Course guide
270027 - AA - Advanced Algorithmics

Last modified: 30/01/2024

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

Degree: BACHELOR'S DEGREE IN INFORMATICS ENGINEERING (Syllabus 2010). (Optional subject).

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

LECTURER

Coordinating lecturer: MARIA DEL CARME ALVAREZ FAURA

Others: Segon quadrimestre:
MARIA DEL CARME ALVAREZ FAURA - 11, 12
MARIA JOSE SERNA IGLESIAS - 11, 12

PRIOR SKILLS

Knowledge of algorithms and related concepts: efficiency of algorithms, asymptotic notation, greedy algorithms, dynamic programming, ...

Basic knowledges of the theory of computation: automata, grammars, Turing machines, decidibilitat, complexity.

Critical capacity.

Mathematical maturity.

REQUIREMENTS

- Prerequisite A

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CCO1.1. To evaluate the computational complexity of a problem, know the algorithmic strategies which can solve it and recommend, develop and implement the solution which guarantees the best performance according to the established requirements.
CCO2.5. To implement information retrieval software.
CCO2.6. To design and implement graphic, virtual reality, augmented reality and video-games applications.

Generical:
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

TEACHING METHODOLOGY

The theoretical contents of the course is taught in theory classes.

In the classes of problems students solve problems with the help of the professor and also present some of their solutions on the board.

Students have to deliver different written submissions presenting the solution of problems assigned by the professor. In some cases, it will be necessary to use methods that complement the ones seen in theory class and it will require some bibliographic research. In these cases the students will be
be asked to present solutions in public during the problem sessions.

LEARNING OBJECTIVES OF THE SUBJECT

1.To know the fundamental concepts of Computational Problem and Algorithm. To be able to analyze the computational resources like Time and Space, which are required by an algorithm.
2.To know how to classify the complexity of a computational problem. To be able to distinguish between tractable problems and intractable problems. Knowing the techniques of reducibility and completeness to analyze the computational difficulty of a problem.
3.To know some classical intractable problems and the classes that are identified by these problems: NP, PSPACE, EXP i NEXP.
4.To know Random Algorithms to solve intractable problems. In particular, to know two varieties of random algorithms: Monte Carlo algorithms which compute in polynomial time a solution that it may be not correct with low probability and Las Vegas algorithms which always compute a correct solution and guarantee polynomial time with high probability.
5.To know Approximation Algorithms to compute efficiently approximate solutions (solutions close to the optimum) for optimization intractable problems.
Knowing their limitations or problems that can not be approximated in polynomial time.
6.To know Fixed Parameter Algorithms that allow to solve in polynomial time certain restrictions of intractable problems. To know how to identify specific parameters of a problem so that when they are fixed then the problem can be solved efficiently.
7.To know Data Stream Algorithms to solve efficiently
problems where the inputs must be processed
by making one
or a small number of passes over it, using only a limited amount of working memory.
The streaming model applies to settings where the size of the input far exceeds the size
of the main memory available.
8.To know basic concepts of Game Theory: Games, strategies, costs, payoffs, selfish players. New solution concept: Nash equilibrium. Efficiency of solutions: Price of Stability and Price of Anarchy. Brief introduction to Network Formation Games.

STUDY LOAD

Type	Hours	Percentage
Hours large group	45,0	30.00
Self study	84,0	56.00
Hours medium group	15,0	10.00
Guided activities	6,0	4.00

Total learning time: 150 h

CONTENTS

Problems and Algorithms

Description:
Computational problems.
Complexity of algorithms: Time and Space.
Complexity of problems.
Tractable problems: Accessibility, Shortest paths.
Intractable problems: Traveling Salesman Problem, Knapsack.

Intractable Problems

Description:
Reducibility and Completeness.
NP-complete problems: Satisfiability, Subgraphs, Colorability, Tours, Partitions, Scheduling.
PSPACE, EXP, and NEXP problems: Quantified boolean formulae, games, tilling, equivalence of regular expressions.

Random Algorithms

Description:
Monte-Carlo Algorithms. Las Vegas Algorithms. Generation of random numbers. Factoritzation (Heurístic Pollard Rho). Criptography (RSA)

Algorithmics and Internet: Modelling Internet

Description:
Basic definitions: Game, strategy, cost and payoff, selfish players.
Nash Equilibrium, Social Cost, Price of Stability and Price of Anarchy
Introduction to Neetwork Formation Games. Understanding the behavior of Internet: A game equilibrium.

Approximation Algorithms

Description:
Optimization Problems and Approximability.
Algorithmic methods: Greedy algorithms, methods based on Linear Programming.

Fixed Parameter Algorithms

Description:
Parameterized problems: Vertex cover, Max Sat, Knapsack.
Algorithmic Methods: Bounded-depth Search trees, Kernelization.

Data Stream Algorithms

Description:
Some basic problems.
Computational models for data flows.
Algorithmic Methods: Sampling, Sketches, techniques for streams of graphs.

ACTIVITIES

Delivery of problems: Intractability

Specific objectives:
1, 2, 3

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 5h
Self study: 5h

Delivery of problems: Solutions to Intractable problems (I)

Specific objectives:
1, 2, 4, 5

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 5h
Self study: 5h

Delivery of problems: Solutions to Intractable problems (II)

Specific objectives:
1, 2, 3, 4, 5, 6, 7, 8

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 5h
Self study: 5h

Midterm Exam 1

Specific objectives:
1, 2, 3, 4, 8

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 9h
Guided activities: 3h
Self study: 6h

Midterm Exam 2

Description:
Written exam

Specific objectives:
5, 6, 7

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 9h
Guided activities: 3h
Self study: 6h

Final Exam

Description:
Written exam.

Specific objectives:
1, 2, 3, 4, 5, 6, 7, 8

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 11h
Guided activities: 3h
Self study: 8h

Learning the topic "Problems and Algorithms"

Description:
Students attend the theory classes, try to understand this subject and solve problems, asking professor for help in the class of problems. Furthermore the students can also be asked to present one of the assigned problems to the blackboard.

Specific objectives:
1

Full-or-part-time: 8h
Theory classes: 4h
Self study: 4h

Learning the topic "Intractable Problems"

Description:
Students attend the theory classes, try to understand this subject and solve problems, asking professor for help in the class of problems. Furthermore the students can also be asked to present one of the assigned problems to the blackboard.

Specific objectives:
2, 3

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 22h
Theory classes: 8h
Practical classes: 2h
Self study: 12h

Learning the topic "Random Algorithms"

Description:
Students attend the theory classes, try to understand this subject and solve problems, asking professor for help in the class of problems. Furthermore the students can also be asked to present one of the assigned problems to the blackboard.

Specific objectives:
4

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 12h
Theory classes: 5h
Practical classes: 1h
Self study: 6h

Learning the topic "Algorithmics and Game Theory: Modelling Internet"

Description:
Students attend the theory classes, try to understand this subject and solve problems, asking professor for help in the class of problems. Furthermore the students can also be asked to present one of the assigned problems to the blackboard.

Specific objectives:
8

Full-or-part-time: 11h
Theory classes: 5h
Practical classes: 1h
Self study: 5h

Learning the topic "Approximation Algorithms"

Description:
Students attend the theory classes, try to understand this subject and solve problems, asking professor for help in the class of problems. Furthermore the students can also be asked to present one of the assigned problems to the blackboard.

Specific objectives:
5

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 19h
Theory classes: 7h
Practical classes: 2h
Self study: 10h

Learning the topic "Fixed Parameter Algorithms"

Description:
Students attend the theory classes, try to understand this subject and solve problems, asking professor for help in the class of problems. Furthermore the students can also be asked to present one of the assigned problems to the blackboard.

Specific objectives:
6

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 18h
Theory classes: 7h
Practical classes: 2h
Self study: 9h

Learning the topic "Data Stream Algorithms"

Description:
Students attend the theory classes, try to understand this subject and solve problems, asking professor for help in the class of problems. Furthermore the students can also be asked to present one of the assigned problems to the blackboard.

Specific objectives:
7

Related competencies :
G7. AUTONOMOUS LEARNING: to detect deficiencies in the own knowledge and overcome them through critical reflection and choosing the best actuation to extend this knowledge. Capacity for learning new methods and technologies, and versatility to adapt oneself to new situations.

Full-or-part-time: 16h
Theory classes: 6h
Practical classes: 1h
Self study: 9h

GRADING SYSTEM

There are three types of evaluation activities: Delivery of problems, Presentations, and Final Exam.

Delivery of problems:
This part consist of solving lists of problems that have been assigned to each student as indicated in the plan. In the class of problems, the students can discuss their doubts together jointly with the professor, but it is considered as a personal and autonomous work that must be completed during their time of study. In general the solution will require to apply the acquired knowledge, to choose the appropriate method in each case and also to do some bibliographic research.
The students deliver their written solutions and present them in public if it is deemed appropriate (when the solutions extend the knowledge introduced in the current issue). The self-learning will be evaluated by this work.

The mark Pro of the delivery of problems is the average grade of all deliveries.

Exams:

There are two midterm exams and a final exam
in which it will be evaluated if the student has achieved the most general knowledge introduced throughout the course.

The mark of the continuous assessment of the subject is calculated from the mark of problems Pro and the marks of the partial exams P1 and P2 as follows:

Continuous = 0.2 Pro + 0.4 P1 + 0.4 P2

If Continuous >= 5, the student may not take the final exam and the Final Grade = Continuous.

If the student takes the final exam and obtains an ExF mark, then

Final Grade = max {ExF, (Continuous + ExF) / 2}

The evaluation of competence G7.3 will be carried out individually for each student based on public presentations and written solutions to the assigned problems.

The assessment of competence G7.3 does not affect the evaluation of the course.

BIBLIOGRAPHY

Basic:
- Dasgupta, S.; Papadimitriou, C.H.; Vazirani, U.V. Algorithms. Mc Graw Hill Higher Education, 2008. ISBN 978-0-07-352340-8.
- Kleinberg, J.; Tardos, E. Algorithm design. New Int. ed. Pearson, 2014. ISBN 9781292023946.
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Complementary:
- Vazirani, V.V. Approximation algorithms. Springer, 2010. ISBN 9783642084690.
- Niedermeier, R. Invitation to fixed-parameter algorithms. Oxford University Press, 2006. ISBN 0198566077.
- Mitzenmacher, M.; Upfal, E. Probability and computing: randomized algorithms and probabilistic analysis. Cambridge University Press, 2005. ISBN 9780521835404.
- Nisan, N. [et al.] (eds.). Algorithmic game theory. Cambridge University Press, 2007. ISBN 9780521872829.
- Moore, C.; Mertens, S. The nature of computation. Oxford University press, 2011. ISBN 9780199233212.
- Nayak, A.; Stojmenovic, I. (eds.). Handbook of applied algorithms: solving scientific, engineering and practical problems [Chapter 8. Algorithms for Data Streams]. Wiley Interscience, 2008. ISBN 9780470044926.