ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

593000505 - Cyberphysical Systems Modelling

DEGREE PROGRAMME

59AH - University Master Degree in Internet of Things (IoT)

ACADEMIC YEAR & SEMESTER

2022/23 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	593000505 - Cyberphysical Systems Modelling
No of credits	4.5 ECTS
Type	Compulsory
Academic year ot the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	59AH - University Master Degree in Internet of Things (IoT)
Centre	59 - Escuela Tecnica Superior De Ingenieria Y Sistemas De Telecomunicacion
Academic year	2022-23

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Jose Carlos Gamazo Real (Subject coordinator)	4307	josecarlos.gamazo@upm.es	Not scheduled. Tutoring timetable will be published in the start of semester.

Javier Garcia Martin	4419	javier.garciam@upm.es	Not scheduled. Tutoring timetable will be published in the start of semester.

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

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

3.2. Other recommended learning outcomes

- General knowledge about software engineering and programming

- Basic knowledge about systems modelling, such as SysML, is recommendable

- Basic skills of implementing electronic prototypes based on COTS hardware and data interfaces

- General knowledge about databases is recommendable

- Basic knowledge about object-oriented software modeling, such as UML, is recommendable

4. Skills and learning outcomes *

4.1. Skills to be learned

CB07 - Knowing how to apply the 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

CB08 - Being able to integrate knowledge and face the complexity of formulating judgments based on information that, being incomplete or limited, includes considerations about the social and ethical responsibilities linked to the application of their knowledge and judgments

CE.04 - Designing high/low level architectures for IoT applications as well as Cyber-Physical Systems (CPS) using specific languages of this domain and evaluating the interaction between the models of the components that integrate them

CE.13 - Analyzing the use of IoT devices and services in specific application domains and select the most appropriate devices for the IoT ecosystem

CG03 - Students will demonstrate having the necessary skills to integrate and apply the knowledge acquired so that they can develop innovative solutions and IoT services in general

CG04 - Students will have the ability to apply efficiency, scalability, reliability and security criteria in different areas of intelligent applications and cyber-physical systems, such as Smart Living, Smart Cities or eHealth

CT.01 - Ability to use the English language for working in international contexts

CT.02 - Teamwork and leading, organizing and supervising multidisciplinary teams' skills

4.2. Learning outcomes

RA14 - To describe software architectures for a proposed cyber-physical system using a formal language

RA15 - To use the appropriate modeling languages to develop the detailed design of an application in the domain of cyberphysical systems and IoT

RA21 - To establish the building or selection criteria of embedded hardware platforms for the integration of a specific IoT application

RA22 - To combine the development tools for the integration of all software elements required to use a hardware platform in an IoT solution

RA41 - To identify the requeriments and the technological solutions that allow to develop intelligent applications supported by IoT devices. Some examples are Smart- Cities, Smart Environment, Smart Grid, Smart Water, Smart Agriculture, Smart Animal Farming, Domotic& Home Automation, e-health, etc.

RA40 - To identify new application domains for IoT.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

This course introduces modelling as a paradigm for Cyber-Physical Systems (CPS) development and Internet of Things (IoT). CPS, according to the National Institute of Standards and Technology (NIST), comprise interacting digital, analogue, physical, and human components engineered for function through integrated physics and logic. CPS and IoT are heavily system-based and they are usually integrated into even more complex systems called Systems of Systems such as smart cities, smart campus, smart buildings, etc. This complexity requires rigorous requirements definition, modeling, and design in order to be properly implemented. As a result, one of the main objectives of this subject is to provide students the skills of IoT systems modelling and design, so the management and tracking of these systems is of remarkable importance. Therefore, the subject presents the methodologies to perform the specification, analysis and design of systems, and some relevant modeling languages, such as System Modeling Language (SysML) and Model-Driven Development (MDD), from a theoretical and practical point of view.

5.2. Syllabus

1. Analysis of CPS and IoT Systems: Definitions, Requirements Engineering, and Use Cases

2. Design and Architecture of CPS and IoT Systems: Specification, Modelling, and Implementation

3. Model-Driven Development (MDD) Engineering for CPS and IoT Systems

4. CPS Modelling with SysML

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Presentation Lesson** Duration: 01:00 **Lesson 1: CPS Analysis** Duration: 01:30	**Lesson 1: CPS Analysis** Duration: 01:00		
2	**Lesson 1: CPS Analysis** Duration: 02:30	**Lesson 1: CPS Analysis. Sustainable Development** Duration: 01:00		
3	**Lesson 2: CPS Design and Architecture** Duration: 02:00	**ASSIGNMENT 1: Presentation to Students and Laboratory Groups** Duration: 01:30		
4	**Lesson 2: CPS Design and Architecture** Duration: 02:00 **Lesson 2: CPS Design and Architecture** Duration: 01:00	**Lesson 2: CPS Design and Architecture. Sustainable Development** Duration: 01:30 **ASSIGNMENT 1: Task Completion** Duration: 02:30		
5	**Lesson 3: CPS Model-Driven Development Engineering** Duration: 02:00	**ASSIGNMENT 1: Task Completion** Duration: 01:30		
6	**Lesson 3: CPS Model-Driven Development Engineering** Duration: 01:00	**ASSIGNMENT 2: Presentation to Students** Duration: 01:00		**Deliverable 1.1: ASSIGNMENT 1 Report** Continuous assessment Not Presential Duration: 00:00 **Deliverable 1.2: ASSIGNMENT 1 Presentation** Continuous assessment Presential Duration: 01:30
7	**Lesson 3: CPS Model-Driven Development Engineering** Duration: 01:30	**ASSIGNMENT 2: Task Completion** Duration: 02:00		

8	**Lesson 3: CPS Model-Driven Development Engineering** Duration: 01:00	**ASSIGNMENT 2: Task Completion** Duration: 02:30 **ASSIGNMENT 2: Task Completion. Summary Report** Duration: 01:00 **ASSIGNMENT 3: Presentation to Students** Duration: 01:00		**Deliverable 2.1: ASSIGNMENT 2 Report** Continuous assessment Not Presential Duration: 00:00 **Deliverable 2.2: ASSIGNMENT 2 Presentation** Continuous assessment Presential Duration: 01:30
9	**Tema 4: CPS Modelling with SysML** Duration: 02:00	**ASSIGNMENT 3: Task Completion** Duration: 01:30		
10				
11	**Tema 4: CPS Modelling with SysML** Duration: 01:00	**ASSIGNMENT 3: Task Completion** Duration: 02:30		
12				**Deliverable 3: ASSIGNMENT 3 Report** Continuous assessment Not Presential Duration: 00:00 **Deliverable 1.1: ASSIGNMENT 1 Report** Final examination Not Presential Duration: 00:00 **Deliverable 2.1: ASSIGNMENT 2 Report** Final examination Not Presential Duration: 00:00 **Deliverable 3: ASSIGNMENT 3 Report** Final examination Not Presential Duration: 00:00 **Deliverable 1.2 and 2.2: ASSIGNMENT 1 and ASSIGNMENT 2 Presentation** Final examination Presential Duration: 02:00
13				
14				
15				
16				

17				

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
6	Deliverable 1.1: ASSIGNMENT 1 Report		No Presential	00:00	25%	4 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
6	Deliverable 1.2: ASSIGNMENT 1 Presentation		Face-to-face	01:30	10%	4 / 10	CG03 CT.01 CB08 CT.02
8	Deliverable 2.1: ASSIGNMENT 2 Report		No Presential	00:00	25%	4 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
8	Deliverable 2.2: ASSIGNMENT 2 Presentation		Face-to-face	01:30	10%	4 / 10	CB08 CT.02 CG03 CT.01
12	Deliverable 3: ASSIGNMENT 3 Report		No Presential	00:00	30%	4 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
12	Deliverable 1.1: ASSIGNMENT 1 Report		No Presential	00:00	35%	5 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
12	Deliverable 2.1: ASSIGNMENT 2 Report		No Presential	00:00	30%	5 / 10	CB08 CE.04 CG03 CT.01 CE.13 CG04 CB07
12	Deliverable 3: ASSIGNMENT 3 Report		No Presential	00:00	30%	5 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
12	Deliverable 1.2 and 2.2: ASSIGNMENT 1 and ASSIGNMENT 2 Presentation		Face-to-face	02:00	5%	5 / 10	CB08 CT.02 CG03 CT.01

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Deliverable 1.1: ASSIGNMENT 1 Report		Face-to-face	00:00	35%	5 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
Deliverable 2.1: ASSIGNMENT 2 Report		Face-to-face	00:00	30%	5 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01

						CE.13
Deliverable 3: ASSIGNMENT 3 Report		Face-to-face	00:00	30%	5 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
Deliverables 1.2 and 2.2: ASSIGNMENT 1 and ASSIGNMENT 2 Presentation		Face-to-face	02:00	5%	5 / 10	CB08 CT.02 CG03 CT.01

7.2. Assessment criteria

CONTINUOUS ASSESSMENT GRADING

Assessment will evaluate the level of apprenticeship concerning skills and learning outcomes regarding to:

- Deliverable 1 (1.1 and 1.2): RA14, RA15, RA40, RA41
- Deliverable 2 (2.1 and 2.2): RA15, RA21, RA22, RA40, RA41
- Deliverable 3: RA15, RA21, RA22, RA40, RA41

(*) *Students will have to team up to produce deliverables (continuous assessment)*

Pass threshold (grading):

- Deliverable 1 (1.1 and 1.2): 4
- Deliverable 2 (2.1 and 2.2): 4
- Deliverable 3: 4

Final Grading Formula = (Deliverable 1.1 * 25% + Deliverable 1.2 * 10%) + (Deliverable 2.1 * 25% + Deliverable 2.2 * 10%) + (Deliverable 3 * 30%)

ONE EXAM ASSESSMENTs ("solo examen final") and EXTRA EXAM

Assessment will evaluate the level of apprenticeship concerning skills and learning outcomes regarding to:

- Deliverable 1 (1.1 and 1.2): RA14, RA15, RA40, RA41
- Deliverable 2 (2.1 and 2.2): RA15, RA21, RA22, RA40, RA41
- Deliverable 3: RA15, RA21, RA22, RA40, RA41

(*) *Those students that choose the option of "one exam" (solo examen final) will have to make an oral presentation of the deliverables produced, which will receive questions related to the material produced and the skills and learning outcomes of the course.*

Pass threshold (grading):

- Deliverable 1 (1.1 and 1.2): 5
- Deliverable 2 (2.1 and 2.2): 5
- Deliverable 3: 5

Final Grading formula= (Deliverable 1.1 * 35%) + (Deliverable 2.1 * 30%) + (Deliverable 3 * 30%) + ([Deliverable 1.2 + Deliverable 2.2] * 5%)

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Guide to Computing Fundamentals in Cyber-Physical Systems	Bibliography	Dietmar P.F. Möller, Guide to Computing Fundamentals in Cyber-Physical Systems: Concepts, Design Methods, and Applications, Computer Communications and Networks, Springer, 1617-7975, 2016
Cyber-Physical Systems	Bibliography	Ragunathan (Raj) Rajkumar, Dionisio de Niz, Mark H. Klein, Cyber-Physical Systems (SEI Series in Software Engineering), Addison-Wesley, January 2017.
A Practical Guide to SysML: Systems Modeling Language	Bibliography	Sanford Friedenthal, Alan Moore, and Rick Steiner. 2008. A Practical Guide to SysML: Systems Modeling Language. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.
SysML Distilled: A Brief Guide to the Systems Modeling Language	Bibliography	Lenny Delligatti. 2013. SysML Distilled: A Brief Guide to the Systems Modeling Language (1st ed.). Addison-Wesley Professional.
SysML	Web resource	http://www.omgsysml.org/
Model- Driven Software Development	Bibliography	Beydeda, S., Book, M. & Gruhn V., Model-Driven Software Development, Springer, 2005.
MDA Explained The Model Driven Architecture: Practice and Promise	Bibliography	Kleppe A., Warmer J., Bast W., MDA Explained The Model Driven Architecture: Practice and Promise, Addison Wesley, Object Technology Series, Grady Booch, Ivar Jacobson, and James Rumbaugh, 2004.

Software Factories	Bibliography	Greenfield J., Short K, Cook S., and Kent S, Software Factories, Wiley Publising Inc., 2004.
Specific Modeling: Enabling Full Code Generation	Bibliography	Kelly, S. and Tolvanen, J.-P., Domain-Specific Modeling: Enabling Full Code Generation, John Wiley & Sons, New Jersey. ISBN 978-0-470-03666-2, 2008
Moodle	Web resource	Moodle platform with all the resources of the course.
Architecting Principles for Systems-of-Systems	Bibliography	Maier, M. (1998). Architecting Principles for Systems-of-Systems. Systems Engineering, 1(4), 267-284.
System-of-Systems Engineering: A Definition	Bibliography	Mo Jamshidi, System-of-Systems Engineering: A Definition, IEEE SMC 2005, Big Island, Hawaii
Systems of Systems Engineering - Principles and Applications	Bibliography	Jamshidi, M. (ed.) 2009. Systems of Systems Engineering - Principles and Applications. Boca Raton, FL, USA: CRC Press.
The Past, Present and Future of Cyber-Physical Systems: A Focus on Models	Bibliography	Lee, E., & A., E. (2015). The Past, Present and Future of Cyber-Physical Systems: A Focus on Models. Sensors, 15(3), 4837?4869. https://doi.org/10.3390/s150304837
Requirements engineering for systems of systems	Bibliography	Lewis, G., Morris, E., Place, P., Simanta, S., & Smith, D. (2009). Requirements engineering for systems of systems. In IEEE Systems Conference (SysCon) (pp. 247?252). IEEE. https://doi.org/10.1109/SYSTEMS.2009.4815806
Taxonomy of Systems-of-Systems	Bibliography	Gideon, J., Dagli, C., & Miller, A. (2005). Taxonomy of Systems-of-Systems. In Systems Engineering Research.

SysML executable systems of system architecture definition: A working example	Bibliography	Dahmann, J. et al (2017). SysML executable systems of system architecture definition: A working example. 11th Annual IEEE International Systems Conference, SysCon https://doi.org/10.1109/SYSCON.2017.7934816
Cyber-Physical Systems	Web resource	https://cordis.europa.eu/project/id/644400/es
Cyber-Physical systems NIST Laboratory	Web resource	https://www.nist.gov/el/cyber-physical-systems

9. Other information

9.1. Other information about the subject

This subject is related to several of the Sustainable Development Goals (SDG) defined by the United Nations, in concrete:

- **SDG 4 "Quality Education"**: Ensure inclusive and equitative quality education and promote lifelong learning opportunities for all. Within this objective it is relevant the Target 4.4, which states by 2030 a substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.

- **SDG 9 "Industry, Innovation and Infraestructure"**: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Within this objective it is relevant the Target 9.C, which states a significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020.

The development of activities within the framework of the previously mentioned SDGs is part of the **EELISA - DISCOVERY Community (DesIgning a Sustainable and deCarbOnized uniVERsitY)**, which works with and for the university community, in order to design, develop and implement collaborative actions that contribute to the transition of university campuses towards more sustainable models. In this sense, DISCOVERY seeks to promote urban decarbonization by experimenting with innovative solutions on university campuses that could then be scaled to the city level.

(*) *The schedule presented in this guide is based on an a priori planning of the subject and it might be modified during the academic year, especially considering the COVID-19 evolution.*