Course guide
270613 - CC - Computational Complexity

Last modified: 02/02/2024

Unit in charge: Barcelona School of Informatics
Teaching unit: 723 - CS - Department of Computer Science.

Degree: MASTER'S DEGREE IN INNOVATION AND RESEARCH IN INFORMATICS (Syllabus 2012). (Optional subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: ALBERT ATSERIAS PERI

Others: Segon quadrimestre:
ALBERT ATSERIAS PERI - 10
ANTONI LOZANO BOIXADORS - 10

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEE3.1. Capability to identify computational barriers and to analyze the complexity of computational problems in different areas of science and technology as well as to represent high complexity problems in mathematical structures which can be treated effectively with algorithmic schemes.
CEE3.3. Capability to understand the computational requirements of problems from non-informatics disciplines and to make significant contributions in multidisciplinary teams that use computing.

Generical:
CG1. Capability to apply the scientific method to study and analyse of phenomena and systems in any area of Computer Science, and in the conception, design and implementation of innovative and original solutions.
CG3. Capacity for mathematical modeling, calculation and experimental designing in technology and companies engineering centers, particularly in research and innovation in all areas of Computer Science.

Transversal:
CTR6. REASONING: Capacity for critical, logical and mathematical reasoning. Capability to solve problems in their area of study. Capacity for abstraction: the capability to create and use models that reflect real situations. Capability to design and implement simple experiments, and analyze and interpret their results. Capacity for analysis, synthesis and evaluation.

Basic:
CB8. Capability to communicate their conclusions, and the knowledge and rationale underpinning these, to both skilled and unskilled public in a clear and unambiguous way.
CB9. Possession of the learning skills that enable the students to continue studying in a way that will be mainly self-directed or autonomous.

TEACHING METHODOLOGY

Blackboard lectures for theory classes and discussion sessions for the problem classes. The theory classes will follow the main textbook for the class [Arora and Barak] rather closely. Since we plan to cover more topics than is possible in the given time, students will be required to read the details in the textbook as homework (a draft of the book is available on-line for free). The aim of the discussion sessions is to solve some problems from that book and to discuss the reading material.

LEARNING OBJECTIVES OF THE SUBJECT

STUDY LOAD

Type	Hours	Percentage
Hours medium group	18,0	12.00
Hours large group	36,0	24.00
Self study	96,0	64.00

Total learning time: 150 h

CONTENTS

Computational Models and Complexity Measures

Description:
Turing machine model. RAM model. Boolean circuit model.
Time complexity. Space complexity. Circuit size. Circuit depth.
Time and space hierarchy theorems.

P, NP and NP-completeness

Description:
Polynomial time. Reducibilities. Non-deterministic algorithms and class NP. Cook-Levin Theorem. Many other NP-complete problems.

Polynomial-time Hierarchy and Alternations

Description:
Oracle reducibility. NP and co-NP. Levels of the hierarchy. Quantifier alternations. Complete problems.

Space Complexity

Description:
Polynomial space. Unbounded alternations. PSPACE-complete problems.
Savitch Theorem. Immerman-Szcelepscenyi Theorem.
Logarithmic space. NL-complete problems.

Randomized Computation

Description:
Bounded-error and zero-error probabilistic polynomial time. Error-reduction.
Randomized reductions. Valiant-Vazirani reduction to Unique SAT.

Counting and Enumeration

Description:
Some examples: graph reliability, counting matchings and the permanent, partition functions.
Counting computation paths in non-deterministic machines. Valiant's Theorem.
Random self-reducibility of the permanent.

Probabilistic Proofs

Description:
Interaction and randomness in proofs. Probabilistic proofs for graph non-isomorphism. Probabilistic proofs for #P and Shamir's Theorem: IP = PSPACE.

Circuit Lower Bounds

Description:
Monotone circuits. Lower bounds for clique and perfect matching.
Bounded-depth circuits. Hastad's switching lemma.
Approximation by polynomials.

ACTIVITIES

Submission first problems sheet

Full-or-part-time: 8h
Self study: 8h

Submission second problems sheet

Full-or-part-time: 8h
Self study: 8h

Submission third problems sheet

Full-or-part-time: 8h
Self study: 8h

Submission forth problems sheet

Full-or-part-time: 8h
Self study: 8h

Submission fifth problems sheet

Full-or-part-time: 8h
Self study: 8h

Final exam

Full-or-part-time: 15h
Guided activities: 3h
Self study: 12h

GRADING SYSTEM

Students will be required to submit 5 problem/discussion sheets. Each will be given a grade in [0,1] (P1,...,P5).
There will be a final exam graded in [0,10] (E).
The final grade of the course will be MAX(P1+P2+P3+P4+P5+E/2, E).

The problem/discussion sheets will consist of problems from the main textbook [Arora-Barak] and/or multiple choice questions that test if the student understood the material from the theory class (also covered in the main textbook).

BIBLIOGRAPHY

Basic:
- Arora, S.; Barak, B. Computational complexity: a modern approach. Cambridge ; New York: Cambridge University Press, 2009. ISBN 9780521424264.

Complementary:
- Papadimitriou, C.H. Computational complexity. Reading, Mass.: Addison-Wesley, 1994. ISBN 0201530821.
- Goldreich, O. Computational complexity: a conceptual perspective. Cambridge ; New York: Cambridge University Press, 2008. ISBN 9780521884730.