COURSE OUTLINE

(1) GENERAL

SCHOOLS	NATURAL SCIENCES		
ACADEMIC UNIT/UNITS	MATHEMATICS		
TITLE OF MASTER'S DEGREE	COMPUTATIONAL AND STATISTICAL DATA ANALYTICS (MCDA)		
LEVEL OF STUDIES	POSTGRADUATE		
COURSE CODE	MCDA201	**SEMESTER**	A
COURSE TITLE	NATURAL COMPUTING AND NEURAL NETWORKS		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*	WEEKLY TEACHING HOURS	CREDITS
Lectures	3	7.5
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (d).		

COURSE TYPE *general background, special background, specialised general knowledge, skills development*	General background
PREREQUISITE COURSES:	None
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	Greek
IS THE COURSE OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	https://eclass.upatras.gr/courses/MATH1142/

(2) LEARNING OUTCOMES

Learning outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.

Consult Appendix A

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning*

and Appendix B

- *Guidelines for writing Learning Outcomes*

The aim of the course is to present advanced computational paradigms (mathematical models) and related computational methods inspired from nature and biology, and their application for solving various problems such as, optimization, classification, regression, etc. Moreover, emphasis is given to problems characterized by uncertainty, that is, problems for which the available data is incomplete, erroneous or even unclear.

The course focuses; first, on the presentation of the mathematical structure of the computational models resulting from nature and the biological models and, on the other hand, it deals with the algorithms implementing these models. The relevance and the connection of the course to other subjects is examined from the point of view of the statistical learning theory and the probabilistic aspects of the natural and biological models with main reference to evolutionary algorithms, swarm intelligence and neural computation.

Upon successful completion of the course the students are expected to be able to select and apply the most suitable computational paradigm in order to approach, model and solve scientific and technological problems in a systematic way. More specifically, it is expected that the students will have developed the following skills:

- understanding of various methods,
- ability to discern the advantages and disadvantages of different methods in order to be able to choose and apply the most appropriate method for the problem they are asked to solve,
- ability to apply these methods to solve real world problems.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

Search for, analysis and synthesis of data and information, with the use of the necessary technology	*Project planning and management*
Adapting to new situations	*Respect for difference and multiculturalism*
Decision-making	*Respect for the natural environment*
Working independently	*Showing social, professional and ethical responsibility and sensitivity to gender issues*
Team work	*Criticism and self-criticism*
Working in an international environment	*Production of free, creative and inductive thinking*
Working in an interdisciplinary environment	*……*
Production of new research ideas	*Others…*

- Search for, analysis and synthesis of data and information, with the use of the necessary technology.
- Adapting to new situations.
- Decision making.
- Working independently.
- Team work.
- Working in an interdisciplinary environment.
- Production of free, creative and inductive thinking.

(3) SYLLABUS

PART A

Elements of theory of computation. Computational Intelligence. Machine Learning. Neural networks, fuzzy logic and evolutionary computation. Natural computing and computational intelligence. Elements of optimization for computational intelligence. Theoretical foundations and problems. No-free lunch theorem. Different aspects of optimization (combinatorial, global, local, constrained, etc.). Multi-objective optimization, problems and applications. Evolutionary computation and algorithms. Genetic algorithm. Basic principles and mechanisms (selection, crossover and mutation). Techniques of evolution. Genetic programming, grammatical evolution and evolutionary strategies. Different versions of genetic and evolutionary algorithms. Applications. Algorithms based on the social behavior of populations. Swarm intelligence. Particle swarm optimization. Basic approach and different versions. Issues related to initialization, convergence and exploration of the space of feasible solutions. Exploration and exploitation. Applications of particle swarm optimization. Models of computations based on paradigms such as ant colony, bee colony, mimetic and differential-evolution algorithms.

PART B

Neural networks and neural computation. Biological and artificial neurons. Structure, basic operation, stimulation and activation function of the neuron. Training, learning and generalization. Methods for training neural networks. Supervised training. Unsupervised training. Reinforcement learning. Applications of neural networks in science and technology. Classification and regression problems and issues. Linear and non-linear classifiers. Neural networks as classifiers optimizing a cost function. Perceptron and multi-layer perceptron. Support vector machines. Probabilistic neural networks. Recurrent neural networks, Boltzman machines, time delay networks, radial basis function neural networks. Unsupervised learning, vector quantization and Kohonen self-organizing maps. Deep learning networks and applications. Statistical learning theory. Neural network output interpretation. Specific issues on cellular neural networks, artificial immune systems and membrane computing.

(4) TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Lectures (face to face)
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	• Use of ICT in teaching ✓ lecturing with electronic slides, ✓ communication with the students using email and video conference. • Use of the *eClass* platform to support self-study and comprehension.
TEACHING METHODS *The manner and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.* *The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS*	

Activity	*Semester workload*
Lectures	39
Study (no driven)	100
Essay writing	45
Final examination	3.5
Total number of hours for the Course (25 hours of work-load per ECTS credit)	***187.5***

STUDENT PERFORMANCE EVALUATION *Description of the evaluation procedure* *Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other* *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	**Assessment Language:** Greek **Assessment Language for Erasmus students:** English **Assessment methods:** For the evaluation of the students the following elements are taken into account: (a) the public presentation of his essay, the literature review and his understanding of a subject related to the course (b) the preparation of a personnal folder which includes: (1) the assignments given in the course, (2) the processing of the material for the presentation of the essay, (3) the educational material used for the public presentation, (4) the brief descriptions for all the assignments presented. (c) questions with brief answers concerning the items (a) and (b) above. Minimum passing grade: 5 Maximum passing grade: 10

(5) ATTACHED BIBLIOGRAPHY

- Brabazon, A., O'Neill, M. and McGarraghy, S. (2015). *Natural Computing Algorithms*. Springer.
- De Castro, L.N. (2006). *Fundamentals of Natural Computing: Basic Concepts, Algorithms, and Applications*. CRC Press.
- Graupe, D. (2016). *Deep Learning Neural Networks: Design and Case Studies*. World Scientific Publishing Co Inc.
- Hassoun, M. H. (1995). *Fundamentals of Artificial Neural Networks*. MIT Press.
- Haykin, S. S. (1999). *Neural Networks: A Comprehensive Foundation*. Prentice-Hall.
- Nocedal J. and Wright, S.J. (2006). *Numerical Optimization*. 2nd ed. Springer.
- Ortega, J.M. and Rheinboldt, W.C. (2000). *Iterative Solution of Nonlinear Equations in Several Variables*. SIAM.

- Parsopoulos, K.E. and Vrahatis, M.N. (2010). *Particle Swarm Optimization and Intelligence: Advances and Applications*. Information Science Publishing (IGI Global).
- Russell, S.J. and Norvig, P. (2016). *Artificial Intelligence: A Modern Approach*. 3nd ed., Pearson Education.
- Smith, M. (1993). *Neural Networks for Statistical Modeling*. Van Nostrand Reinhold.

(in Greek)

- Βραχάτης, Μ.Ν. (2012). *Αριθμητική Ανάλυση: Υπερβατικές Εξισώσεις*. Εκδόσεις Κλειδάριθμος.