



# Course guide

## 270716 - CN - Complex Networks

Last modified: 02/02/2024

**Unit in charge:** Barcelona School of Informatics  
**Teaching unit:** 1042 - URV - Universitat Rovira i Virgili.

**Degree:** MASTER'S DEGREE IN ARTIFICIAL INTELLIGENCE (Syllabus 2017). (Optional subject).

**Academic year:** 2023    **ECTS Credits:** 5.0    **Languages:** English

### LECTURER

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**Coordinating lecturer:** SERGIO GÓMEZ JIMÉNEZ

**Others:**

### PRIOR SKILLS

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Prior skills on Algorithmics and Programming:

- Abstract data types and computational cost
- Graphs, trees and algorithms

### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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**Specific:**

CEA11. Capability to understand the advanced techniques of Computational Intelligence, and to know how to design, implement and apply these techniques in the development of intelligent applications, services or systems.

CEP2. Capability to solve the decision making problems from different organizations, integrating intelligent tools.

**Generical:**

CG3. Capacity for modeling, calculation, simulation, development and implementation in technology and company engineering centers, particularly in research, development and innovation in all areas related to Artificial Intelligence.

**Transversal:**

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

CT6. REASONING: Capability to evaluate and analyze on a reasoned and critical way about situations, projects, proposals, reports and scientific-technical surveys. Capability to argue the reasons that explain or justify such situations, proposals, etc..

CT7. ANALISIS Y SINTESIS: Capability to analyze and solve complex technical problems.

**Basic:**

CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

### TEACHING METHODOLOGY

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Master classes, practice with computers, resolution of practical exercises.

## LEARNING OBJECTIVES OF THE SUBJECT

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1. Detection of systems which may be represented using complex networks
2. To know how to study and characterize the structure of complex networks
3. To know models of complex networks and their implementation
4. To know the main dynamics on top of complex networks
5. To know how to perform and validate Monte Carlo simulations
6. To know how to apply the knowledge in complex networks to extract information of systems which can be described using this framework

## STUDY LOAD

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Type	Hours	Percentage
Hours large group	16,0	12.80
Hours medium group	16,0	12.80
Self study	80,0	64.00
Guided activities	5,0	4.00
Hours small group	8,0	6.40

**Total learning time:** 125 h

## CONTENTS

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### Introduction

**Description:**

Examples of complex networks in many knowledge fields. Complex network types.

### Structure of complex network

**Description:**

Main topological and structural characteristics of complex networks: degree distribution, small-world, transitivity, assortativity, community structure, centrality. Community detection algorithms.

### Complex network models

**Description:**

Erdős-Rényi random networks, Barabási-Albert model, Watts-Strogatz model, configuration model.

### Dynamics on complex networks

**Description:**

Most important dynamics on complex networks: epidemic spreading, synchronization, diffusion, evolutionary games, percolation. Monte Carlo simulations. Phase transitions.



## ACTIVITIES

### Introduction

**Description:**

Introduction

**Specific objectives:**

1

**Related competencies :**

CG3. Capacity for modeling, calculation, simulation, development and implementation in technology and company engineering centers, particularly in research, development and innovation in all areas related to Artificial Intelligence.

CEP2. Capability to solve the decision making problems from different organizations, integrating intelligent tools.

CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

**Full-or-part-time:** 2h

Theory classes: 2h

### Structure of complex network

**Description:**

Development of the topic

**Specific objectives:**

2

**Related competencies :**

CEA11. Capability to understand the advanced techniques of Computational Intelligence, and to know how to design, implement and apply these techniques in the development of intelligent applications, services or systems.

CT7. ANALISIS Y SINTESIS: Capability to analyze and solve complex technical problems.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

**Full-or-part-time:** 26h 30m

Theory classes: 12h

Laboratory classes: 2h 30m

Guided activities: 2h

Self study: 10h



### Complex network models

**Description:**

Development of the topic

**Specific objectives:**

3

**Related competencies :**

CT7. ANALISIS Y SINTESIS: Capability to analyze and solve complex technical problems.

CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

**Full-or-part-time:** 30h

Theory classes: 6h

Laboratory classes: 2h

Guided activities: 2h

Self study: 20h

### Dynamics on complex networks

**Description:**

Development of the topic

**Specific objectives:**

4, 5

**Related competencies :**

CT7. ANALISIS Y SINTESIS: Capability to analyze and solve complex technical problems.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

**Full-or-part-time:** 24h

Theory classes: 10h

Laboratory classes: 2h

Guided activities: 2h

Self study: 10h



## Project

### Description:

Complex networks project

### Specific objectives:

1, 2, 3, 4, 5, 6

### Related competencies :

CG3. Capacity for modeling, calculation, simulation, development and implementation in technology and company engineering centers, particularly in research, development and innovation in all areas related to Artificial Intelligence.  
CEA11. Capability to understand the advanced techniques of Computational Intelligence, and to know how to design, implement and apply these techniques in the development of intelligent applications, services or systems.  
CEP2. Capability to solve the decision making problems from different organizations, integrating intelligent tools.  
CT6. REASONING: Capability to evaluate and analyze on a reasoned and critical way about situations, projects, proposals, reports and scientific-technical surveys. Capability to argue the reasons that explain or justify such situations, proposals, etc..  
CT7. ANALISIS Y SINTESIS: Capability to analyze and solve complex technical problems.  
CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

### Full-or-part-time: 42h

Laboratory classes: 1h

Guided activities: 1h

Self study: 40h

## Delivery of practical exercises about structure of complex networks

### Description:

Delivery of practical exercises about structure of complex networks

### Specific objectives:

2

### Related competencies :

CEA11. Capability to understand the advanced techniques of Computational Intelligence, and to know how to design, implement and apply these techniques in the development of intelligent applications, services or systems.  
CT7. ANALISIS Y SINTESIS: Capability to analyze and solve complex technical problems.  
CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

## Delivery of practical exercises about complex networks models

### Description:

Delivery of practical exercises about complex networks models

### Specific objectives:

3

### Related competencies :

CT7. ANALISIS Y SINTESIS: Capability to analyze and solve complex technical problems.  
CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.



### Delivery of practical exercises about community detection

**Description:**

Delivery of practical exercises about community detection

**Specific objectives:**

2

**Related competencies :**

CEA11. Capability to understand the advanced techniques of Computational Intelligence, and to know how to design, implement and apply these techniques in the development of intelligent applications, services or systems.

CT7. ANALISIS Y SINTESIS: Capability to analyze and solve complex technical problems.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

### Delivery of practical exercises about simulation of dynamics

**Description:**

Delivery of practical exercises about simulation of dynamics

**Specific objectives:**

4, 5

**Related competencies :**

CT7. ANALISIS Y SINTESIS: Capability to analyze and solve complex technical problems.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

### Interview of the project

**Description:**

Interview of the project

**Specific objectives:**

1, 6

**Related competencies :**

CG3. Capacity for modeling, calculation, simulation, development and implementation in technology and company engineering centers, particularly in research, development and innovation in all areas related to Artificial Intelligence.

CEA11. Capability to understand the advanced techniques of Computational Intelligence, and to know how to design, implement and apply these techniques in the development of intelligent applications, services or systems.

CEP2. Capability to solve the decision making problems from different organizations, integrating intelligent tools.

CT6. REASONING: Capability to evaluate and analyze on a reasoned and critical way about situations, projects, proposals, reports and scientific-technical surveys. Capability to argue the reasons that explain or justify such situations, proposals, etc..

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

**Full-or-part-time:** 0h 30m

Guided activities: 0h 30m



## GRADING SYSTEM

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Resolution of practical exercises

Development of a complex networks project

## BIBLIOGRAPHY

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### Basic:

- Newman, M.E.J. Networks. 2nd ed. Oxford: Oxford University Press, 2018. ISBN 0198805098.

- Boccaletti, S.; Latora, V.; Moreno, Y.; Chavez, M.; Hwang, D.-U. "Complex networks: structure and dynamics". Physics Reports [on line]. 424 (2006) 175-308 [Consultation: 04/03/2020]. Available on: <https://www.sciencedirect.com/science/journal/03701573>.

- Fortunato, S. "Community detection in graphs". Physics Reports [on line]. 486 (2010) 75-174 [Consultation: 04/03/2020]. Available on: <https://www.sciencedirect.com/science/journal/03701573>.

## RESOURCES

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### Hyperlink:

- <http://deim.urv.cat/~sergio.gomez/radatools.php>- <http://gephi.github.io/>- <http://igraph.org/>- <http://pajek.imfm.si/doku.php>-  
<https://networkx.github.io/>