Course guide
270415 - XNDL - Neural Networks and Deep Learning

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: LUIS ANTONIO BELANCHE MUÑOZ

Others:

PRIOR SKILLS

Knowledge of machine learning and basic AI algorithms.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE01. To be able to solve the mathematical problems that may arise in the field of artificial intelligence. Apply knowledge from: algebra, differential and integral calculus and numerical methods; statistics and optimization.
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.
CE15. To acquire, formalize and represent human knowledge in a computable form for solving problems through a computer system in any field of application, particularly those related to aspects of computing, perception and performance in intelligent environments or environments.
CE18. To acquire and develop computational learning techniques and to design and implement applications and systems that use them, including those dedicated to the automatic extraction of information and knowledge from large volumes of data.
CE20. To select and put to use techniques of statistical modeling and data analysis, assessing the quality of the models, validating and interpreting.
CE26. To design and apply techniques for processing and analyzing images and computer vision techniques in the area of artificial intelligence and robotics

Generical:
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.
CG9. To face new challenges with a broad vision of the possibilities of a professional career in the field of Artificial Intelligence. Develop the activity applying quality criteria and continuous improvement, and act rigorously in professional development. Adapt to organizational or technological changes. Work in situations of lack of information and / or with time and / or resource restrictions.

Transversal:
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.

Basic:
CB3. That students have the ability to gather and interpret relevant data (usually within their area of ??study) to make judgments that include a reflection on relevant social, scientific or ethical issues.

TEACHING METHODOLOGY

The course delves into one of the most important machine learning paradigms today: artificial neural networks, with a strong foundation in probability, statistics and mathematics. The theory is introduced in lectures where the teacher explains the concepts. These concepts are put into practice in laboratory classes, where the student learns to develop machine learning solutions to real problems of some complexity. Students must work on and hand in a project at the end of the course.

LEARNING OBJECTIVES OF THE SUBJECT

1.To know how to identify a data analysis problem and solve it from start to finish (end to end)
2.To know the theoretical foundations of neural networks as models of machine learning
3.To know and understand the fields of application of neural networks and know how to develop solutions to specific problems
4.To know how to design solutions for problems related to language, image or sound

STUDY LOAD

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

Total learning time: 150 h

CONTENTS

General concepts of machine learning

Description:
Review of the general theoretical concepts of machine learning. Learning as an optimization problem. Bayesian interpretation of the learning problem. Generalized linear models.

Foundations of artificial neural networks.

Description:
Foundations of artificial neural networks. Basic biological concepts. McCulloch-Pitts model. Cognitive and computational implications. Lippmann networks. Loss functions, activation functions.

Feed-forward neural networks

Description:
Feed-forward neural networks.
Linear networks (I): the Perceptron.
Linear networks (II): the Delta rule.
Multilayer Perceptrons and Backpropagation.
Descent of gradients and variants.
Other optimizers: pseudo-Newton, CG, Rprop.
Networks of radial basis functions.
Autoencoders.
Support vector machines.
Convolutional networks.
Good experimental practices.

Recurrent neural networks

Description:
Recurrent neural networks. Hopfield networks.
Bidirectional associative networks.
Short-term memory (LSTM) networks.

ACTIVITIES

Theoretical classes

Description:
Development of theoretical classes in the assigned hours. These are eminently masterful classes supported by projections and blackboards.

Specific objectives:
1, 2, 3, 4

Related competencies :
CB3. That students have the ability to gather and interpret relevant data (usually within their area of ??study) to make judgments that include a reflection on relevant social, scientific or ethical issues.
CE15. To acquire, formalize and represent human knowledge in a computable form for solving problems through a computer system in any field of application, particularly those related to aspects of computing, perception and performance in intelligent environments or environments.
CE18. To acquire and develop computational learning techniques and to design and implement applications and systems that use them, including those dedicated to the automatic extraction of information and knowledge from large volumes of data.
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.
CE01. To be able to solve the mathematical problems that may arise in the field of artificial intelligence. Apply knowledge from: algebra, differential and integral calculus and numerical methods; statistics and optimization.
CE20. To select and put to use techniques of statistical modeling and data analysis, assessing the quality of the models, validating and interpreting.
CE26. To design and apply techniques for processing and analyzing images and computer vision techniques in the area of artificial intelligence and robotics
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.
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.
CG9. To face new challenges with a broad vision of the possibilities of a professional career in the field of Artificial Intelligence. Develop the activity applying quality criteria and continuous improvement, and act rigorously in professional development. Adapt to organizational or technological changes. Work in situations of lack of information and / or with time and / or resource restrictions.
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.
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.

Full-or-part-time: 63h
Self study: 35h
Theory classes: 28h

Laboratory classes

Description:
Examples of the application of the concepts seen in theory classes. Explanations related to the triats programming languages. Additional explanations relevant to the subject: practical skills, experimental methodology, etc.

Specific objectives:
1, 4

Related competencies :
CB3. That students have the ability to gather and interpret relevant data (usually within their area of ??study) to make judgments that include a reflection on relevant social, scientific or ethical issues.
CE15. To acquire, formalize and represent human knowledge in a computable form for solving problems through a computer system in any field of application, particularly those related to aspects of computing, perception and performance in intelligent environments or environments.
CE18. To acquire and develop computational learning techniques and to design and implement applications and systems that use them, including those dedicated to the automatic extraction of information and knowledge from large volumes of data.
CE26. To design and apply techniques for processing and analyzing images and computer vision techniques in the area of artificial intelligence and robotics
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.
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.
CG9. To face new challenges with a broad vision of the possibilities of a professional career in the field of Artificial Intelligence. Develop the activity applying quality criteria and continuous improvement, and act rigorously in professional development. Adapt to organizational or technological changes. Work in situations of lack of information and / or with time and / or resource restrictions.
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.
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.

Full-or-part-time: 53h
Self study: 25h
Laboratory classes: 28h

Partial Exam

Description:
Partial exam (in the middle of the semester) that covers all the syllabus seen up to that point, or a little earlier, at the teacher's discretion. The exam will take place in a laboratory classroom and may consist of theory, methodological or practical questions.

Specific objectives:
1, 2, 3

Related competencies :
CE15. To acquire, formalize and represent human knowledge in a computable form for solving problems through a computer system in any field of application, particularly those related to aspects of computing, perception and performance in intelligent environments or environments.
CE18. To acquire and develop computational learning techniques and to design and implement applications and systems that use them, including those dedicated to the automatic extraction of information and knowledge from large volumes of data.
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.
CE01. To be able to solve the mathematical problems that may arise in the field of artificial intelligence. Apply knowledge from: algebra, differential and integral calculus and numerical methods; statistics and optimization.
CE20. To select and put to use techniques of statistical modeling and data analysis, assessing the quality of the models, validating and interpreting.
CE26. To design and apply techniques for processing and analyzing images and computer vision techniques in the area of artificial intelligence and robotics
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.
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.
CG9. To face new challenges with a broad vision of the possibilities of a professional career in the field of Artificial Intelligence. Develop the activity applying quality criteria and continuous improvement, and act rigorously in professional development. Adapt to organizational or technological changes. Work in situations of lack of information and / or with time and / or resource restrictions.
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.
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.

Full-or-part-time: 2h
Guided activities: 2h

Final Exam

Description:
Final exam (during the period of final exams) that covers all the syllabus seen in the subject. The exam will be held in a theory classroom and may consist of theory or methodological questions.

Specific objectives:
1, 2, 3, 4

Related competencies :
CB3. That students have the ability to gather and interpret relevant data (usually within their area of ??study) to make judgments that include a reflection on relevant social, scientific or ethical issues.
CE15. To acquire, formalize and represent human knowledge in a computable form for solving problems through a computer system in any field of application, particularly those related to aspects of computing, perception and performance in intelligent environments or environments.
CE18. To acquire and develop computational learning techniques and to design and implement applications and systems that use them, including those dedicated to the automatic extraction of information and knowledge from large volumes of data.
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.
CE01. To be able to solve the mathematical problems that may arise in the field of artificial intelligence. Apply knowledge from: algebra, differential and integral calculus and numerical methods; statistics and optimization.
CE20. To select and put to use techniques of statistical modeling and data analysis, assessing the quality of the models, validating and interpreting.
CE26. To design and apply techniques for processing and analyzing images and computer vision techniques in the area of artificial intelligence and robotics
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.
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.
CG9. To face new challenges with a broad vision of the possibilities of a professional career in the field of Artificial Intelligence. Develop the activity applying quality criteria and continuous improvement, and act rigorously in professional development. Adapt to organizational or technological changes. Work in situations of lack of information and / or with time and / or resource restrictions.
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.
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.

Full-or-part-time: 2h
Guided activities: 2h

Practical project

Description:
Development of a practical project where you can demonstrate that you know how to apply the concepts, methods and techniques specific to the subject.

Specific objectives:
1, 4

Related competencies :
CB3. That students have the ability to gather and interpret relevant data (usually within their area of ??study) to make judgments that include a reflection on relevant social, scientific or ethical issues.
CE15. To acquire, formalize and represent human knowledge in a computable form for solving problems through a computer system in any field of application, particularly those related to aspects of computing, perception and performance in intelligent environments or environments.
CE18. To acquire and develop computational learning techniques and to design and implement applications and systems that use them, including those dedicated to the automatic extraction of information and knowledge from large volumes of data.
CE26. To design and apply techniques for processing and analyzing images and computer vision techniques in the area of artificial intelligence and robotics
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.
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.
CG9. To face new challenges with a broad vision of the possibilities of a professional career in the field of Artificial Intelligence. Develop the activity applying quality criteria and continuous improvement, and act rigorously in professional development. Adapt to organizational or technological changes. Work in situations of lack of information and / or with time and / or resource restrictions.
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.
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.

Full-or-part-time: 30h
Self study: 30h

GRADING SYSTEM

The course is graded as follows:

P = Grade obtained in the partial exam (control).
F = Grade obtained in the Final exam
T = Grade obtained in the practical work

Final grade = 40% T + 40% F + 20% P

Reassessment:

Only those students who had previously taken the final exam and failed to pass it can take the reassessment exam (a failure to take it is no enough).

BIBLIOGRAPHY

Basic:
- Bishop, Christopher M. Pattern recognition and machine learning. New York : Springer: Springer, cop. 2006. ISBN 0387310738.
- Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron. Deep learning. Cambridge, Massachusetts: MIT Press, 2016. ISBN 9780262035613.
- Aggarwal, Charu C. Neural networks and deep learning : a textbook [on line]. 2nd ed. Cham: Springer, 2023 [Consultation: 05/03/2025]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=30620507. ISBN 9783031296420.
- Haykin, Simon S. Neural networks and learning machines. 3rd ed. Upper Saddle River: Prentice Hall, cop. 2009. ISBN 9780131471399.