Postgraduate Course
Bio-inspired Learning
(MSc)

Instructor Information

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Course Information

Course Description

The goal of this course is to develop biologically-inspired approaches to Machine Learning. The course starts with an introduction to Intelligent Systems. It then addresses the role of Artificial Neural Networks in Machine Learning and presents the main principles in Neurocomputing Systems and Deep Learning. The course also introduces Processing of Biological and Nature signals, that are characterized by Fractality and Fuzzyness. Swarm Systems are studied as biologically-inspired approaches based on robust collective behaviour. The course also covers System of System Engineering and the Simulation of Intelligent Systems, and provides practical use cases in different application scenarios.

Prerequisites

Computer Science and Signal Processing fundamentals.

Probability and Estimation Theory for Engineers.

Digital Signal Processing fundamentals.

In addition, a working knowledge of MATLAB is required.

Course Goal

To develop an understanding of the concepts and mathematical properties of Biological signal and systems to model them as artificial systems. Achieving insight in biologically inspired as well as traditional machine learning methods for search, optimization and classification. Knowledge of using the methods for real-world applications and coding your own algorithms.

Summary of intended course outcomes

The students will understand fundamentals as well as advanced concepts in exploiting engineering solutions inspired in the knowledge of biological brain and swarms: biologically inspired engineering. They will be able to give answers to a challenging question: How can Engineering, Mathematics, Computation, Artificial Intelligence (AI) and Knowledge Engineering (KE) find inspiration in the behaviour and internal functioning of physical, biological Nervous Systems to conceive, develop and build-up new concepts, materials, mechanisms and algorithms of potential value in real world applications?. Through several case studies they will also practise biologically inspired multidisciplinary solutions including fields as diverse as Forecasting and Prediction, extracting information form Big Data, Unattended Robotics, Computing and Mathematical Sciences, or Medicine. By the end of the course, students should be able to:

- Familiarise students with computational concepts and methods inspired by biological systems
- Introduce the concepts of algorithm design for biologically inspired computing
- Develop skills in biologically inspired algorithm design with an emphasis on solving real world multidisciplinary problems
- Understand the most appropriate types of algorithms for different data analysis problems and to introduce some of the most appropriate implementation strategies in the state-of-the art.

Syllabus

1. Biological Computation Concepts
    - 1.1 Introduction
    - 1.2 Fractality and Fuzziness in Nature
    - 1.3 Sensors, Information extraction and data classification
    - 1.4 Biological Brains: Plasticity, learning and memory
    - 1.5 Emergent Intelligence

2. Biological Information in Nature: Fractal and Fuzzy Processing
    - 2.1 Fractal Properties and Scalability
    - 2.2 Clustering Big Data
    - 2.3 Hybrid Algorithms and Fuzzy C-Means

2.4 The concept and relevance of Atypicality in Big Data
2.5 Sub-Segmentation

3. Neuroengineering: From Biological Learning to Artificial Design
   3.1 Supervised Learning in Artificial Neural Networks
   3.2 Unsupervised Learning in Artificial Neural Networks
   3.3 Associative Networks and Evolutionary Algorithms
   3.3 Automated classification and decision
   3.4 Hybrid Networks for Deep Learning
   3.5 Higher order Plasticity for higher order Learning
   3.6 Artificial Metaplasticity, Intrinsic Plasticity and Deep Learning.

4. IV Collective Intelligence: Swarms as System of Systems Engineering.
   4.1 Ant Colony Optimization
   4.2 Particle Swarm Optimization
   4.3 Bees Algorithm
   4.5 System of Systems Engineering, a technology for the 21st Century.

5. Multidisciplinary Applications.
   5.1 Case study 1: A Neural Network to solve Air Pollutant Level Estimation
   5.2 Case study 2: ROI Identification for Computer Aided Diagnosis
   5.3 Case study 3: Credit Scoring and Bankrupt Prediction
   5.4 Case study 4: UAV path optimization
   5.5 Case study 5: Edge detection
   5.6 Case study 6: Big Data clustering
   5.7 Case study 7: Task allocation

Textbooks:
D Andina, DT Pham. *Computational Intelligence for Engineering and Manufacturing*. Springer (2007)

Recommended reading material:

1. E Bonabeau, M Dorigo, G Theraulaz. *Swarm intelligence: from natural to artificial systems.* Oxford university press (1999)
2. DO Hebb. The *Organization of Behavior: A Neuropsychological Theory*. Psychology Press, (2002).
3. M Jamshidi *System of systems engineering: innovations for the twenty-first century.* John Wiley & Sons (2011)
4. J Mira, JM. Ferrández, JR Alvarez-Sanchez. *Bioinspired Applications in Artificial and Natural Computation* (2009).
5. J.M. Ferrández, D. Maravall and J.R. Álvarez-Sánchez. "Searching for the interplay between neuroscience and computation" *Neurocomputing.*Volume 114, (2013).

Recommended reading papers:

1. MG Cortina–Januchs, J Quintanilla–Dominguez, A Vega–Corona, D. Andina. "Development of a model for forecasting of PM 10 concentrations in Salamanca, Mexico". *Atmospheric Pollution Research* 6 (4), 626-634 (2015)
2. A Jevtić, A Gutiérrez, D Andina, M Jamshidi. "Distributed bees algorithm for task allocation in swarm of robots" *Systems Journal, IEEE* 6 (2), 296-304 (2012)
3. A Jevtić, J Quintanilla-Domínguez, JM Barrón-Adame, Diego Andina. "Image segmentation using ant system-based clustering algorithm" *Soft Computing Models in Industrial and Environmental Applications,* 35-45. Springer Berlin/Heidelberg (2011).
4. A Jevtić, D Andina. "Adaptive artificial ant colonies for edge detection in digital images". *IECON 2010-36th Annual Conference on IEEE Industrial Electronics Society*, 2813-2816 (2010)
5. Marcano-Cedeno, A Marin-De-La-Barcena, J Jiménez-Trillo, JA Pinuela "Artificial metaplasticity neural network applied to credit scoring". *International Journal of Neural Systems* 21 (04), 311-317 (2011)
6. J Quintanilla-Dominguez, B Ojeda-Magaña, MG Cortina-Januchs, R Ruelas, A Vega-Corona, D Andina. "Image segmentation by fuzzy and possibilistic clustering algorithms for the identification of microcalcifications". *Scientia Iranica.* Vol 18, Num 3, 580-589 (2011)
7. J Ropero-Pelaez, D Andina "Do biological synapses perform probabilistic computations?" Neurocomputing 114, 24-31 Elsevier (2013).

Student Assessment Criteria

Case studies: 70%

- Teamwork: 40%
- Independent work 30%

Final Exam 30%

Matlab computer programs to simulate and practise practical cases will be provided.