ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93000947 - Bio-inspired Learning

DEGREE PROGRAMME

09AT - Master Universitario En Teoria De La Señal Y Comunicaciones

ACADEMIC YEAR & SEMESTER

2023/24 - Semester 2

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	93000947 - Bio-Inspired Learning
No of credits	3 ECTS
Type	Optional
Academic year ot the programme	First year
Semester of tuition	Semester 2
Tuition period	February-June
Tuition languages	English
Degree programme	09AT - Master Universitario en Teoria de la Señal y Comunicaciones
Centre	09 - Escuela Tecnica Superior De Ingenieros De Telecomunicacion
Academic year	2023-24

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Diego Andina De La Fuente	C-310	d.andina@upm.es	Sin horario. Appointment arranged by email
Juan Isidoro Seijas Martinez-Echevarria	C-319	juan.seijas@upm.es	Sin horario. Appointment arranged by email

Juan Ignacio Godino Llorente (Subject coordinator)	C-312	ignacio.godino@upm.es	Sin horario. Appointment arranged by email
Jose Luis Blanco Murillo	C-331	jl.blanco@upm.es	Sin horario. Appointment arranged by email
Luis Alfonso Hernandez Gomez	C-330	luisalfonso.hernandez@upm.es	Sin horario. Appointment arranged by email
Eduardo Lopez Gonzalo	C-330	eduardo.lopez@upm.es	Sin horario. Appointment arranged by email

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

2.3. External faculty

Name and surname	Email	Institution
Juan Luis Fernández Martínez	jlf@uniovi.es	Universidad de Oviedo

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

- Fundamentos De OptimizaciÓn

- Tratamiento De SeÑal Multimedia

- TeorÍa De La InformaciÓn

- Tratamiento EstadÍstico De SeÑales

3.2. Other recommended learning outcomes

- Probability and Estimation Theory for Engineers

- Digital Signal Processing fundamentals

- Knowledge of MATLAB

- Computer Science fundamentals

- Signal Processing fundamentals

4. Skills and learning outcomes *

4.1. Skills to be learned

CB06 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB08 - Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios

CB09 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo

CE01 - Analizar y aplicar técnicas para el diseño y desarrollo avanzado de equipos y sistemas, basándose en la teoría de la señal y las comunicaciones, en un entorno internacional

CE02 - Evaluar y sintetizar los resultados de un trabajo en equipo en proyectos relacionados con la teoría de la señal y las comunicaciones, en un entorno internacional.

CETFM - Capacidad de realizar un trabajo o proyecto integrando y relacionando las competencias adquiridas en las distintas asignaturas del máster, junto con la capacidad de defenderlo en público ante un grupo de personas expertas en el tema del trabajo

CT01 - Capacidad para comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa

CT03 - Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas

CT04 - Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo

CT05 - Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de documentos técnicos y científicos, de una manera adecuada y eficiente

4.2. Learning outcomes

RA46 - Knowledge of using the methods for real-world applications and coding your own algorithms.

RA34 - Capability to develop and evaluate machine-learning techniques and to design big data learning systems

RA44 - To develop an understanding of the concepts and mathematical properties of Biological signal and systems to model them as artificial systems

RA45 - To achieve insight in biologically inspired as well as traditional machine learning methods for search, optimization and classification

RA41 - Ability to select and apply adequate machine learning techniques to large-scale multimedia datasets and evaluate their performance

RA42 - knowledge on Big Data technologies and their application to multimedia content

RA7 - Capacidad para desarrollar y evaluar técnicas de aprendizaje automático y diseñar sistemas de aprendizaje para datos masivos

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

This course aims to develop biologically inspired approaches to machine learning. The course begins with an introduction to Intelligent Systems in Nature. The course gradually covers the key features of biological and natural signals that are characterized by complexity, imprecision, and chaotic behavior, in order to understand how to select the appropriate signal processing and data mining methods for signal processing. Once the differences between the artificial and natural worlds are understood, it addresses the role of artificial neural networks in machine learning and introduces the fundamental principles of neurocomputing systems and biological learning modelling. But intelligence in Nature is not limited to brains made up of neurons. There is also collective intelligence and learning, so swarm systems are studied as a source of biological inspiration based on emergent intelligent collective behaviours and learning. The course lets the student practice bio-inspired techniques in different multidisciplinary application scenarios. As an added value, this course paves the way for students to add bio-inspired competitive and cooperative advantages in their future professional activities.

5.2. Syllabus

1. Biological Computation Concepts
    1.1. Presentation
    1.2. Bioinspired Learning, a key to the origin, present and future of Machine Learning
    1.3. Role in Industrial revolution 4.0
    1.4. Objective and Ethics
    1.5. Brainstorming exercise
2. Biological Information and Computing: successful imprecision and complexity processing
    2.1. Fractality and Fuzziness in Nature
    2.2. Fractal Properties and Scalability
    2.3. Natural Data Clustering
    2.4. The concept and relevance of Atypicality in Big Data
    2.5. Fractasl & Chaos
    2.6. Brianstorming Exercise

2.7. Forming successful Work Teams: Collaboration and competition rules for creativity and sustainability

2.8. Lab Practice: Data Mining Atypical Data

3. Neuroengineering: From Biological Learning to Artificial Design

3.1. Neuroengineering: the bridge between natural and artificial brains

3.2. Supervised Learning in Artificial Neural Networks

3.3. Unsupervised Learning in Artificial Neural Networks

3.4. Reinforcement Learning and Associative Networks

3.5. Automated classification and decision

3.6. .Integration of networks and Deep Networks

3.7. Plasticity and Metaplasticity of neurons for Bioinspired Deep Learning implementation

3.8. Case study: The Koniocortex-Like Network

3.9. Brainstorming exercise

3.10. Lab. Practice on real bionspired network for multidisciplinary applications

4. Collective (emergent) Intelligence: Swarms and System of Systems Engineering.

4.1. Swarm Intelligence

4.2. Evolutionary Computation

4.3. Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Bees Algorithm

4.4. System of Systems Engineering, a technology for the 21st Century Technological Revolution

5. Multidisciplinary Applications

5.1. Case Studies. Learning from real databases and taking complex decisions for: Management, Ecology, Medicine, Bussiness, Education, an almost any multidisciplinar field.

5.2. Student selection of applications to be sucessfully solved by bioinspired systems

6. Practice Classes

6.1. Final Work Orientation and presentation of proposals brianstormed by class

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Presentations** Duration: 02:00 Problem-solving class **Biological Computation Concepts** Duration: 01:00 Lecture **Braistorming** Duration: 01:00 Problem-solving class			
2	**Biological Information in Nature: Fractal and Fuzzy Processing** Duration: 02:00 Lecture **Lab Practice** Duration: 02:00 Laboratory assignments			
3	**Neuroengineering: from biological learning to artificial design** Duration: 02:00 Lecture **Lab Practice** Duration: 02:00 Laboratory assignments			
4	**Neuroengineering: from biological learning to artificial design** Duration: 02:00 Problem-solving class **Collective Intelligence: Swarms as System of Systems Engineering** Duration: 02:00 Lecture			
5	**Applications** Duration: 02:00 Lecture **Lab. Practice** Duration: 02:00 Problem-solving class			

6		**Brianstorming on final works** Duration: 04:00 Cooperative activities		
7		**Conclusions and questions. End of Course** Duration: 02:00 Cooperative activities		**Participation in classes, questions, initiatives, Written activities. Home work. Active interaction in Classes is valued 20% and the rest 10% of the score.** Other assessment Continuous assessment Presential Duration: 01:00 **Practical development: they are customary and serve as Progress Examinations** Individual work Continuous assessment Presential Duration: 01:00
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				**Written examination** Written test Final examination Presential Duration: 03:00 **Individual Final Work plus final examination (20% each)** Individual work Continuous assessment Presential Duration: 07:00

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
7	Participation in classes, questions, initiatives, Written activities. Home work. Active interaction in Classes is valued 20% and the rest 10% of the score.	Other assessment	Face-to-face	01:00	30%	1 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CT04 CE01 CT05 CB10
7	Practical development: they are customary and serve as Progress Examinations	Individual work	Face-to-face	01:00	30%	1 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CETFM CE02 CE01 CT05
17	Individual Final Work plus final examination (20% each)	Individual work	Face-to-face	07:00	40%	1 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CETFM CE02 CT04 CE01 CT05 CB10

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Written examination	Written test	Face-to-face	03:00	100%	5 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CETFM CE02 CT04 CE01 CT05 CB10

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Extraordinary examination will be carried out exclusively by the final assessment method	Other assessment	Face-to-face	02:30	100%	5 / 10	CB08 CB09 CT01 CB07 CT03 CE02 CT04 CT05

7.2. Assessment criteria

Students will be qualified through continuous evaluation by default. According to the "Normativa de Evaluación del Aprendizaje de la Universidad Politécnica de Madrid", students will perform a final examination. Their performance will be progressively evaluated through laboratory practices and individual work scores.

Evaluation will assess if students have acquired all the competencies of the subject. Thus, evaluation through final assessment will be carried out considering all the evaluation techniques used in continuous evaluation (EX, ET, TG, etc.), and will be celebrated in the exam period approved by Junta de Escuela for the current academic semester and year. Evaluation activities that assess learning outcomes that cannot be evaluated through a single exam can be carried out during the semester.

The extraordinary examination will be carried out exclusively by the final assessment method.

A. ORDINARY CALL

PROGRESSIVE EVALUATION:

EXAMINATION: Students will participate individually and in teams to cooperate in common tasks. They will prepare and deliver presentations and written tasks.

EVALUATION PARAMETERS:

- Technical (Expert Thinking)

- Presentations (Flipped Classroom)

- Team Work and Brainstorming (Divergent thinking)

- Attitude & participation in class (Soft skills: Motivation, Maturity, leadership, etc)

30%

- Practice results (Experiential Learning - Lab)

30%

- Individual final work and Examination:

40 %

FINAL INDIVIDUAL WORK: in the last week of courses (17th week) the students will deliver a final individual work about a modern neuroengineeering application and

MAXIMUM SCORE 20% OF TOTAL. The remaining 20% will be scored by the final examination.

TOTAL100 %

GLOBAL EVALUATION:

The global examination will be carried out exclusively by the final assessment method: a written exam with a maximum score of 100%.

B. EXTRAORDINARY EVALUATION:

The extraordinary examination will be carried out exclusively by the final assessment method: a written exam with a maximum score of 100%. Just in the same way as the global examination in the ordinary call.

Academic fraud:

Any assessment or report may require a complementary oral assessment by the professor in order to validate that

the task has been done by the student without help. According to the current assessment norms at UPM, if academic fraud is detected on any assessment, the student(s) will receive a grade of zero in the final grade of the examination to which the assessment belonged (ordinary or extraordinary).

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Bio-Inspired Artificial Intelligence Theories, Methods, and Technologies, MIT Press, Dario Floreano and Claudio Mattiussi, 2008	Bibliography	
Introduction to Evolutionary Computing,? 2nd Edition, by A. E. Eiben and J. E. Smith, Springer 2015	Bibliography	
Evolutionary Optimization Algorithms, by D. Simon, Wiley 2013	Bibliography	
Notebooks in the Moodle space of the course	Others	
Scientific papers about specific applications linked with the course	Bibliography	
PowerPoint Presentations available in the Moodle space of the course	Others	

9. Other information

9.1. Other information about the subject

The course is best enjoyed if students have their own access to a PC computer.

This matter contributes to the development of the following Sustainable Development Goals (SDGs):

SDG 4: ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

SDG 8: achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value.

SDG 10: reduce inequality within and among countries.

SDG 17: partnerships for the goals.