100% on-site attendance, 0.15 ECTS]
Individualized attendance (individual tutoring) or in-group (group tutoring)
for students with a teacher.

STUDENT INDIVIDUAL WORK OR GROUP WORK [98 hours with 0 % on-site, 3.72 ECTS]

WORKSHOPS AND LABORATORY SESSIONS [8 hours with 100% on site, 0.3 ECTS]

FINAL EXAM. [4 hours with 100% on site, 0.15 ECTS]
Global assessment of knowledge, skills and capacities acquired throughout the
course.

METHODOLOGIES

THEORY CLASS. Classroom presentations by the teacher with IT and audiovisual
support in which the subject's main concepts are developed, while providing
material and bibliography to complement student learning.

PRACTICAL CLASS. Resolution of practical cases and problem, posed by the

teacher, and carried out individually or in a group.

TUTORING SESSIONS. Individualized attendance (individual tutoring sessions) or in-group (group tutoring sessions) for students with a teacher as tutor.

LABORATORY PRACTICAL SESSIONS. Applied/experimental learning/teaching in workshops and laboratories under the tutor's supervision.

ASSESSMENT SYSTEM

SE1 - FINAL EXAM. [35 %]
Global assessment of knowledge, skills and capacities acquired throughout the course.

SE2 - CONTINUOUS EVALUATION. [65 %]
Assesses papers, projects, class presentations, debates, exercises, internships and workshops throughout the course.

The continuous assessment mark will be determined based on:
- Mid term exam: 33%
- Practical exercises: 67%

A minimum mark for the final-term exam (4 out of 10) is required to pass the subject.

% end-of-term-examination:	35
% of continuous assessment (assigments, laboratory, practicals…):	65

BASIC BIBLIOGRAPHY

 - Enrique Alfonseca Cubero, Manuel Alfonseca Cubero, Roberto Moriyón Salomón Teoría de autómatas y lenguajes formales, McGraw-Hill, 2007
 - John E. Hopcroft, Rajeev Motwani, Jeffrey D. Ullman Introduction to Automata Theory, Languages, and Computation, Addison-Wesley 3rd Edition.
 - John E. Hopcroft, Rajeev Motwani, Jeffrey D. Ullman Introducción a la teoría de autómatas, lenguajes y computación, Addison-Wesley, 2007
 - Michael Sipser Introduction to the Theory of Computation. 2nd ed., Boston, MA: Course Technology, 2005

 - Michael Sipser Introduction to the Theory of Computation. 3d ed., Boston, MA: Course Technology, 2013

 - S. Wolfram Cellular Automata and Complexity, Addison-Wesley, 1996

ADDITIONAL BIBLIOGRAPHY

 - C. Papadimitriou Computational Complexity, Addison-Wesley, 1995

 - C. Papadimitriou, K. Steiglitz Combinatorial Optimization, Dover, 1998

 - H. S. Wilf Algorithms and Complexity, Prentice-Hall, 1986

 - Jeffrey Shallit A Second Course in Formal Languages and Automata Theory, Cambridge University Press, 2008

 - S. Wolfram A New Kind of Science, Wolfram Media, 2003