UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH

Course guide
270026 - TC - Theory of Computation

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, Spanish

LECTURER

Coordinating lecturer:	MARIA DEL CARME ALVAREZ FAURA
Others:	Primer quadrimestre:
	MARIA DEL CARME ALVAREZ FAURA - 11, 22
	ANTONI LOZANO BOIXADORS - 12
	ENRIQUE ROMERO MERINO - 21, 22
	Segon quadrimestre:
	MARIA DEL CARME ALVAREZ FAURA - 12
	ILARIO BONACINA - 21
	ENRIQUE ROMERO MERINO - 11

PRIOR SKILLS

Ability to express problems framed in terms of logical formulae in everyday language.
Ability to manipulate logical formulae.
Fundamental algebraic concepts: monoids, groups, closures, morphisms.
Basic principles of combinatorial algebra.
Ability to fully exploit the properties of Boolean algebra.
Understand basic data structures and the fundamental principles governing algorithms.
Ability to evaluate the temporal complexity of algorithms.

REQUIREMENTS

- Prerequisite EDA
- Corequisite PROP

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.
CCO1.2. To demonstrate knowledge about the theoretical fundamentals of programming languages and the associated lexical, syntactical and semantic processing techniques and be able to apply them to create, design and process languages.
CCO1.3. To define, evaluate and select platforms to develop and produce hardware and software for developing computer applications and services of different complexities.
CCO2.2. Capacity to acquire, obtain, formalize and represent human knowledge in a computable way to solve problems through a computer system in any applicable field, in particular in the fields related to computation, perception and operation in intelligent environments.
CCO3.1. To implement critical code following criteria like execution time, efficiency and security.

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.

G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

TEACHING METHODOLOGY

The main characteristic of this teaching methodology is the self-learning based on the use
of the teaching material in order to know
the theoretical fundaments of the subject as well as the discussion of the solutions of problems at the blackboard.The lecturer introduces the basic theoretical foundations of each topic during the theory class and solves some problems. Students learn the theory during their personal work time by studying the topics indicated by the lecturer of the bibliography or also of the videos and other complementary materials such as notes, books and lists of problems resolved, all of them freely accessible through of the web.

In problem solving classes, students explain their solutions to problems which have been assigned to them in advance. The teacher takes part of the explanation in order to correct mistakes or improve explanations. Also, the teacher takes notes about students presentations in order to take them into account in the final evaluation of the subject.

In laboratory classes, students try to solve problems in front of the computer that are evaluated automatically. The teacher is present to solve any question. The students can use these classes to solve the problems which have been assigned to them, and for which they will have to present a solution in the blackboard.

LEARNING OBJECTIVES OF THE SUBJECT

1.To learn how to classify problems in the Chomsky's hierarchy. In particular, to learn techniques to determine when a set is regular, contex-free, decidable (recursive) and semi-decidable (recursively enumerable).
2.Learning to describe languages □□using formal systems like context-free grammars and automata. To know the computational capabilities of these formalisms and their practical applications.
3.Solve theoretical and practical problems of this matter and make public presentations of the solutions.

STUDY LOAD

Type	Hours	Percentage
Hours small group	33,0	22.00
Self study	84,0	56.00
Guided activities	3,0	2.00
Hours medium group	30,0	20.00

Total learning time: 150 h

CONTENTS

Formal languages.

Description:
Alphabets, words, languages, operations on languages (concatenation, reverse, star), morphisms, rewriting systems.

Finite automata.

Description:
Deterministic finite automata, non-deterministic finite automata, finite automata with lambda-transitions, equivalence between automata models, operations on automata, minimization of automata.

Context-free grammars.

Description:
Context-free grammars, generated language by a grammar, derivation tree, ambiguity, operations over grammars, grammar transformations.

Regular expressions.

Description:
Regular expressions, equivalence with automata by Arden's Lemma, operations on regular expressions.

Pushdown automata.

Description:
Non-deterministic pushdown automata and its equivalence to context-free languages, deterministic pushdown finite automata, pushdown automata with unique accepting execution and its equivalence with non-ambiguous context-free languages, closure operations, Chomsky hierarchy.

Non-regularity and non-context freeness.

Description:
Proofs of non-regularity by state repetition and by regularity preserving transformations. Proofs of non-context freeness by variable repetition.

Turing machines.

Description:
Turing machines, extensions by allowing non-determinism or multi-tape, equivalence of Turing machines with high-level algorithms.

Decidability (recursivity), semi-decidability (recursive enumerability), computability.

Description:
Decidable (recursive) languages, semi-decidable (recursively enumerable) languages, computable functions, closure operations, complementation theorem, projection theorem, connexions between semi-decidability and computability.

Non-decidability, non-semi-decidability, non-computability.

Description:
The language K, K is semi-decidable but non-decidable, reductions for proving non-decidability and non-semi-decidability, equivalence between non-semi-decidability and non-computability.

Natural non-decidable problems.

Description:
Reachability of words by word rewriting, PCP, intersection non-emptiness and ambiguity of context free grammars, universality of context free grammars and satisfiability of logic over words.

ACTIVITIES

Learning the subject "language theory".

Description:
The students complete the theoretical concepts introduced in the theory classes with the study of the basic bibliography topics indicated by the professor or trying to watch and understand the videos of this topic (AA: 3h). They also try to solve the problems assigned to them on this subject (AA: 3h), attend the class of theory of this subject and ask questions to the teacher (T: 2 hours) and attend the class of problems where all students present their problems publicly on this subject (P: 2h).

Specific objectives:
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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 7h
Theory classes: 1h
Practical classes: 2h
Self study: 4h

Learning the subject "Finite automata".

Description:
The students complete the theoretical concepts introduced in the theory classes with the study of the basic bibliography topics indicated by the professor or trying to watch and understand the videos of this topic (AA: 3h).
They also try to solve the problems assigned to them on this topic (AA: 3h), attend the laboratory class of this topic and try to solve the problems in front of the computer (L: 4 hours) and attend the class of problems where all students present their problems publicly on this topic (P: 2h).

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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 16h
Theory classes: 2h
Practical classes: 2h
Laboratory classes: 4h
Self study: 8h

Learning the subject "Context-free grammars".

Description:
The students complete the theoretical concepts introduced in the theory classes with the study of the basic bibliography topics indicated by the professor or trying to watch and understand the videos of this topic (AA: 3h).
They also try to solve the problems assigned to them on this topic (AA: 3h), attend the laboratory class of this topic and try to solve the problems in front of the computer (L: 4 hours) and attend the class of problems where all students present their problems publicly on this topic (P: 2h).

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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 18h
Theory classes: 2h
Practical classes: 2h
Laboratory classes: 6h
Self study: 8h

Learning the subject "Regular expressions".

Description:
Students try to watch and understand the videos of this topic (AA: 3h), try to solve the problems assigned to them on this topic (AA: 3h), attend the laboratory class of this topic and try to solve the problems in front of the computer (L: 2 hours) and attend the class of problems where all students present their problems publicly on this topic (P: 2h).

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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 11h 30m
Practical classes: 2h
Laboratory classes: 2h
Guided activities: 1h 30m
Self study: 6h

First exam.

Description:
An exam with a duration of 3 hours, partially done in front of the computer and partially hand-written, where the hability to describe regular and context free languages.

Specific objectives:
1, 2

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

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

Learning the subject "Pushdown automata".

Description:
Students try to understand the corresponding theory studying the chapters of the bibliography indicated by the professor or by watching the videos of this topic (AA: 3h). They also try to solve the problems assigned to them on this topic (AA: 3h), attend the laboratory class of this topic and try to solve the problems in front of the computer (L: 2 hours) and attend the class of problems where all students present their problems publicly on this topic (P: 2h).

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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 8h
Laboratory classes: 2h
Self study: 6h

Learning the subject "Non-regularity and non-context-freeness".

Description:

Students try to understand the corresponding theory attending the theory class (T: 1h) and studying the chapters of the bibliography indicated by the professor or by watching the videos of this topic (AA: 3h). They also try to solve the problems assigned to them on this topic (AA: 3h)
and attend the class of problems where all students present their problems publicly on this topic (P: 1h).

Specific objectives:
1, 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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 8h
Theory classes: 1h
Practical classes: 1h
Self study: 6h

Learning the subject "Turing machines".

Description:
Students try to complete the theoretical concepts introdued in the class of theory (T: 1h) by studying the chapters of the basic bibliograpy indicated by the professor or by watching and understanding the videos of this topic (AA: 3h), try to solve the problems assigned to them on this topic (AA: 3h), and attend the class of problems where all students present their problems publicly on this topic (P: 1h).

Specific objectives:
1, 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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 9h
Theory classes: 2h
Practical classes: 1h
Self study: 6h

Learning the subject "Decidability (recursivity), semi-decidability (recursive enumerability), computability".

Description:
Students try to complete the theoretical concepts introdued in the class of theory (T: 1h) by studying the chapters of the basic bibliograpy indicated by the professor or by watching and understanding the videos of this topic (AA: 3h), try to solve the problems assigned to them on this topic (AA: 3h),
attend the laboratory class of this topic and try to solve the problems in front of the computer (L: 2 hours) and attend the class of problems where all students present their problems publicly on this topic (P: 1h).

Specific objectives:
1, 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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 11h
Theory classes: 2h
Practical classes: 1h
Laboratory classes: 2h
Self study: 6h

Learning the subject "Non-decidability, non-semi-decidability, non-computability".

Description:
Students try to complete the concepts introduced in the classes of theory (T: 1h) studying the chapters of the basic bibliography indicated by the professot or by watching and understanding the videos of this topic (AA: 4h), try to solve the problems assigned to them on this topic (AA: 4h), attend the laboratory class of this topic and try to solve the problems in front of the computer (L: 4 hours) and attend the class of problems where all students present their problems publicly on this topic (P: 3h).

Specific objectives:
1, 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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 17h
Theory classes: 2h
Practical classes: 3h
Laboratory classes: 4h
Self study: 8h

Learning the subject "Natural non-decidable problems".

Description:
Students try to understand the corresponding theoretical concepts studying the chapters of the basic bibliography indicated by the professor or by watching and understanding the videos of this topic (AA: 4h), try to solve the problems assigned to them on this topic (AA: 4h), attend the laboratory class of this topic and try to solve the problems in front of the computer (L: 4 hours) and attend the class of problems where all students present their problems publicly on this topic (P: 4h).

Specific objectives:
1, 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.
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 9h 30m
Practical classes: 1h
Laboratory classes: 4h
Guided activities: 1h 30m
Self study: 3h

Second exam

Description:
An exam with a duration of 3 hours, partially done in front of the computer and partially hand-written, where the hability of analyzing the regularity and incontextuality of languages, as well as the decidability of problems and of constructing reductions in order to prove non-decidability and non-semi-decidability.

Specific objectives:
1, 2

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

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

Final exam.

Specific objectives:
1, 2

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 13h
Guided activities: 3h
Self study: 10h

GRADING SYSTEM

This subject can be passed during the class period, i.e. by continuous evaluation (without attending to the final exam). The grade of the continuous evaluation is obtained from the mark L corresponding to the 2 exams (the ones of the evaluation acts, with a value between 0 and 8 in total, with a weight of 50% the first exam and a weight of 50% the second), and the mark P corresponding to the presentations of the student in the blackboard (between 0 and 2 points). The grade of the continuous evaluation C is defined as C=L+P.

Those students who have a grade C greater than or equal to 5 and do not attend to the final exam, have as final grade, the continuous grade C.

The students who have a grade C less than 5 and do not attend to the final exam obtain a final qualification of NP.

Those students who attend to the final exam resign to the continuous course grade (in the case it was passed). In such a case, the grade is obtained from the mark C, and the mark F of the final exam (between 0 and 10) according to the following formula:

max(F,0.5 F+0.5 C)

The evaluation of competences G7.3, G9.1 and CCO1.1 is done by the professor according to the public presentations made during the continuous evaluation. Te evaluation of the competences is independent from the avaluation of the course.

BIBLIOGRAPHY

Basic:

- Sipser, M. Introduction to the theory of computation. 3rd ed. Boston, MA: Cengage Learning, 2013. ISBN 9781133187790.
- Godoy, G. Vídeos que expliquen els continguts de l'assignatura (linkats des del final de la web de l'assignatura). 2010.
- Cases, R.; Màrquez, L. Llenguatges, gramàtiques i autòmats: curs bàsic. 2a ed. Barcelona: Edicions UPC, 2003. ISBN 8483017288.
- Serna, M [et al.]. Els Límits de la computació: indecidibilitat i NP-completesa. 2a ed. Barcelona: Edicions UPC, 2004. ISBN 8483017849.
- Hopcroft, J.E.; Motwani, R.; Ullman, J.D. Introduction to automata theory, languages, and computation. 3rd ed. Pearson/Addison Wesley, 2007. ISBN 0321462254.

Complementary:

- Comon, H. [et al]. Tree automata techniques and applications. 2008. ISBN 1111154816191.
- Kelley, D. Automata and formal languages: an introduction. Englewood Cliffs, N.J.: Prentice Hall, 1995. ISBN 9780134977775.
- Garey, M.R.; Johnson, D.S. Computers and intractability: a guide to the theory of NP-Completeness. New York: W.H. Freeman, 1979. ISBN 9780716710455.

RESOURCES

Hyperlink:

- http://www.cs.upc.edu/~alvarez/tc.html