# AI: STATISTICAL LEARNING & PREDICTION

**Grado en Computación e Inteligencia Artificial / Bachelor in Computer Science and Artificial Intelligence BCSAI SEP-2025 AISLP-CSAI.3.M.B**

Area Computer Science

Number of sessions: 30

Academic year: 25-26

Degree course: THIRD

Number of credits: 6.0

Semester: 2º

Category: COMPULSORY

Language: English

Professor: **LUCIANO DYBALLA**

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Luciano Dyballa is an Assistant Professor at IE University in the School of Science & Technology since 2024. He obtained his Ph.D. in Computer Science from Yale University focusing on machine learning, vision, and computational neuroscience. His research aims at investigating the mechanisms and principles behind real and artificial intelligence, and in bridging the gap between biological and deep neural networks. Prior to Yale, he obtained a B.S. in Chemical Engineering and an M.S. in Computer Science, both from the Federal University of Rio de Janeiro, in Brazil. He has also worked as an engineer, developing software for data mining and natural language processing.

### Office Hours

Office hours will be on request. Please contact at:

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## SUBJECT DESCRIPTION

This course introduces some of the fundamental algorithms in machine learning, with an emphasis on their theoretical foundations and underlying mathematical principles. Examples using a variety of datasets are presented to build intuition for how the different methods work. Assignments give students hands-on experience with the methods on different types of data. Topics include nearest neighbors, neural networks, support vector machines, trees, clustering, dimensionality reduction, and generative models. Many lectures will include a short coding demo using Python.

## LEARNING OBJECTIVES

- Consolidate basic machine learning concepts: regression vs. classification, cross-validation, overfitting, bias-variance tradeoff, regularization;
- Become familiar with the details behind a variety of machine learning algorithms and techniques: k-nearest neighbors, SVMs, multi-layer perceptrons, deep networks, trees and forests, and more;
- Demonstrate practical knowledge on how to select an appropriate algorithm for a specific problem, and adequately assess its performance.
- Understand in detail the principles and challenges of using neural networks for deep learning;
- Demonstrate proficiency in implementing ML algorithms using the Python programming language.

## TEACHING METHODOLOGY

Before each class, students are expected to work on assignments and readings at home. The course lectures will cover both theoretical explanations and practical examples. Most lectures will also include a coding demonstration. Each new technique introduced will be followed by one or more examples. Students need to participate in class to acquire the skills needed to understand, implement, and apply each of the concepts and algorithms covered. Problem sets and brief quizzes will be used throughout the course to assess student progress.

Problem sets will be designed for students to develop intuition behind the theory and to develop the coding skills necessary to implement the algorithms. While students are encouraged to work with others on understanding the lecture material and assignments, all written work (including code) should be your own — plagiarism will not be accepted. If you benefit from hints or solutions received from fellow students or from an outside source, please make sure to acknowledge all of them in your work.

Brief quizzes will be given throughout the semester, covering previously taught material. These quizzes are meant to test the overall understanding of the material and help the professor assess the overall performance and evolution of the class.

| **Learning Activity** | **Weighting** | **Estimated time a student should dedicate to prepare for and participate in** |
|---|---|---|
| Lectures | 30.0 % | 45.0 hours |
| Discussions | 13.3 % | 20.0 hours |
| Exercises in class, Asynchronous sessions, Field Work | 20.0 % | 30.0 hours |
| Group work | 6.7 % | 10.0 hours |
| Individual studying | 30.0 % | 45.0 hours |
| TOTAL | 100.0 % | 150.0 hours |

### AI POLICY

Generative artificial intelligence (GenAI) tools may be used in this course for some specific tasks/assignments with appropriate acknowledgment. GenAI may **not** be used in group projects, quizzes or exams. If a student is found to have used AI-generated content inappropriately, it will be considered academic misconduct, and the student might fail the respective assignment or the course. If you are in doubt as to whether you are using GenAI tools appropriately in this course, we encourage you to discuss your situation with the professor.

Below is a suggested format to acknowledge the use of generative AI tools, **when allowed**. Please note that acknowledging AI will not impact your grade.

“I acknowledge the use of [AI systems link] to [specify how you used generative AI]. The prompts used include [list of prompts]. The output of these prompts was used to [explain how you used the outputs in your work]”

If AI was permitted to be used in your assignment, but you have chosen not to include any AI-generated content, the following disclosure is recommended:

“No content generated by AI technologies has been used in this assignment.”

## PREREQUISITES

Calculus for CS, Matrices & Linear Transformations, Probability for CS, Machine Learning Foundations, Computer Programming II

## PROGRAM

***Disclaimer:*** The following description of the material covered is tentative. While an attempt will be made to cover all listed topics and include other advanced topics that will help students throughout their careers in computer science, the pace of the classes will depend on group performance, which may introduce some variations in the syllabus.

## SESSION 1 (LIVE IN-PERSON)

- Introduction
- Nearest neighbors
- Curse of dimensionality

## SESSION 2 (LIVE IN-PERSON)

- Review of linear classifiers
- The perceptron

## SESSION 3 (LIVE IN-PERSON)

- Intro to neural nets
- Multi-layer perceptron

## SESSION 4 (LIVE IN-PERSON)

- Loss functions, activation functions
- Gradient descent

## SESSION 5 (LIVE IN-PERSON)

- Backpropagation

## SESSION 6 (LIVE IN-PERSON)

- Vanishing/exploding gradients
- Improving MLPs
- Deep networks

## SESSION 7 (LIVE IN-PERSON)

- Neural networks review
- Exercises

## SESSION 8 (LIVE IN-PERSON)

Midterm Exam

## SESSION 9 (LIVE IN-PERSON)

- Decision trees

## SESSION 10 (LIVE IN-PERSON)

- Linear SVMs

## SESSION 11 (LIVE IN-PERSON)

- Linear SVMs part II

## SESSION 12 (LIVE IN-PERSON)

- Losses and regularizers

## SESSION 13 (LIVE IN-PERSON)

- Bias-variance decomposition

## SESSION 14 (LIVE IN-PERSON)

- Ensemble methods I: Bagging

## SESSION 15 (LIVE IN-PERSON)

- Ensemble methods II: Boosting

## SESSION 16 (LIVE IN-PERSON)

- Ensemble methods III: stacking

## SESSION 17 (LIVE IN-PERSON)

- Kernel methods I

## SESSION 18 (LIVE IN-PERSON)

- Kernel methods II

**SESSION 19 (LIVE IN-PERSON)**

- Clustering I

**SESSION 20 (LIVE IN-PERSON)**

- Clustering II

**SESSION 21 (LIVE IN-PERSON)**

- Clustering III

**SESSION 22 (LIVE IN-PERSON)**

- Dimensionality reduction I

**SESSION 23 (LIVE IN-PERSON)**

- Dimensionality reduction II

**SESSION 24 (LIVE IN-PERSON)**

- Topics in deep learning I

**SESSION 25 (LIVE IN-PERSON)**

- Topics in deep learning II

**SESSION 26 (LIVE IN-PERSON)**

- Topics in deep learning III

**SESSION 27 (LIVE IN-PERSON)**

- Topics in deep learning IV

**SESSION 28 (LIVE IN-PERSON)**

Group presentations

**SESSION 29 (LIVE IN-PERSON)**

Group presentations

**SESSION 30 (LIVE IN-PERSON)**

Final Exam

## EVALUATION CRITERIA

| criteria | percentage | Learning Objectives | Comments |
|---|---|---|---|
| Final Exam | 40 % | | The final exam is worth 40% of the overall grade. You need to score at least 3.5 to pass the overall course, even if you have already passed the course through the other course assessments. |
| Midterm Exam | 25 % | | The midterm exam is worth 25% of the overall grade. |
| Group Project | 25 % | | The group project includes a written report and an in-class presentation. |
| Class Participation | 10 % | | The student is expected to turn in selected exercises that will be announced throughout the course. Students may be asked to present their work in class. Active participation during lectures is expected, with students encouraged to ask questions and make remarks. This grade will also take into account punctuality and class conduct. |

**RE-SIT / RE-TAKE POLICY**

Each student has four chances to pass any given course distributed over two consecutive academic years: ordinary call exams and extraordinary call exams (re-sits) in June/July.

Students who do not comply with the 80% attendance rule during the semester will fail both calls for this Academic Year (ordinary and extraordinary) and have to re-take the course (i.e., re-enroll) in the next Academic Year.

Evaluation criteria:

- Students failing the course in the ordinary call (during the semester) will have to re-sit the exam in June / July (except those not complying with the attendance rule, who will not have that opportunity and must directly re-enroll in the course on the next Academic Year).
- The extraordinary call exams in June / July (re-sits) require your physical presence at the campus you are enrolled in (Segovia or Madrid). There is no possibility to change the date, location or format of any exam, under any circumstances. Dates and location of the June / July re-sit exams will be posted in advance. Please take this into consideration when planning your summer.

- The June / July re-sit exam will consist of a comprehensive exam. Your final grade for the course will depend on the performance in this exam only; continuous evaluation over the semester will not be taken into consideration. Students will have to achieve the minimum passing grade of 5 and can obtain a maximum grade of 8.0 (out of 10.0) – i.e., “notable” in the in the re-sit exam.

- Retakers: Students who failed the subject on a previous Academic Year and are now re- enrolled as re-takers in a course will be needed to check the syllabus of the assigned professor, as well as contact the professor individually, regarding the specific evaluation criteria for them as retakers in the course during that semester (ordinary call of that Academic Year). The maximum grade that may be obtained in the retake exam (3rd call) is 10.0.

After ordinary and extraordinary call exams are graded by the professor, you will have a possibility to attend a review session for that exam and course grade. Please be available to attend the session in order to clarify any concerns you might have regarding your exam. Your professor will inform you about the time and place of the review session. Any grade appeals require that the student attended the review session prior to appealing.

Students failing more than 18 ECTS credits in the academic year after the June-July re-sits will be asked to leave the Program. Please, make sure to prepare yourself well for the exams in order to pass your failed subjects.

In case you decide to skip the opportunity to re-sit for an exam during the June / July extraordinary call, you will need to enroll in that course again for the next Academic Year as a re-taker and pay the corresponding extra cost. As you know, students have a total of four allowed calls to pass a given subject or course, in order to remain in the program.

## BIBLIOGRAPHY

### Recommended


- Michael A. Nielsen. (2015). *Neural Networks and Deep Learning.* Determination Press. ISBN 0000000000 (Digital)
  http://neuralnetworksanddeeplearning.com
- Trevor Hastie, Robert Tibshirani, Jerome Friedman. (2017). *The Elements of Statistical Learning.* 2nd edition. Springer. ISBN 0387848576 (Digital)
  https://hastie.su.domains/ElemStatLearn/download.html
- Ian Goodfellow, Yoshua Bengio, Aaron Courville. (2016). *Deep Learning.* 1st edition. ISBN 0262035618 (Printed)
  https://www.deeplearningbook.org


## BEHAVIOR RULES

Please, check the University's Code of Conduct here. The Program Director may provide further indications.

## ATTENDANCE POLICY

Please, check the University's Attendance Policy here. The Program Director may provide further indications.

## ETHICAL POLICY

Please, check the University's Ethics Code here. The Program Director may provide further indications.