



## Course guide

# 270407 - PA2 - Programming and Algorithms II

Last modified: 03/02/2025

**Unit in charge:** Barcelona School of Informatics

**Teaching unit:** 723 - CS - Department of Computer Science.

**Degree:** BACHELOR'S DEGREE IN ARTIFICIAL INTELLIGENCE (Syllabus 2021). (Compulsory subject).

**Academic year:** 2024    **ECTS Credits:** 6.0    **Languages:** Catalan

### LECTURER

**Coordinating lecturer:** JOSÉ LUIS BALCÁZAR NAVARRO - JORDI DELGADO PIN

**Others:** Segon quadrimestre:

JORDI DELGADO PIN - 11, 12

CAROLINE LEONORE KÖNIG - 11, 12

### PRIOR SKILLS

PA1 course, or equivalent

### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

#### Specific:

CE02. To master the basic concepts of discrete mathematics, logic, algorithmic and computational complexity, and its application to the automatic processing of information through computer systems. To be able to apply all these for solving problems.

CE03. To identify and apply the basic algorithmic procedures of computer technologies to design solutions to problems by analyzing the suitability and complexity of the proposed algorithms.

CE04. To design and use efficiently the most appropriate data types and structures to solve a problem.

CE10. To analyze, design, build and maintain applications in a robust, secure and efficient way, choosing the most appropriate paradigm and programming languages.

CE12. To master the fundamental principles and models of computing and to know how to apply them in order to interpret, select, assess, model, and create new concepts, theories, uses and technological developments related to artificial intelligence.

CE13. To evaluate the computational complexity of a problem, identify algorithmic strategies that can lead to its resolution and recommend, develop and implement the one that guarantees the best performance in accordance with the established requirements.

#### General:

CG2. To use the fundamental knowledge and solid work methodologies acquired during the studies to adapt to the new technological scenarios of the future.

CG4. Reasoning, analyzing reality and designing algorithms and formulations that model it. To identify problems and construct valid algorithmic or mathematical solutions, eventually new, integrating the necessary multidisciplinary knowledge, evaluating different alternatives with a critical spirit, justifying the decisions taken, interpreting and synthesizing the results in the context of the application domain and establishing methodological generalizations based on specific applications.

CG8. Perform an ethical exercise of the profession in all its facets, applying ethical criteria in the design of systems, algorithms, experiments, use of data, in accordance with the ethical systems recommended by national and international organizations, with special emphasis on security, robustness, privacy, transparency, traceability, prevention of bias (race, gender, religion, territory, etc.) and respect for human rights.

#### Transversal:

CT4. Teamwork. Be able to work as a member of an interdisciplinary team, either as a member or conducting management tasks, with the aim of contributing to develop projects with pragmatism and a sense of responsibility, taking commitments taking into account available resources.

CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.



## TEACHING METHODOLOGY

Teaching the course is structured in lectures and laboratory sessions.

Teachers will use lectures to introduce the essential contents of the course. In the laboratory sessions the contents of the course will be brought to the computer by carrying out practical problems. The laboratory classes will be a continuation of the lectures, where new concepts will be implemented as they appear in lectures.

## LEARNING OBJECTIVES OF THE SUBJECT

1. Learn new data structures: Stacks, Queues, Lists, Trees and Graphs and the algorithms associated with the necessary operations on these structures.
2. Learn different implementations of data structures: Implementations using simpler data structures provided by the programming language, and dynamic implementations.
3. Learn the basics of object oriented programming: Concepts of class, instance, method, inheritance (single and multiple), etc.
4. Extension of Computational Complexity: Big O, Big Omega, Master Theorems
5. Solve a small/medium-sized problem in group, applying what they have learned about object orientation

## STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	20.00
Hours small group	30,0	20.00
Self study	90,0	60.00

**Total learning time:** 150 h

## CONTENTS

### Trees and Graphs

#### Description:

We will start the course using the data structures that the programming language provides us to implement Trees and Graphs. We will look at path algorithms for both structures, and other important algorithms related to these, such as Dijkstra's algorithm.

### Objects and Classes

#### Description:

The fundamental concepts of object orientation are introduced: Class, object, instance, delegation, inheritance, etc. and other particularities of the implementation of object orientation specific to the programming language we work with.

### Dynamic data structures

#### Description:

We will learn how to implement known data structures using the concept of reference to an object. We will re-implement data structures that the programming language provides by default, and new data structures that we have already seen implemented more easily.



### Sets and Dictionaries: Implementation

**Description:**

We will look at different ways to implement sets and dictionaries: Hash Tables and Binary Search Trees (BSTs). The properties, advantages and disadvantages of these structures will be studied.

### Algorithm Complexity (II)

**Description:**

In PA1 we started the study of the concept of complexity of a program, an algorithm and a problem, and we introduced the asymptotic notation, though only the definition of Theta (f). This topic is a continuation, where we will see the Big O, the Big Omega, etc., and the Master Theorems.

## ACTIVITIES

### Building Abstractions with Data: Trees and Graphs

**Description:**

The student should pay attention to the lecture and he/she should work through the exercises suggested by the lecturer.

**Specific objectives:**

1, 2

**Related competencies :**

CE02. To master the basic concepts of discrete mathematics, logic, algorithmic and computational complexity, and its application to the automatic processing of information through computer systems . To be able to apply all these for solving problems.

CE03. To identify and apply the basic algorithmic procedures of computer technologies to design solutions to problems by analyzing the suitability and complexity of the proposed algorithms.

CE04. To design and use efficiently the most appropriate data types and structures to solve a problem.

CE12. To master the fundamental principles and models of computing and to know how to apply them in order to interpret, select, assess, model, and create new concepts, theories, uses and technological developments related to artificial intelligence.

CG4. Reasoning, analyzing reality and designing algorithms and formulations that model it. To identify problems and construct valid algorithmic or mathematical solutions, eventually new, integrating the necessary multidisciplinary knowledge, evaluating different alternatives with a critical spirit, justifying the decisions taken, interpreting and synthesizing the results in the context of the application domain and establishing methodological generalizations based on specific applications.

CG2. To use the fundamental knowledge and solid work methodologies acquired during the studies to adapt to the new technological scenarios of the future.

CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

**Full-or-part-time:** 19h

Self study: 10h

Theory classes: 4h

Laboratory classes: 5h



### Building Abstractions with Functions: Objects and Classes

**Description:**

The student should pay attention to the lecture and he/she should work through the exercises suggested by the lecturer.

**Specific objectives:**

2, 3

**Related competencies :**

CE02. To master the basic concepts of discrete mathematics, logic, algorithmic and computational complexity, and its application to the automatic processing of information through computer systems . To be able to apply all these for solving problems.

CE03. To identify and apply the basic algorithmic procedures of computer technologies to design solutions to problems by analyzing the suitability and complexity of the proposed algorithms.

CE10. To analyze, design, build and maintain applications in a robust, secure and efficient way, choosing the most appropriate paradigm and programming languages.

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CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

**Full-or-part-time:** 32h

Self study: 16h

Theory classes: 8h

Laboratory classes: 8h



## Building Abstractions with Data: Dynamic Data Structures

**Description:**

The student should pay attention to the lecture and he/she should work through the exercises suggested by the lecturer.

**Specific objectives:**

1, 2

**Related competencies :**

CE02. To master the basic concepts of discrete mathematics, logic, algorithmic and computational complexity, and its application to the automatic processing of information through computer systems . To be able to apply all these for solving problems.

CE03. To identify and apply the basic algorithmic procedures of computer technologies to design solutions to problems by analyzing the suitability and complexity of the proposed algorithms.

CE04. To design and use efficiently the most appropriate data types and structures to solve a problem.

CE12. To master the fundamental principles and models of computing and to know how to apply them in order to interpret, select, assess, model, and create new concepts, theories, uses and technological developments related to artificial intelligence.

CG4. Reasoning, analyzing reality and designing algorithms and formulations that model it. To identify problems and construct valid algorithmic or mathematical solutions, eventually new, integrating the necessary multidisciplinary knowledge, evaluating different alternatives with a critical spirit, justifying the decisions taken, interpreting and synthesizing the results in the context of the application domain and establishing methodological generalizations based on specific applications.

CG2. To use the fundamental knowledge and solid work methodologies acquired during the studies to adapt to the new technological scenarios of the future.

CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

**Full-or-part-time:** 20h

Self study: 10h

Theory classes: 6h

Laboratory classes: 4h



## Sets and Dictionaries: Implementation

### Description:

The student should pay attention to the lecture and he/she should work through the exercises suggested by the lecturer.

### Specific objectives:

2, 3

### Related competencies :

CE02. To master the basic concepts of discrete mathematics, logic, algorithmic and computational complexity, and its application to the automatic processing of information through computer systems . To be able to apply all these for solving problems.

CE03. To identify and apply the basic algorithmic procedures of computer technologies to design solutions to problems by analyzing the suitability and complexity of the proposed algorithms.

CE10. To analyze, design, build and maintain applications in a robust, secure and efficient way, choosing the most appropriate paradigm and programming languages.

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CE12. To master the fundamental principles and models of computing and to know how to apply them in order to interpret, select, assess, model, and create new concepts, theories, uses and technological developments related to artificial intelligence.

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**Full-or-part-time:** 16h

Self study: 8h

Theory classes: 4h

Laboratory classes: 4h



## Algorithmic Complexity (II)

### Description:

The student should pay attention to the lecture and he/she should work through the exercises suggested by the lecturer.

### Specific objectives:

4

### Related competencies :

CE02. To master the basic concepts of discrete mathematics, logic, algorithmic and computational complexity, and its application to the automatic processing of information through computer systems . To be able to apply all these for solving problems.

CE13. To evaluate the computational complexity of a problem, identify algorithmic strategies that can lead to its resolution and recommend, develop and implement the one that guarantees the best performance in accordance with the established requirements.

CE12. To master the fundamental principles and models of computing and to know how to apply them in order to interpret, select, assess, model, and create new concepts, theories, uses and technological developments related to artificial intelligence.

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CG2. To use the fundamental knowledge and solid work methodologies acquired during the studies to adapt to the new technological scenarios of the future.

CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

**Full-or-part-time:** 20h

Self study: 8h

Theory classes: 6h

Laboratory classes: 6h



## Practical Work

### Description:

Students will do a pair practice related to a small-medium size problem.

### Specific objectives:

1, 2, 3, 5

### Related competencies :

CE02. To master the basic concepts of discrete mathematics, logic, algorithmic and computational complexity, and its application to the automatic processing of information through computer systems . To be able to apply all these for solving problems.

CE03. To identify and apply the basic algorithmic procedures of computer technologies to design solutions to problems by analyzing the suitability and complexity of the proposed algorithms.

CE10. To analyze, design, build and maintain applications in a robust, secure and efficient way, choosing the most appropriate paradigm and programming languages.

CE04. To design and use efficiently the most appropriate data types and structures to solve a problem.

CE12. To master the fundamental principles and models of computing and to know how to apply them in order to interpret, select, assess, model, and create new concepts, theories, uses and technological developments related to artificial intelligence.

CG4. Reasoning, analyzing reality and designing algorithms and formulations that model it. To identify problems and construct valid algorithmic or mathematical solutions, eventually new, integrating the necessary multidisciplinary knowledge, evaluating different alternatives with a critical spirit, justifying the decisions taken, interpreting and synthesizing the results in the context of the application domain and establishing methodological generalizations based on specific applications.

CG2. To use the fundamental knowledge and solid work methodologies acquired during the studies to adapt to the new technological scenarios of the future.

CG8. Perform an ethical exercise of the profession in all its facets, applying ethical criteria in the design of systems, algorithms, experiments, use of data, in accordance with the ethical systems recommended by national and international organizations, with special emphasis on security, robustness , privacy, transparency, traceability, prevention of bias (race, gender, religion, territory, etc.) and respect for human rights.

CT4. Teamwork. Be able to work as a member of an interdisciplinary team, either as a member or conducting management tasks, with the aim of contributing to develop projects with pragmatism and a sense of responsibility, taking commitments taking into account available resources.

CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

**Full-or-part-time:** 12h

Self study: 12h



## Partial Exam

### Specific objectives:

1, 2, 3

### Related competencies :

CE02. To master the basic concepts of discrete mathematics, logic, algorithmic and computational complexity, and its application to the automatic processing of information through computer systems . To be able to apply all these for solving problems.

CE03. To identify and apply the basic algorithmic procedures of computer technologies to design solutions to problems by analyzing the suitability and complexity of the proposed algorithms.

CE10. To analyze, design, build and maintain applications in a robust, secure and efficient way, choosing the most appropriate paradigm and programming languages.

CE04. To design and use efficiently the most appropriate data types and structures to solve a problem.

CE12. To master the fundamental principles and models of computing and to know how to apply them in order to interpret, select, assess, model, and create new concepts, theories, uses and technological developments related to artificial intelligence.

CG4. Reasoning, analyzing reality and designing algorithms and formulations that model it. To identify problems and construct valid algorithmic or mathematical solutions, eventually new, integrating the necessary multidisciplinary knowledge, evaluating different alternatives with a critical spirit, justifying the decisions taken, interpreting and synthesizing the results in the context of the application domain and establishing methodological generalizations based on specific applications.

CG2. To use the fundamental knowledge and solid work methodologies acquired during the studies to adapt to the new technological scenarios of the future.

CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

**Full-or-part-time:** 14h

Self study: 12h

Guided activities: 2h

## Final Exam

### Specific objectives:

1, 2, 3, 4

### Related competencies :

CE02. To master the basic concepts of discrete mathematics, logic, algorithmic and computational complexity, and its application to the automatic processing of information through computer systems . To be able to apply all these for solving problems.

CE03. To identify and apply the basic algorithmic procedures of computer technologies to design solutions to problems by analyzing the suitability and complexity of the proposed algorithms.

CE10. To analyze, design, build and maintain applications in a robust, secure and efficient way, choosing the most appropriate paradigm and programming languages.

CE13. To evaluate the computational complexity of a problem, identify algorithmic strategies that can lead to its resolution and recommend, develop and implement the one that guarantees the best performance in accordance with the established requirements.

CE04. To design and use efficiently the most appropriate data types and structures to solve a problem.

CE12. To master the fundamental principles and models of computing and to know how to apply them in order to interpret, select, assess, model, and create new concepts, theories, uses and technological developments related to artificial intelligence.

CG4. Reasoning, analyzing reality and designing algorithms and formulations that model it. To identify problems and construct valid algorithmic or mathematical solutions, eventually new, integrating the necessary multidisciplinary knowledge, evaluating different alternatives with a critical spirit, justifying the decisions taken, interpreting and synthesizing the results in the context of the application domain and establishing methodological generalizations based on specific applications.

CG2. To use the fundamental knowledge and solid work methodologies acquired during the studies to adapt to the new technological scenarios of the future.

CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

**Full-or-part-time:** 17h

Self study: 14h

Guided activities: 3h



## GRADING SYSTEM

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Grading the course will consist of two theoretical tests (T1 and T2), one mid-course and the other at the end, and one medium-sized practical work (Practice).

Then, the evaluation method would be:

$$0.8 * \text{Theory} + 0.2 * \text{Practice}$$

where:

$$\text{Theory: } \text{MAX}(T2, 0.5 * T1 + 0.5 * T2)$$

Reassessment: Only those who have failed the theory part, after taking the final exam, may take the reassessment. The maximum grade that can be obtained in the reassessment is 7.

Teamwork:

Evaluated using a simple rubric that each group tutor group uses to rank different aspects of teamwork of every member of the group.

## BIBLIOGRAPHY

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### Basic:

- DeNero, John. Composing programs.
- Abelson, Harold; Sussman, Gerald Jay; Sussman, Julie. Structure and interpretation of computer programs. 2nd ed. Cambridge [Massachusetts]: MIT Press [etc.], 1996. ISBN 9780262011532.
- Lee, Kent D; Hubbard, Steve. Data structures and algorithms with Python. New York: Springer, 2014. ISBN 9783319130712.

### Complementary:

- Lutz, Mark. Python pocket reference. 5th ed. Sebastopol: O'Reilly Media, 2014. ISBN 9781449356941.

## RESOURCES

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### Hyperlink:

- <http://composingprograms.com/> - <https://docs.python.org/3/reference/index.html>