



INTERNATIONAL
CAMPUS OF
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COORDINATION PROCESS OF
LEARNING ACTIVITIES
PR/CL/001



E.T.S. de Ingenieria de
Sistemas Informaticos

ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

615000735- Distributed Systems

DEGREE PROGRAMME

61IW – Degree in Software Engineering

ACADEMIC YEAR & SEMESTER

2022/23 - Semester 1

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1. Description

1.1. Subject details

Name of the subject	615000735- Distributed Systems
No of credits	6 ECTS
Type	Optional
Academic year of the programme	Third year
Semester of tuition	Semester 5
Tuition period	September-January
Tuition languages	English
Degree programme	61IW – Software Engineering Bachelor
Centre	61 - Escuela Tecnica Superior De Ingenieria De Sistemas Informaticos
Academic year	2022-23

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Isabel Muñoz Fernández (Subject coordinator)	4412	isabel.munoz@upm.es	To be confirmed.

* 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

- Concurrent and Advanced Programming
- Computer Networks
- Operating Systems

3.2. Other recommended learning outcomes

- Java programming

4. Skills and learning outcomes *

4.1. Skills to be learned

CE02 - Ability to select, design, deploy, integrate, evaluate, build, manage, exploit and maintain hardware, software and network technologies, within appropriate cost and quality parameters.

CE06 - Ability to conceive systems, applications and services based on network technologies, including internet, web, electronic commerce, multimedia, interactive services and mobile computing.

CT06 - Critical Thinking: The ability to think critically involves three things: (1) an attitude of being willing to reflectively consider the problems and issues that fall within the range of one's experiences, (2) knowledge of the methods of logical investigation and reasoning, and (3) a certain skill in the application of those methods.

4.2. Learning outcomes

RA120 - Defines the fundamental model and the architectural model of a distributed system

RA119 - Identifies the most common problems that a distributed system presents due to the lack of memory and common clock, the lack of synchrony and the presence of errors in the network and in the processes.

RA121 - Select the most appropriate algorithms for solving the above problems given a certain fundamental model

RA118 - Identify the elementary concepts and abstractions that underlie all distributed systems

RA122 - Build distributed applications using both well-known and proprietary algorithms, as well as existing middleware platforms for distributed computing

RA257 - RA 64. Make reasoned judgments and decisions. Analyzes, interprets and evaluates information and arguments from different points of view. Synthesizes and relates information and draws reasoned conclusions

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

This course explores the concept of a distributed system comprising autonomous programmable entities. Typically, these entities communicate with each other asynchronously through a communication channel. However, both the channel and the entities themselves may encounter failures, posing challenges to the reliability and consistency of the system. The primary objective of this course is to enable students to comprehend the fundamental concepts and models that underpin distributed systems. Additionally, students will learn to apply these concepts and models to select appropriate algorithms, ensuring the development of robust and coherent applications based on the specific model being considered.

This subject is taught in modality ENGLISH FRIENDLY. It means the following rules:

- o Theoretical lessons (magistral lessons) are taught in Spanish. Students can make questions in English and the professor will answer in English, but these lessons are totally in Spanish.
- o Practical lessons (laboratory lessons) are taught in English.
- o Material and documentation for both theoretical and practical lesson are available in English.

5.2. Syllabus

1. Characterization of Distributed Systems
 - 1.1. Introduction
 - 1.2. Examples of distributed systems
 - 1.3. Trends in distributed systems
 - 1.4. Challenges
2. System Models
 - 2.1. Introduction
 - 2.2. Architectural Models
 - 2.3. Fundamental Models
3. Clock Synchronization
 - 3.1. Introduction
 - 3.2. Synchronizing Physical Clocks
 - 3.3. Logical Time and Logical Clocks
4. Distributed Global states
 - 4.1. Snapshot algorithm
 - 4.2. Vector clocks algorithm
5. Distributed leader election
 - 5.1. Definition
 - 5.2. Bully Algorithm
6. Multicast Communication
 - 6.1. Definition
 - 6.2. Multicast protocols with delivery guarantees
 - 6.3. Multicast protocols with order guarantees
- Distributed Consensus
 - 7.1. Definition
 - 7.2. Algorithm for synchronous systems
8. Distributed Transactions
 - 8.1. Introduction
 - 8.2. Two phase locking algorithms for concurrency control
 - 8.3. Undo/redo recovery protocols
 - 8.4. Two phase commit algorithm
9. Lab 1. Java Review
10. Lab 2. Operating System Support. Java threads.
11. Lab 3. Interprocess Communication
12. Lab 4. Remote Invocation. RMI
13. Lab 5. ORB
14. Skills. Critical Thinking

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	Subject presentation Lecture Chapter 1. Characterization of a Distributed System	Presentation of the subject. Part practical part. Duration: 00:10 LM: Master Class type activity. Lab 1. Java Review Duration: 01:30 PL: Activity of type Practical Lab Lab Presentation. Transversal competence. Critical thinking. Duration: 00:10 CA: Activity type Actions Cooperatives		
2	Chapter 1. Characterization of a Distributed System Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 2. Operating System Support Duración: 01:45 PL: Actividad del tipo Prácticas de Laboratorio		
3	Chapter 2. System Models Duración: 02:00 LM: Actividad tipo Lección Magistral	Lab 2. Operating System Support Duración: 01:45 PL: Actividad del tipo Prácticas de Laboratorio Skills. Critical Thinking Duración: 00:15 AC: Actividad		
4	Chapter 2. System Models Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 3. Interprocess Communication. Duración: 01:45 PL: Actividad del tipo Prácticas de Laboratorio		
5	Chapter 3. Clock Synchronization Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 3. Interprocess Communication. Duración: 01:45 PL: Actividad del tipo Prácticas de Laboratorio		
6	Chapter 3. Clock Synchronization Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 4. Remote Invocation Duración: 01:45 PL: Actividad del tipo Prácticas de Laboratorio		TE-EX-1-Theoretical Progressive Evaluation. Topics 1 to 3 (Up to Physical clocks) (RA118 to RA121) (CC14) EX: Written Examination type technique Continuous assessment Presential Duration: 01:00 PR-EX-1- LAB4-Progressive assessment
7				Java. TCP y Marshalling/Unmarshalling. (RA122)(CC11) EP: Técnica del tipo Examen de Prácticas Evaluación continua Presencial Duración: 01:00 CT-EX1-Evaluación progresiva. Skills. Critical Thinking (RA161) OT: Otras técnicas evaluativas Evaluación continua Presencial Duración: 00:15
8	Chapter 4. Distributed Global State Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 4. Remote Invocation Duración: 01:45 PL: Actividad del tipo Prácticas de Laboratorio Skills. Critical Thinking Duración: 00:15 AC: Actividad del tipo Acciones Cooperativas		First practical work. Front-End development with ECMAScript (RA416, RA417, RA418, RA419) Online test Continuous assessment Not Presential Duration: 00:00
9	Chapter 4. Distributed Global State Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 4. Remote Invocation Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio		
10	Chapter 5. Leader Election Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 5. Object Request Broker Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio		

11	Chapter 6. Multicast Communication Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 5. Object Request Broker Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio		
12	Chapter 6. Multicast Communication Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 5. Object Request Broker Duración: 01:45 PL: Actividad del tipo Prácticas de Laboratorio		
13	Chapter 7. Distributed Consensus Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 5. Object Request Broker Duración: 01:45 PL: Actividad del tipo Prácticas de Laboratorio		
14	Chapter 8. Distributed Transactions Duración: 02:00 LM: Actividad del tipo Lección Magistral	Lab 5. Object Request Broker. Name Server Duración: 01:45 PL: Actividad del tipo Prácticas de Laboratorio		
15				CT-EX2-Progressive evaluation. Skills. Critical Thinking (RA161) OT: Other assessment techniques Continuous assessment Classroom Duration: 00:15 TE-EX-2-Theoretical progressive assessment. Topics 3 (From logical clocks) to Topic 5. (RA118 to RA121)(CC14) EX: Written exam type technique Continuous assessment Presential Duration: 02:00
16				
17				Comprehensive theory exam (RA118 to RA121) (RA118 to RA121)(CC14) RA121)(CC14) EX: Written examination technique Evaluation only final exam Presential Duration: 01:00 Comprehensive Practical Exam (RA122) (CC11) EP: Practical Examination type technique Evaluation only final exam Presential Duration: 01:00 Global exam of CT. Skills. Critical Thinking (RA64) EX: Written exam type technique Assessment only final test Face-to-face Duration: 00:15

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
7	7 TE-EX-1-Evaluación progresiva teoría. Temas 1 al 3 (Hasta Relojes físicos) (RA118 a RA121) (CC14)	Written exam	Face to face	01:00	25%	/10	CE02 CE06
7	PR-EX-1- LAB4-Evaluation progressive-Java. TCP and Marshalling/Unmarshalling. (RA122)(CC11)	Practical exam	Face to face	01:00	25%	/10	CE02 CE06
7	CT-EX1-Progressive evaluation. Skills. Critical Thinking (RA161)	Other evaluating techniques	Face-to-face	00:15	5%	/ 10	CT06
15	CT-EX2-Progressive evaluation. Skills. Critical Thinking (RA161)	Other evaluating techniques	Face-to-face	00:15	5%	/ 10	CT06
15	PR-EX-2- LAB5-Evaluation progressive-RMI. ORB. (RA122) (CC11)	Practical exam	Face to face	01:45	20%	/10	CE02 CE06
15	TE-EX-2-Progressive evaluation theory. Topics 3 (From logical clocks) to Topic 5. (RA118 to RA121) (CC14)	Written exam	Face to face	02:00	25%	/10	CE02 CE06

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Comprehensive theory exam (RA118 to RA121) (RA118 to RA121)(CC14) RA121)(CC14)	Written exam	Face to face	01:00	50%	/ 10	CE02 CE06
17	Comprehensive practical exam (RA122) (CC11)	Practical exam	Face to face I	10:00	40%	/ 10	CE02 CE06
17	CT Global Examination. Skills. Critical thinking (RA64)	Written exam	Face-to-face	00:15	10%	/ 10	CT06

7.1.3. Referred (re-sit) examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Comprehensive theory exam (RA118 to RA121) (RA118 to RA121)(CC14) RA121)(CC14)	Written exam	Face to face	01:00	50%	/ 10	CE02 CE06

17	Comprehensive practical exam (RA122) (CC11)	Practical exam	Face to face I	10:00	40%	/ 10	CE02 CE06
17	CT Global Examination. Skills. Critical thinking (RA64)	Written exam	Face-to-face	00:15	10%	/ 10	CT06

7.2. Assessment criteria

1. ASSESSMENT IN THE ORDINARY SESSION

a) Progressive evaluation of the subject

The progressive evaluation of the subject consists of the following blocks:

Block I. Theory. 2 individual written tests (25% + 25%).

Block II. Practical work. 2 individual written tests (20% + 20%).

Block III. Critical Thinking. 2 written tests (5% + 5%)

The final mark/grade for the subject for progressive assessment is calculated using the following algorithm:

$notaTeoria := exTeoria1 * 0.25 + exTeoria2 * 0.25$

$notaPracticas := exPrac1 * 0.2 + exPrac2 * 0.2$

$notaPensCritico := exPensCrit1 * 0.05 + exPensCrit2 * 0.05$

$notaTotal := notaTeoria + notaPracticas + NotaPensCritico$

If $notaTotal \geq 5$ then $notaFinal := notaTotal$ else $notaFinal := "suspenso"$

b) Assessment by global test

The evaluation by global test consists of 3 evaluable blocks: theory, practice, and critical thinking. The students whose final mark by progressive assessment is a fail (final mark = fail) but who have obtained a mark equal to or higher than 4 out of 10 in the practical have obtained a mark equal to or higher than 4 out of 10 in the practice mark (Practicals mark ≥ 4), in the theory mark (Theory mark ≥ 4), in the theory mark (gradeTeoria ≥ 4) or in the Critical Thinking grade (gradePens ≥ 4) will not have to take the exam for this block again. block again.

The evaluation by global test is made up of the following blocks:

Block I. Theory. 1 individual written test (50%)

Block II. Practical work. 1 individual written test (40%)

Block III. Critical Thinking. 1 Written Test (10%)

The final mark/grade for the overall test is calculated with the following algorithm:

if $notaTeoria$ is less than 4 **then**

$gradeTeoria := exGlobalTeoria * 0.5$

if $gradePracticas$ is less than 4 **then**

$gradePracticals := exGlobalPracticals * 0.4$

If $notaPensCrit$ is less than 4 **then**

$notePensCrit := exGlobalPensCrit * 0.1$

$gradeTotal := gradeTeoria + gradePracticas + gradePensCrit$

If $totalTest \geq 5$ then $finalTest := totalTest$

else $finalTest := fail$.

2. ASSESSMENT IN THE EXTRAORDINARY SESSION

The evaluation in the extraordinary call consists of 3 evaluable blocks: theory, practice and critical thinking. Students whose final mark through progressive assessment or assessment by means of a global test is fail (final grade = fail) but who have obtained a grade equal to or higher than 4 in the practice grade ($\text{gradePractice} \geq 4$). (Practicals grade ≥ 4), in the theory grade (Theory grade ≥ 4) or in critical thinking (PensCrit grade ≥ 4) will not have to take the exam for this block.

The evaluation in the extraordinary exam consists of the following blocks:

- Block I. Theory. 1 individual written test (50%)
- Block II. Practical work. 1 individual written test (40%)
- Block III. Critical Thinking. 1 written test (10%)

The final grade of the subject for the extraordinary evaluation is calculated with the following algorithm:

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if gradeTeoria is less than 4 then gradeTeoria := exExtraordinaryTeoria * 0.5
if gradePracticals is less than 4 then gradePracticals := exExtraordinaryPracticals * 0.4
if notePensCrit is less than 4 then notePensCrit := exExtraordinaryPensCrit * 0.1
gradeTotal = gradeTheory + gradePracticals + gradePensCrit
If notaTotal >= 5 then notaFinal := notaTotal else notaFinal := suspenso.
    
```

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Moodle UPM	Web resource	The whole pack of documentation and examples used in class by the teacher. It is documentation elaborated by the teacher
George Coulouris, Jean Dollimore, Tim Kindberg, and Gordon Blair. 2011. Distributed Systems: Concepts and Design (5th ed.). Addison- Wesley Publishing Company, USA.	Bibliography	Basic book for reference.
Rachid Gerraoui, Luis Rodrigues. Introduction to Reliable Distributed Programming. Springer-Verlag 2006.	Bibliography	Basic book for reference.
Andrew S. Tanenbaum and Maarten van Steen. 2006. Distributed Systems: Principles and Paradigms (2nd Edition). Prentice-Hall, Inc., Upper Saddle River, NJ, USA.	Bibliography	Complementary book for the theoretical concepts.
Nancy A. Lynch. 1996. Distributed Algorithms. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA	Bibliography	Complementary book.
Hagit Attiya and Jennifer Welch. 2004. Distributed Computing: Fundamentals, Simulations and Advanced Topics. John Wiley & Sons.	Bibliography	Complementary book.



Wan Fokkink, Distributed Algorithms: An Intuitive Approach, MIT Press, 2013.	Bibliografía	Complementary book.
Practical laboratory	Equipment	Building 4. Laboratory 4401

9. Other information

COMMON COMPETENCES

This subject includes the following common competences which are not available for selection:

- CC11 Knowledge and application of the characteristics, functionalities and structure of Distributed Systems,
- Computer Networks and the Internet and to design and implement applications based on them.
- CC14 Knowledge and application of the fundamental principles and basic techniques of parallel, concurrent, distributed and time-controlled programming.

TRANSVERSAL COMPETENCES

This subject evaluates the transversal competence CT06 "Critical Thinking" according to the evaluation with this competence does not appear. Therefore, a new learning outcome has been added.

RA64. Makes judgements and decisions in a reasoned manner. Analyses, interprets and evaluates information and arguments from different points of view. Synthesises and relates information and draws conclusions in a reasoned way.

ACTIVITIES OF THE TRANSVERSAL COMPETENCE

The critical thinking activity consists of identifying the items that measure the quality of a scientific text. The activity is carried out in each laboratory session. In the first session, as an example, the students will analysis of a simple article, providing them with a rubric to be filled in with the items to be identified from the text. This is corrected in class. In the following session, a more complex text is provided and analysed during the rest of the lab sessions in order to design a rubric with the critical thinking items sought. This rubric is corrected in the last session.