ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

593000505 - Cyberphysical Systems Modelling

DEGREE PROGRAMME

59AH - Master Universitario En Internet Of Things (iot)

ACADEMIC YEAR & SEMESTER

2024/25 - 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 - Master Universitario en Internet Of Things (Iot)
Centre	59 - Escuela Tecnica Superior De Ingenieria Y Sistemas De Telecomunicacion
Academic year	2024-25

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	Sin horario. No scheduled. Tutoring timetable will be published in the start of semester.

Javier Garcia Martin	4419	javier.garciam@upm.es	Sin horario. No 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 knowledge about object-oriented software modeling, such as UML, is recommendable

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

- General knowledge about databases is recommendable

4. Skills and learning outcomes *

4.1. Skills to be learned

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB08 - Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios

CE.04 - Diseñar arquitecturas de alto/bajo nivel para aplicaciones IoT así como Sistemas Ciberfísicos (CPS) usando lenguajes específicos de este dominio y evaluando la interacción entre los modelos de los componentes que lo forman

CE.13 - Analizar el uso de dispositivos y servicios IoT en dominios de aplicación específicos y seleccionar los dispositivos más adecuados para el ecosistema IoT

CG03 - Los alumnos demostrarán tener las destrezas necesarias para integrar y aplicar los conocimientos adquiridos de forma que puedan desarrollar soluciones innovadoras y servicios IoT en general

CG04 - Los alumnos tendrán la capacidad de aplicar criterios de eficiencia, escalabilidad, fiabilidad y seguridad en distintos ámbitos de aplicaciones inteligentes y sistemas ciberfísicos, tales como Smart Living, Smart Cities o eHealth

CT.01 - Capacidad de uso de la lengua inglesa para el trabajo en contextos internacionales

CT.02 - Capacidad para el trabajo en grupo y dirigir, organizar y supervisar equipos multidisciplinares.

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

RA40 - To identify new application domains for IoT.

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.

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

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 Unified Modelling Language (UML), System Modeling Language (SysML), and Model-Driven Development (MDD), from a theoretical and practical point of view. In the practical assignments, the students will use **Enterprise Architect** from Spark Systems as the modelling tool for implementing UML and SysML models.

5.2. Syllabus

1. Analysis of CPS and IoT Systems
   1.1. Concept of CPS
   1.2. CPS Development Process
   1.3. Conceptual Modelling
   1.4. Application Example: Software Modelling
   1.5. Sustainable Development
2. Design and Architecture of CPS and IoT Systems
   2.1. Introduction and Architectural Views-Styles-Patterns
   2.2. Practical Guidelines to Architecture Design
   2.3. Architectures in IoT Systems
   2.4. Systems Engineering and Architecture
3. Model-Driven Development (MDD) Engineering for CPS and IoT Systems
   3.1. Introduction to MDE and MDD
   3.2. Model Transformation
   3.3. MDD Approaches
   3.4. Domain-Specific Modelling (DSM) and Languages (DSL)
   3.5. Practical Creation of a DSL Project. Tools for DSM
   3.6. Practical Constructing a DSL: DSL Construction and DSL Generator
   3.7. Automatic Code Generation with DSL Tools
4. CPS Modelling with SysML
   4.1. Introduction and goals
   4.2. CPS Programming Scheme
   4.3. Block Definition Diagrams (BDD)
   4.4. State Machine Diagrams (Statecharts)

6. Schedule

6.1. Subject schedule*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1	**Presentation Lesson** Duration: 01:00 Lecture **Lesson 1: Analysis of CPS and IoT Systems** Duration: 01:30 Lecture	**Practical Guidelines to Architecture Design** Duration: 01:00 Laboratory assignments		
2	**Lesson 1: Analysis of CPS and IoT Systems** Duration: 01:30 Lecture **Practical Creation of Class Diagrams** Duration: 01:00 Problem-solving class	**ASSIGNMENT 1: Presentation to Students and Laboratory Groups** Duration: 01:00 Cooperative activities		
3	**Lesson 2: Design and Architecture of CPS and IoT Systems** Duration: 02:00 Lecture	**ASSIGNMENT 1: Task Completion** Duration: 01:30 Laboratory assignments		
4	**Lesson 2: Design and Architecture of CPS and IoT Systems (WEEK SESSION 1)** Duration: 02:00 Lecture	**ASSIGNMENT 1: Task Completion (WEEK SESSION 1)** Duration: 01:30 Laboratory assignments **ASSIGNMENT 1: Task Completion (WEEK SESSION 2)** Duration: 02:00 Laboratory assignments		
5	**Lesson 3: Model-Driven Development Engineering for CPS** Duration: 01:30 Lecture	**ASSIGNMENT 1: Task Completion** Duration: 02:00 Laboratory assignments		
6	**Lesson 3: Model-Driven Development Engineering for CPS** Duration: 01:00 Problem-solving class	**ASSIGNMENT 2: Presentation to Students** Duration: 01:00 Cooperative activities		**Deliverable 1.2: ASSIGNMENT 1 Presentation** Group presentation Progressive assessment Presential Duration: 01:30
7	**Lesson 3: Model-Driven Development Engineering for CPS** Duration: 01:30 Problem-solving class	**ASSIGNMENT 2: Task Completion** Duration: 02:00 Laboratory assignments		**Deliverable 1.1: ASSIGNMENT 1 Report** Group work Progressive assessment Not Presential Duration: 00:00

8	**Tema 4: CPS Modelling with SysML** Duration: 01:30 Lecture	**ASSIGNMENT 2: Task Completion** Duration: 02:00 Laboratory assignments		
9	**Tema 4: CPS Modelling with SysML** Duration: 01:30 Lecture	**ASSIGNMENT 3: Presentation to Students** Duration: 01:00 Cooperative activities **ASSIGNMENT 3: Task Completion** Duration: 01:00 Laboratory assignments		**Deliverable 2: ASSIGNMENT 2 Report** Group work Progressive assessment Not Presential Duration: 00:00
10	**Tema 4: CPS Modelling with SysML (WEEK SESSION 1)** Duration: 01:30 Lecture	**ASSIGNMENT 3: Task Completion (WEEK SESSION 1)** Duration: 02:00 Laboratory assignments **ASSIGNMENT 3: Task Completion (WEEK SESSION 2)** Duration: 02:00 Laboratory assignments		
11	**Tema 4: CPS Modelling with SysML** Duration: 01:30 Lecture	**ASSIGNMENT 3: Task Completion** Duration: 02:00 Laboratory assignments		
12				**Deliverable 3: ASSIGNMENT 3 Report** Group work Progressive assessment Not Presential Duration: 00:00 **Deliverable 1: ASSIGNMENT 1 Report** Group work Global examination Not Presential Duration: 00:00 **Deliverable 2: ASSIGNMENT 2 Report** Group work Global examination Not Presential Duration: 00:00 **Deliverable 3: ASSIGNMENT 3 Report** Group work Global examination Not Presential Duration: 00:00 **Theory Ordinary Exam** Written test Progressive assessment and Global Examination Presential Duration: 01:30
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.

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 1.2: ASSIGNMENT 1 Presentation	Group presentation	Face-to-face	01:30	5%	4 / 10	CG03 CT.01 CB08 CT.02
7	Deliverable 1.1: ASSIGNMENT 1 Report	Group work	No Presential	00:00	25%	4 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
9	Deliverable 2: ASSIGNMENT 2 Report	Group work	No Presential	00:00	15%	4 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
12	Deliverable 3: ASSIGNMENT 3 Report	Group work	No Presential	00:00	30%	4 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
12	Theory Ordinary Exam	Written test	Face-to-face	01:30	25%	4 / 10	CG04 CB07 CB08 CG03 CT.01

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
12	Deliverable 1: ASSIGNMENT 1 Report	Group work	No Presential	00:00	30%	5 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
12	Deliverable 2: ASSIGNMENT 2 Report	Group work	No Presential	00:00	15%	5 / 10	CB08 CE.04 CG03 CT.01 CE.13 CG04 CB07
12	Deliverable 3: ASSIGNMENT 3 Report	Group work	No Presential	00:00	30%	5 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
12	Theory Ordinary Exam	Written test	Face-to-face	01:30	25%	4 / 10	CG04 CB07 CB08 CG03 CT.01

7.1.3. Referred (re-sit) examination

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

Deliverable 2: ASSIGNMENT 2 Report	Group work	Face-to-face	00:00	15%	5 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
Deliverable 3: ASSIGNMENT 3 Report	Group work	Face-to-face	00:00	30%	5 / 10	CG04 CB07 CB08 CT.02 CE.04 CG03 CT.01 CE.13
Theory Extraordinary Exam	Written test	Face-to-face	01:30	25%	4 / 10	CG04 CB07 CB08 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: RA15, RA21, RA22, RA40, RA41
- Deliverable 3: RA15, RA21, RA22, RA40, RA41
- Theory Exam: RA15, RA21, 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: 4
- Deliverable 3: 4
- Theory Exam: 4

Final Grading Formula = (Deliverable 1.1 * 25% + Deliverable 1.2 * 5%) + (Deliverable 2 * 15%) + (Deliverable 3 * 30%) + (Theory Exam * 25%)

To pass the subject, the threshold of the Final Grading Formula is 5 points (5/10).

ONE EXAM ASSESSMENTs ("solo examen final") and EXTRAORDINARY 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: RA15, RA21, RA22, RA40, RA41
- Deliverable 3: RA15, RA21, RA22, RA40, RA41
- Theory Exam: RA15, RA21, RA40, RA41

(*) *Those students that choose the option of "one exam" (solo examen final) could have the option to do the assignments individually.*

Pass threshold (grading):
- Deliverable 1: 5
- Deliverable 2: 5
- Deliverable 3: 5
- Theory Exam: 4

Final Grading Formula = (Deliverable 1 * 30%) + (Deliverable 2 * 15%) + (Deliverable 3 * 30%) + (Theory Exam * 25%)

To pass the subject, the threshold of the Final Grading Formula is 5 points (5/10).

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Moodle	Web resource	Moodle platform with all the resources of the course.
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.
The Unified Modeling Language (UML)	Web resource	https://www.uml-diagrams.org/class-diagrams-overview.html
SysML home from Object Management Group (OMG)	Web resource	https://www.omgsysml.org/index.htm
System Modelling Language (SysML) Diagram Tutorial	Web resource	https://sysml.org/tutorials/sysml-diagram-tutorial/
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.
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.

Enterprise Architect User Guide (practical modelling tool)	Web resource	https://sparxsystems.com/enterprise_architect_user_guide/16.1/welcome/index.html
Enterprise Architect User Guide Library (practical modelling tool)	Web resource	https://sparxsystems.com/resources/user-guides/15.2/
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.
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
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
Software Factories	Bibliography	Greenfield J., Short K, Cook S., and Kent S, Software Factories, Wiley Publising Inc., 2004.

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 Community EGALITARIAN SOCIETIES: Oportunities for Everyone (ES: O4E)** that promotes social equality by carrying out various real-world, social projects like supporting vulnerable social groups, providing education to improve habits about responsible consumption and improving public spaces (cities and buildings)**.**

(*) *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 or similar problems.*