



Non Conventional Computing: Biomolecular and Quantum Computing

Learning Guide – Student Information

(This information is for guidance purposes only. It may vary due to changes in the format of the guide, errors, omissions or any incidents occurred during the semester in which the module takes place.)

1. Description

Degree	MSc in Artificial Intelligence by the Universidad Politécnica de Madrid
Course	Not applicable
Subject	Natural Computing
Module	Non Conventional Computing: Biomolecular and Quantum Computing
Type	Optional module
ECTS Credits	5 ECTS
Responsible Department	Artificial Intelligence
Specialisation	Not applicable

Academic Year	2011-2012
Semester in which it is taught	First Semester
Language in which it is offered	English
Web Page	www.dia.fi.upm.es/masteria

2. Teaching Staff

NAME AND SURNAME	OFFICE	E-Mail
Alfonso Rodríguez-Patón Aradas (Coord.)	2106	arpaton@fi.upm.es
Petr Sosik	2201	psosik@fi.upm.es

3. Prior knowledge required to follow the module content normally

Completed Modules	•
Other Required Learning Outcomes	•

4. Learning Objectives

SPECIFIC MODULE COMPETENCES AND THEIR ACQUISITION LEVEL		
Code	Competences	Level
CG1	Students must be able to apply their acquired knowledge and their ability to solve problems in new or little known environments within broader (or multidisciplinary) contexts related to their area of study.	A
CG2	Students must be able to integrate knowledge and face the complexity of making judgements from information that, being incomplete or limited, may include reflections on social and ethical responsibilities tied to the application of their knowledge and judgement.	A
CG6	Information Management	A
CG8	Approaching and solving problems, also in new and emerging areas of their discipline.	A
CG9	Applying the most recent and innovative problem solving methods, and those which may imply the use of other disciplines.	A
CG15	Ability to contribute to the future development of computer science.	A
CG18	Ability to work and communicate in international contexts.	A
CGI1	Acquiring advanced scientific knowledge in the computer science field that generates new ideas within a line of research	A
CGI2	Understanding of the procedure, worth and limits of the scientific method within the computer science field; being able to identify, locate and obtain the data required for a research work; design and guide analytic research, modelling and experimental, as well as evaluate data in a critical way and draw conclusions.	A
CGI3	Ability to assess the importance of information sources, manage them and search for information for carrying out a given research work	A

CGI4	Ability to read and understand publications within their field of study/research, as well as their cataloguing and their scientific value.	A
CEIA1	Being capable of integrating Artificial Intelligence technologies and systems, of a general nature, in broader and multidisciplinary contexts.	C
CEIA2	Ability to connect cutting-edge Artificial Intelligence with customer needs.	C
CEIA5	Understanding of the main natural computing techniques, both at a symbolic and physical level, and identifying their suitability for different kinds of problems.	S
CEIA10	Identifying application areas in which Artificial Intelligence techniques and methods can be used.	C

Proficiency Level: knowledge (C), comprehension (P), application (A) and analysis and synthesis (S).

LEARNING OUTCOMES OF THE MODULE			
Code	Learning Outcomes	Associated Competences	Acquisition Level
RA1	Understanding how to design and implement bioalgorithms that use DNA molecules as a substrate (memory).	CG1, CG6, CG8, CG9, CG15, CG18, CGI1, CGI2, CGI3, CGI4	S
RA2	Designing synthetic bimolecular logic circuits operating (1) with DNA or (2) with bacteria	CG1, CG6, CG8, CG9, CG15, CG18, CGI1, CGI2, CGI3, CGI4, CEIA1, CEIA5, CEIA10	A
RA3	Understanding how to perform computations with models not based on silicon or electronics	CG1, CG6, CG8, CG9, CG15, CG18	P
RA4	Understanding (1) the reasons behind the power of quantum computing and (2) the security of quantum cryptography.	CG1, CG6, CG8, CG9, CG15, CG18	C



5. Assessment Method for the Module

ACHIEVEMENT INDICATORS		
Ref	Indicator	Related to RA
11	Describing the physical properties of DNA, its functionality and basic genetic operations.	RA1, RA2
12	Analysing and describing the classic “Brute Force” bioalgorithms from DNA computing, grounded on “generating and filtering” solutions.	RA1
13	Understanding how DNA can be used as a memory substrate with which information can be encoded and processed.	RA1, RA2
14	Understanding how DNA can be used as hardware with which to build biological information processing devices (biomolecular automata and genetic circuits).	RA2
15	Understanding how DNA or RNA can be used as software in order to run bioalgorithms or reprogram cells or bacteria.	RA1, RA2
16	Understanding what reversible computation and fluid computation are	RA3
17	Understanding which are the differences between quantum bit and classic bit.	RA4

SUMMATIVE ASSESSMENT			
Brief description of assessment activities	Period	Place	Weight on the final grade
Individual oral presentation	During the semester (compulsory)	Classroom	20%
Written exam about general knowledge of the course	During semester (compulsory)	Classroom	30%
Written work	At the end of the semester	Home	50%
			Total: 100%

ASSESSMENT CRITERIA

Oral presentations will be assessed and graded according to the clarity and depth of the exposition of basic concepts about the selected subject, the size and appropriateness of the consulted bibliography, the conciseness and the respect for the time allocated.

The individual oral presentation is compulsory in order to pass the module and has a maximum value of 20 points out of 100. The final written work has a maximum value of 50 points. The exam has a maximum value of 30 points in the final grade.

In order to complete the module, the student requires at least 50 points over 100 points after summing the 3 qualifications (oral presentation+exam+written work). And a minimum of 12 points over 30 in the exam.

Students must carry out a written work at the end of the module, in which they will study a problem or topic described in the module (or a related module), and previously defined by the professor. This document will contain a description of the selected problem or topic, as well as a critical reflection on the topic by the student. The student should consult at least five relevant papers related to the topic. The report of the work must be original and contain all citations and bibliographical references used for its elaboration. Plagiarising any section will involve failing the module automatically. Only the quality, and not the quantity, will be valued. In other words, the capacity of synthesis, the capacity of the student to understand the analysed problem, the depth of the analysis, and the critics and personal reflections of the student will be valued.

July extraordinary call. Students will pass the module in the extraordinary call of July if they make a written work (whose content should be agreed in advanced with the professors) and pass a written exam about the general topics analysed and seen along the course.

6. Content and Learning Activities

SPECIFIC CONTENT		
Bock / Unit / Chapter	Section	Related Indicators
Unit 1: "Classic" DNA Computing	1.1 DNA: structure, function and operations.	I1
	1.2 Solving the Hamilton Path Problem with DNA (Leonard Adleman's Algorithm).	I2
	1.3 Solving the SAT using DNA and other bioalgorithms for NP-Complete problems.	I2
	1.4 DNA Chip technology and combinatorial chemistry.	I3
Unit 2: DNA Synthetic Biology	2.1 Y. Benenson's Molecular Automata and M. Stojanovic's DNA logic gates.	I4
	2.2 Weiss's Genetic Circuits based on transcription regulation.	I4
	2.3 Pioneering synthetic circuits: Gardner's "Toggle switch" and Elowitz's "Repressilator".	I4



	2.4 DNA circuits based on competitive hybridisation (strand displacement).	15
	2.5 Simulation of synthetic gene circuits.	14, 15

Unit 3: Synthetic Biology from Bacteria	3.1 Inter-bacterial communication: "quorum sensing". Engineering of inter-bacterial communication.	15
	3.2 Bacterial circuits I: patterns.	15
	3.3 Bacterial circuits II: interaction between different populations.	15
	3.4 Simulation of bacterial circuits.	15
Unit 4: Reversible Computation, QCA and Fluid Computation	4.1 Fredkin's gates, Toffoli's gates, billiard ball model. Physical and logical reversibility.	16
	4.2 Quantum Cellular Automata.	16
	4.3 Computation with microfluidic systems (G. Whitesides, C. Calude).	16
Unit 5: Quantum Computation and Cryptography	5.1 Quantum bit versus classic bit: differences.	17
	5.2 Quantum physics: wave-particle duality and Heisenberg's Uncertainty Principle.	17
	5.3 Limitations and potential of quantum computation and cryptography.	17

7. Brief description of the organisational modalities and learning methods used

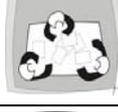
ORGANISATIONAL TEACHING MODALITIES		
Scenario	Modality	Purpose
	Lectures	Lecture the students
	Seminars – Workshops	Construction of knowledge through interaction and students' activities
	Practical Classes	Show students what to do
	Internships	The student completes training in a professional context
	Tutorials	Personalised attention to the students
	Group Working	Allow students to learn from interacting with one another
	Independent Working	Develop self-learning ability

Table 7: Organisational teaching modalities

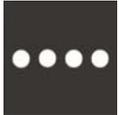
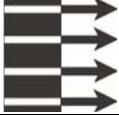
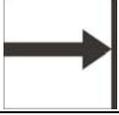
LEARNING METHODS			
	Method	Purpose	
	Presentation Method / Lecture	Transfer knowledge and trigger cognitive processes in the student	The expository method is known as “ <i>the presentation of a logically structured topic in order to provide organised information following criteria appropriate to the intended purpose.</i> ” This methodology – also know as lecture – is focused fundamentally on the oral presentation by the professor of the contents about the subject being studied. The term “master class” (<i>clase magistral</i>) is generally used to describe a specific type of lecture taught by a professor on special occasions.
	Case Study	Acquisition of learning through the analysis of real or simulated cases	Intensive and comprehensive analysis of a real fact, problem or event in order to know it, interpret it, solve it, create hypotheses, compare data, reflect, complete knowledge, diagnose it and, sometimes, train oneself in the possible alternative methods for a solution.
	Solving exercises or problems	Exercise, test and put previous knowledge into practice	Situations in which students are asked to develop appropriate or correct solutions by means of practising routines, application of formulae and algorithms, application of processes for transforming the available information, and interpreting results. These are often used as a complement to the master class.
	Problem based learning (PBL)	Develop active learning through problem solving	A teaching-learning method whose starting point is a problem, designed by the professor, that the student must solve in order to develop certain previously defined competences.
	Project oriented learning	Carry out a project to solve problems, applying acquired skills and knowledge.	A teaching-learning method in which the students complete a project in a certain period of time to solve a problem or deal with a task through planning, designing and carrying out a series of activities, and all this from the development and application of the acquired knowledge and the effective use of resources.
	Cooperative Learning	Develop active and significant learning in a cooperative way	Interactive approach to structuring the work in class, in which students are responsible for their learning and their classmates’ learning, in a strategy of co-responsibility, to achieve group goals and incentives. It is both a method, to be used amongst others and a global approach to teaching, a philosophy.
	Learning Contract	Develop independent learning	An agreement made between the professor and the student towards the achievement of learning through an independent work proposal, under the supervision of the professor, and during a given period. A formalised agreement is a basic tool in the learning contract, as are a relationship of reciprocal effort, a personal involvement and an execution timeframe.

Table 9: Learning methods



BRIEF DESCRIPTION OF THE ORGANISATIONAL MODALITIES AND LEARNING METHODS USED	
LECTURES	In each weekly class (of 2 hours) the teacher will perform the exposition of basic content about the different topics of the module for 1 hour and 15 minutes. 15 minutes will be devoted to doubts from the previous class and 30 minutes to oral presentations by the students.
PROBLEM SOLVING CLASSES	Not applicable.
PRACTICAL CLASSES	Optional practice work that consists of modelling and simulation of a biomolecular process.
INDEPENDENT WORKS	Reading the compulsory documentation of each unit, preparing individual oral presentations and writing the final report.
GROUP WORKS	Not applicable.
TUTORIALS	Doubts, comments and choice of presentation topics.

8. Teaching Resources

TEACHING RESOURCES	
BIBLIOGRAPHY	Scientific journal papers. PDF versions will be post to the Module Moodle site.
	Check out LIA group's website at www.lia.upm.es
WEB RESOURCES	Module webpage (http://)
	Module Moodle site (http://)
EQUIPMENT	Lab
	Classroom
	Group Working Room



9. Work Schedule of the Module

Week	Classroom Activities	Lab Activities	Individual Work	Work in Group	Assessment Activities	Other
Weeks 1 to 14 (2 hours of on-site classes)/week+ (3 hours of paper reading)/week + (6 hours for elaborating oral presentation) + (4 hours for tutorial work in group) + (37 hours for written work) = 117 total hours of work during 14 weeks = 8.35 hours per week	<ul style="list-style-type: none"> Doubts about the previous on-site class (15 minutes)/week + Exposition by the teacher of the module content (1 hour y 15 minutes)/week + 		<ul style="list-style-type: none"> Reading relevant papers about the topic of the week (3 hours)/week Elaboration of a compulsory oral presentation (6 hours in total) 	<ul style="list-style-type: none"> Tutorial work in group to choose oral presentation topics and written work (4 hours) 	<ul style="list-style-type: none"> Elaboration of the final written work of the module (37 hours in total) 	
Week 14 (9 hours)	<ul style="list-style-type: none"> Student oral presentations (2 hours) 		<ul style="list-style-type: none"> Elaboration of a compulsory oral presentation (5 hours) 	<ul style="list-style-type: none"> Tutorial work in group to choose oral presentation topics and written work (2 hours) 		
Week 15 (9 hours)	<ul style="list-style-type: none"> Student oral presentations (2 hours) 		<ul style="list-style-type: none"> Elaboration of a compulsory oral presentation (5 hours) 	<ul style="list-style-type: none"> Tutorial work in group to choose oral presentation topics and written work (2 hours) 		

Note: For each activity, the dedication required from the student is specified in hours.